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CATEGORIES OF USER IMPAIRMENT

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ABSTRACT

This work presents a novel classification scheme for human impairments and aims at being as small as possible while simultaneously representing the vast diversity of users with impairments with sufficient accuracy. The scheme is based on the International Classification of Functioning, Disability, and Health of the WHO and consists of in total 21 impairment categories which are broadly grouped into the four main areas cognition, senses, voice, and movement. The classification scheme is of generic nature and can thus be applied to the design of human artifacts and environments in general, as it considers the plain interaction of the human body with its surroundings in multiple modalities. Simulation of user impairment is a primary application area.

KEYWORDS

Classification, Scheme, Disabilities, Personas, Expert, Artifacts, ICT

1. INTRODUCTION

On an international level, the WHO estimate that around 15% of the population have a moderate to severe disability (World Health Organization, 2011). For all ages, the estimate for Europe is 80 million or 16%, as compared to ~500 million citizens in total[1] (Eurostat, 2015a, 2015b). In Norway, 19% of the Norwegian population aged 18 and older is said to have a disability (The Norwegian Directorate for Children, 2013). The number of people with disabilities is expected to increase due to population ageing in many parts of the world. For instance, a 2015 prognosis in Europe for 2020 was 120 millions (European Commission, 2015).

When it comes to designing and implementing systems (services and products), information, and environments, it is therefore vital to ensure a high degree of accessibility and usability for the widest range of users possible, including people with disabilities. This applies to participation and co-creation as well as testing and evaluation likewise, and is often referred to as user-centred design or development. The use of actual users representing different user groups is generally considered as the best method to take user disabilities into account in a user-centred design process, not only with respect to user experience and usability but also accessibility (Petrie og Bevan, 2009; Fuglerud, 2014; Dumas og Salzman, 2006; Keates, 2006; Brajnik, 2008; Petrie og Bevan, 2009; Fuglerud, 2014). It has, however, also been pointed out that user participation often proves to be costly, time-intensive, and not straight-forward to apply (Petrie og Bevan, 2009; Røssvoll og Fuglerud, 2013; Petrie og Bevan, 2009). Challenges include recruiting the right population representing relevant user groups, finding and organizing the proper co-creating tools and methods, and conducting valid and useful trials.

To simulate user impairment[2] and thereby to partly reduce the need for user participation can be a good strategy to keep costs, time investment and complexity of design, development, and testing processes low. This work discusses which impairments should be considered. While we are targeting systems and applications in the realm of IT and ICT, the below discussion is of a generic nature and hence applicable not only to any technical artifacts, including self-service machines, museum and science center exhibits, smart-watches, smart homes, smart environments, etc., but to the design of everyday things in general (Norman, 2013).

1 The statistics consider 27 countries in 2012.
2 We prefer to use the term impairment over disability to focus on the reduction in function of the human body and not the consequence of someone not being able to do something.

The main contribution of this work is to unify previous work considering various impairment classifications with relevant standards and the WHO's International Classification of Functioning, Disability, and Health to a novel scheme.

The remainder of the article is straightforward: After a brief review of research related to expert testing and personas, the article continues with discussing various classification schemes in other works, before the novel set of categories is presented.

2. REPRESENTING USERS WITH IMPAIRMENTS

As detailed in the following, simulating user impairment (SUI) can be a good strategy to cut costs and complexity while meeting accessibility requirements in (agile) design and development processes and continuous testing. It is, however, stressed that SUI cannot replace the role of real users entirely, even though it can act as a substitute for involving users to some degree. Other research has recommended to combine SUI with methods that involve real users (Nielsen, 1994; Hwang og Salvendy, 2010). SUI can follow the chosen process as with normal user testing but replaces real users with dedicated testers, user advocates or experts who simulate any impairments real users might have. As a side note, any process should involve users from the very beginning and throughout the entire development (Røssvoll og Fuglerud, 2013; Bai *et al.*, 2019).

The research community uses multiple related and partly synonymous terms for SUI, including expert evaluation, expert inspection, empathetic walk-through, accessibility inspection, and others, but there are subtle differences. Expert testing can involve specialists who rely on their experience in the field, but it could also be that those experts follow particular guidelines (Petrie og Bevan, 2009). The main characteristic of SUI is that users with various functional impairments should be considered. The key motivation for this is that such testing is particularly efficient to indicate general usability and accessibility problems (Schmutz, Sonderegger og Sauer, 2016, 2017, 2018; Bai *et al.*, 2018; Stray *et al.*, 2019). Another reason is the necessity to mirror user diversity in development and testing based on population and impairment statistics.

SUI as a concept is also related to working with personas. Personas are fictional characters representing individual users or user groups, and different variants of persona methodologies exist (Fuglerud *et al.*, 2020). Persona testing and expert evaluations have both been considered to be insufficient because, as most variants are simple mental models, they are not representing users and their needs well enough (Sauer, Sonderegger og Schmutz, 2020). It is further argued that personas methodology can be made more robust by combining it with practical models and simulations (Petrie og Bevan, 2009).

3. IMPAIRMENTS TO CONSIDER

As previously mentioned, it is crucial that a great variety of individuals is represented when developing for instance technical solutions, and this includes individuals with impairments. However, there are many different impairments, and thus there is a large number of classification possibilities. The goal of the following discussion is to find the smallest set of categories that represents the diversity of user impairments with sufficient accuracy.

In ICT, it is common to use three broad categories of impairments on a high abstraction level: sensor, motor, and cognition (Fuglerud, 2014). Other research targeting (technical) science center exhibits has suggested to split up senses into vision and hearing, to differentiate between motor and mobility, and to account for voice, which results in six accessibility areas (Halbach og Tjøstheim, 2019). More precisely, the authors define mobility as everything related to the legs and lower extremities, whereas motor is everything related to the hands, arms, and upper extremities.

With the context of software development, a seven-category scheme has been proposed (Bai *et al.*, 2018). It consists of the areas auditory, attention and memory, higher-level logic, language and numbers, physical, speech, and visual. It is hence quite similar to the aforementioned six-category scheme for museum exhibits, but more detailed when it comes to subcategories in the cognition domain.

Early research from the creators of the principles of universal design proposes another seven-category scheme consisting of cognition, vision, hearing and speech, body function, arm function, hand function, and mobility (Story, Molly Follette and Mueller, James L. and Mace, Ronald L., 1998). We believe that hearing and speech should be separate, as the former for a human is about receiving signals / perception, whereas the latter is about sending / controlling. Lessons learned from exhibit evaluation advocates further to combine *arm function* and *hand function* without the loss of generality to *motor*. Also, the term *body function* could be more specific and clarify the difference to for instance *motor*, and this is why we prefer *touch*.

An even more fine-grained classification seems to be necessary, though, as for example there is substantial difference between measures that accommodate for low vision and measures that account for blindness. The European Standard EN 301 549 considers 10 different categories[3] (European Telecommunications Standards Institute, 2019): No vision, limited vision, no color perception, no hearing, limited hearing, no vocals, limited manipulation/strength, limited reach, no photosensitive triggers, and limited cognition. This list seems to have a fair level of differentiation, but it is argued here that it has three important shortcomings. One is the lack of mobility as a category. This is useful as reach and mobility are different (but related) concepts: Mobility is needed for instance to come close to user interfaces, and in situations where the interaction relies on a functioning foot or feets, such as controlling the gas pedal in cars or stepping on a dance mat in some video games. Next is the notion of photosensitive triggers, which is limited in meaning to flashes of light. General photosensitivity, on the other hand, is a much broader term, as it includes impairments related to the brightness of a screen and single user interface elements, and it addresses in addition technical features like dark color schemes. EN 301 549 also mentions "limited cognition, language, and learning[4]". This appears to be too little detailed, as cognition is a quite broad term, and there is a wide range of neurodiversity[5].

The World Wide Web Consortium speaks of neurological disorders and enlists additionally the following examples (W3C Web Accessibility Initiative (WAI)): focus / attention deficits, limited social communication and interaction, and memory impairments. This list can be expanded, as proposed in another work, by the categories orientation deficits, and limited coordination and planning abilities (Halbach og Tjøstheim, 2019). Yet other research has mentioned lingual (text and language) comprehension, which includes reading and writing, and partly speaking, as well as visual comprehension (Halbach, 2010; Røssvoll og Solheim, 2010).

A preliminary conclusion is that multiple schemes have been proposed so far, and the research community does not agree upon which of these schemes is most appropriate to represent the diversity of human impairments. It may hence be helpful to turn to the classification framework used by the World Health Organization, called International Classification of Functioning, Disability, and Health / ICF (International Classification of Functioning, Disability and Health). The ICF framework links body functions and structures that might be affected by particular conditions and disabilities with contextual parameters like environmental and personal factors, such as human activities and participation in the society, as well as barriers. The WHO emphasize that an individual's functioning consists of interactions between a health condition and contextual factors, and that these interactions are multi-directional.

The WHO propose eight major categories to classify these body functions and impairments. Of these categories, some are in our opinion not relevant for a user's access to technical assets: a) Functions of the cardiovascular, hematological, immunological and respiratory systems (ICF no. 4), b) functions of the digestive, metabolic and endocrine systems (ICF no. 5), c) genitourinary and reproductive functions (ICF no. 6), and d) functions of the skin and related structures (ICF no. 8). Touch is already covered by sensory functions. In addition, we have experienced from exhibits that it makes sense to divide the category neuromusculoskeletal and movement-related functions of movement and mobility (ICF no. 7) into functions related to the lower body extremities and functions related to the upper body extremities. The same strategy is employed for example in the statistics of the US Census Bureau (The US Census Bureau, 2012, 2018).

Relevant ICF categories are thus (our labeling in parenthesis):

3 The category privacy is disregarded here as it is not a functional impairment of humans.

4 In the literature in general, multiple terms are used as synonymous to learning disability: intellectual disability, reasoning disability, limited processing ability, and limited problem solving ability.

5 In fact, there cannot be a clear distinction between physical and neurological functioning. Complex biological processes like vision are rooted deeply inside basic brain processes, and mental disorders may affect the sensory and physical system as well. The classification in this work is only a simplification to ease the discussion of the impact of impairments.

1. Mental functions (cognition)
   - Global functions: orientation, intellectual, temperament and personality, etc.
   - Specific functions: attention, memory, emotional, perceptual, calculation, etc.
2. Sensory and pain functions of the human senses (senses)
   - Seeing and related functions (vision)
   - Hearing and vestibular functions (hearing)
   - Additional sensory functions, including smell, taste, and touch (touch)
3. Voice functions to produce sounds and speech (voice)
4. Not applicable (Functions of the cardiovascular, hematological, immunological and respiratory systems)
5. NA (Functions of the digestive, metabolic and endocrine systems)
6. NA (Genitourinary and reproductive functions)
7. Neuromusculoskeletal and movement-related functions of movement and mobility
   - Functions related to the lower body extremities (mobility)
   - Functions related to the upper body extremities (motor)
8. NA (Functions of the skin and related structures)

Moreover, cognition should in our opinion be split up into multiple subtopics, and we propose the following eight impairment classifications: Language, reasoning, attention, communication and interaction, memory, orientation, coordination and planning, and mental health and behavior. The reason for this differentiation is threefold. Each of these classifications typically requires 1) separate inclusion measures during the development of technical solutions, 2) the participation of a separate interest organization in user trials, and 3) the simulation of a separate user group in expert testing.

For instance, *language* targets organizations for people with a migrational or foreign background. *Reasoning* aims at organizations for people with general intellectual impairments. Organizations for individuals with ADHD is a good example for the category *attention*, and organizations for people with Autism Spectrum Disorder / ASD can be mapped to the category *communication and interaction*. Interest organizations for elderly are often involved when *memory* impairment is targeted. And while organizations for individuals with dementia exemplify *orientation*, the category *coordination and planning* targets organizations for people with Downs' syndrome. Finally, the category *mental health and behavior* is well exemplified by organizations for people with bipolar disorder. These eight subtopics seem necessary to cover as much as possible within the range of cognitive impairments. However, we have to admit that some user groups cover multiple areas. For example, the Norwegian Association for Persons with Intellectual Disabilities can be involved in user trials targeting memory, orientation, and reasoning, among others.

When it comes to taking into account individuals with low vision, there is a substantial difference between designing / testing for *lack of vision* and *limited vision*. That is, somebody entirely blind typically uses a screen reader, while many with low vision simply prefer to increase the screen zoom to increase readability. Next, people with color vision deficits are usually neither dependent on screen reader nor zoom, so developing for that user group typically involves measures and tests that check that the meaning of interface elements is not signaled by color alone. Individuals with light sensitivity is a category / area of its own, too, which in most cases relates to oversensitivity to light stimulus. In the hearing domain, we propose to differentiate between l*ack of hearing* and *limited hearing*. While the former considers deaf people with a focus on visual communication, the latter means that audio and sound in fact can be used in interfaces, while there should be measures to account for low volume levels, noise or distracting background music, to give a few examples. Likewise, there is a substantial difference in *lack of voice* and *limited voice*. In the former situation, user interaction has to rely on non-verbal schemes. *Limited voice* covers situations with an unclear or low voice, multiple speakers, background noises, and the like. In the movement domain, it is important to handle *limited reach*, as often experienced by people with a wheelchair, crutches, and similar, separate from *limited strength*, which targets situations where somebody controls an artifact by their feet without moving anywhere else. *Motor* is a corresponding domain for the upper-body functions: There is a significant difference between *reach* and *strength*. The former deals with whether interaction elements can be reached by arms, hands, and fingers, and the latter concerns for instance whether a button can be easily pushed or not. It therefore makes sense to give each of these particular areas an own category.

We propose to merge the ICF categories, diversified for subtopics, with the modified EN 301 549 standard, as well as altered own and other research, as discussed above, to a novel categorization scheme with a total of 21 categories, as enlisted in Table 1 below. A graphical illustration is depicted in .

Table 1. Proposed categories of user impairment and related ICF reference

This novel scheme may serve as an aid during planning, development and testing of human artifacts in general and technical assets in particular, including the simulation of user impairment. A major advantage of such a scheme is that it is generically applicable and globally comparable. Another benefit is that, with the aforementioned mapping of categories to interest organizations, it will be possible to obtain statistical data from those organizations to be used during considerations regarding which interest group to prioritize during development or testing. Also, the approach answers the WHO's recommendation to improve statistical data by adapting the ICF to specific areas (World Health Organization (WHO), 2011)

No.	ICF no.	Category	No.	ICF no.	Category
	1	Cognition		2.2	Hearing
1		Attention	13		Lack of hearing
2		Memory	14		Limited hearing
3		Orientation	15	2.3	Touch
4		Reasoning		3	Voice
5		Coordination & planning	16		Lack of voice
6		Linguistics & speech	17		Limited voice
7		Social communication & interaction		4	Movement
8		Mental health & behavior		4.1	Mobility (lower-body functions)
	2	Senses	18		Limited mobility reach
	2.1	Vision	19		Limited mobility strength / manipulation
9		Lack of vision		4.2	Motor (upper-body functions)
10		Low vision	20		Limited motor reach
11		Reduced color vision	21		Limited motor strength / manipulation
12		Light sensitivity			

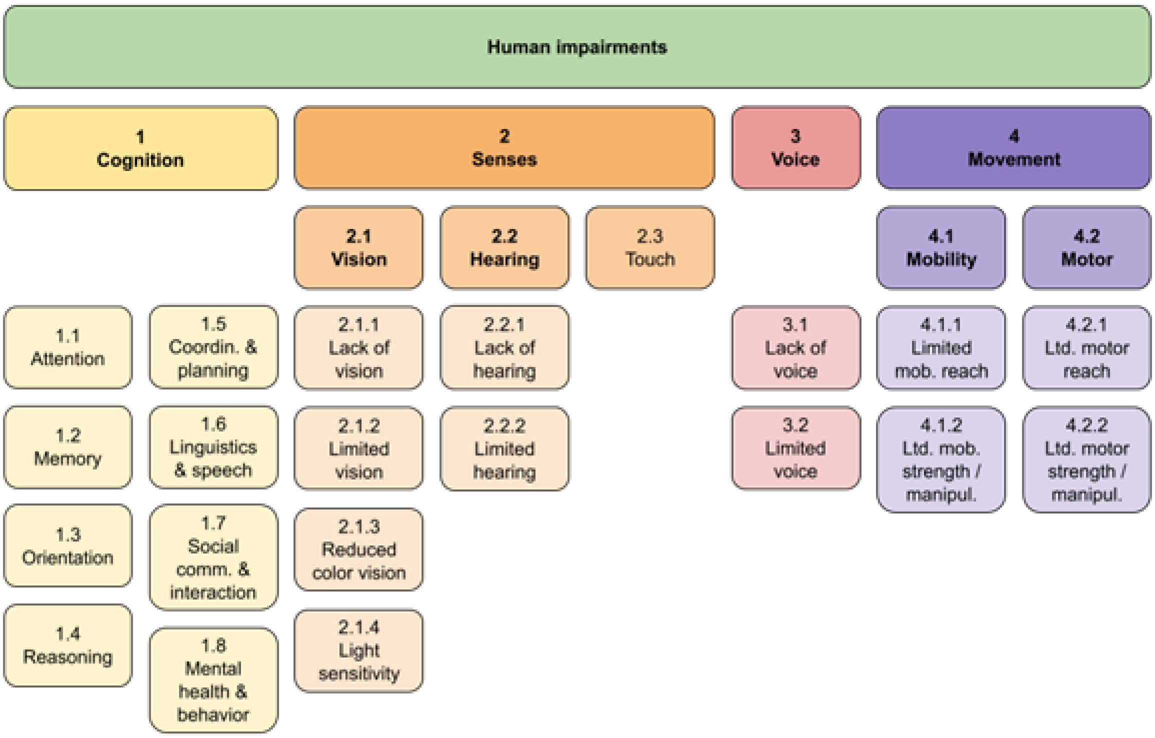

Figure 1. Proposed categories of human impairments relevant for technical artifacts

There are multiple implications of this work. ICT researchers, designers, developers, and others have hopefully been given additional aids to take into account human impairment in their work. Also, the wide range of human impairment has been underlined. Universal design is much more than a screen reader accessibility and a wheel chair ramp. We further hope that those who plan, develop, and test technology start to think of diversity in broader terms. The high number of various impairments underlines the importance of involving more users in the technology development than what is practiced today, or at least to simulate user impairment to a wider extent. Our vision is that a greater share of technology is becoming more inclusive for a wider range of human diversity.

The results in this work are limited by the following considerations. The objective of the literature review has not been to give a complete overview of all related research; however, we are confident that we have covered a sufficiently large share of the literature to develop this new classification scheme. Moreover, the nature of this work has been theoretical, and it needs to be verified in for instance user trials whether the scheme has just about the right number of categories (not too few or too many). It is also stressed that the scheme is not based on any statistics of impairment, which might be a good suggestion for future research.

4. CONCLUSION

By reviewing and discussing relevant work from the literature as well as related standards, we have developed a classification of impairments which we believe finds the right balance between being as small as possible and representing the vast diversity of users with impairments with sufficient accuracy. The scheme consists of 21 impairment categories in total which are broadly grouped into the four main areas cognition, senses, voice, and movement.

While the classification scheme is derived mainly with technical artifacts in mind, it is generic enough to be applicable to the design of human artifacts and environments in general, as it considers the plain interaction of the human body with its surroundings in multiple modalities. The classification scheme can be used in a variety of situations where real users or users with simulated impairments need to be represented in a systematic manner, such as planning and conceptualization, design and co-creation sessions, test iterations, and other development cycles.

We hope that the impairment categories are useful for all stakeholders of design and development processes, primarily usability and accessibility experts, but also graphic designers, interaction designers, developers, testers, architects, curators, carpenters, and more.

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