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Which Diversity? Expanding the Gap Model of Disability for Digital Information Systems

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Abstract. In this paper, we extend the gap model of disability that supports digital equipment and cyber-physical situational variations. We explore an alternative approach to visualizing and understanding disability that takes into account the diversity of personal abilities, the diversity of digital equipment and equally important, the situation (environmental, psychological, and digital) in which the information system is used. The most important implications of this work are twofold. First, this work will contribute to the need for Universal Design to take into account not only the diversity of abilities and impairments of the users that are tangible and recognizable in the physical environment, but also the diversity of digital equipment and usage situations. Second, as part of the systems development cycle, in user testing of digital services, this work highlights the essential need to not only involve a diverse set of users, but also to conduct testing in diverse digital environments (smartphones, tablets, laptops and desktop PCs), and in diverse realistic usage scenarios, including strong sunlight or low light situation, as well as tired, alert, stressed or distracted, and slow network. The proposed model attempts to give a more holistic view and promote a more comprehensive understanding of the disabilities that can occur during use of digital services or mediated communication in daily life.

Keywords. Gap Model, Models of Disability, Cyber-Physical Gap Model

1. Introduction

The Gap model [1-4] of disability [5], also sometimes referred to as the Nordic Gap model, has been used to visualize and place disability in everyday situations. This model highlights the fact that it is not only the abilities or impairments of the person, but the gap between the person's abilities and the affordances of the physical *environment* or a *system*, that creates the disability.

The environment or system in the Gap model is based on physicality or tangible elements such as a physical staircase or a parking automat. The common visualization of The Gap model shows the level of functioning in a situation, and the space or gap between individual abilities that need to be strengthened to meet the requirements from the environment, that in turn need to be reduced. The Gap model is appropriate when the

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environment as mostly static, However, it does not account for environmental variation over time, much like weather system patters such as the transition between sunshine and snow, the user's variation of attention between digital and physical environment. In addition, the Gap model was developed before the prevalence of mobile computing, internet of things and digital services. These digital environments add layers of complexity to common usage situations, thus, exposing some limitations to address digital accessibility.

Digital services, understood as fulfilling needs through digital processes, are increasingly important in our daily lives, as our lives have become intrinsically integrated and influenced by technology. Gone are the days were digital interactions meant only staying in front of the computer on our desk. Now digital services not only need to reach us, but also need to be reached by us, "in action", as an extension of us and our activities, as we go through all kinds of situations using smart phones, smart watches and tablets. A digital service, is used in relation to the environmental, organizational and situational conditions [6]. For example, when digital services can work perfectly fine on a big screen with adequate lighting in calm working conditions. However, they may be totally unusable in a more complex outdoors scenario, thus prompting so-called *situational disabilities* (see Section 2.2).

In the current *cyber-physical* situation where the digital and physical world interact in complex and dynamic ways, the Gap model may be too simplistic, thus calling for a more comprehensive understanding of disabilities to be able to continue designing barrier-free systems. One app or web page may offer completely different user experiences and experienced barriers depending on the equipment in use and the situation in which it is used.

Through extensive research on Universal Design and situational disabilities that may in particular occur during use of information systems in disaster situations [7-11], it is becoming more and more clear that the traditional Gap model has failed to withstand the test of time and fall short of adequately adapt to digital and cyber-physical environments of today. An extended cyber-physical Gap model that can explicitly demonstrate the above-mentioned factors and aspects of disability is therefore needed, and the development of such model is the primary goal of this study, that attempts to answer the following research question:

How can the Gap model of disability be adapted to meet the environmental demands of using digital services in ever evolving cyber-physical environments and thus contribute to reduce situational disabilities and other Universal Design challenges?

To achieve this, we first look into relevant theoretical concepts in Section 2, then we present and analyze a realistic scenario involving digital services, a dynamic environment and situational disabilities in Section 3, and develop an extended Gap model in Section 5. Finally in Section 6, we conclude and point out directions for future work.

2. Theoretical Concepts

In this section, relevant concepts from the literature on disability and related phenomena are introduced. We first conceptualize the meaning of disabilities, followed by situational disabilities.

2.1. Persons With Disabilities

Traditionally, following the Convention on the Rights of Persons with Disabilities, persons with disabilities refer to "… *those who have long-term physical, mental, intellectual or sensory impairments which in interaction with various barriers may hinder their full and effective participation in society on an equal basis with others*" [12]. The World Health Organization (WHO) has a broader scope and mentions that almost everyone will temporarily or permanently experience disability at some point of life. WHO's International Classification of Functioning, Disability and Health (ICF) framework classify disabilities as body and health functions, activities, and participation, that includes environmental factors and body structure [5]. *The body functions* encompass among other thing mental functions, sensory functions, voice, and speech functions. *Activities and participation* include, among other things, learning and applying knowledge, communication, and mobility. *Environmental factors* contain different technologies that support persons with disabilities, including technology for communication. *Body structures* incorporates structures of nervous system, eye-ears related structures, structures involved in voice and speech, structures related to movement and so on [13].

While the medical model of disability sees disability as abnormal bodily functions, the social model of disability recognizes disability as contextual, arising from the interaction between a person and their environment. The social model was promoted by disability movements as a response to the medical model, highlighting that a change in the environment or an improved design of a system removes the barrier, thereby empowering the individual [1]. This implies that society has the responsibility to remove barriers, rather than forcing the individuals to find ways to overcome their disabilities.

2.2. Situational Disabilities

Situational Disabilities can occur to people who are not usually considered to be in the category of "person with disabilities". Situational Disabilities are momentaneous impairments or disabilities experienced by a person in a given situation. A common situational disability can be illustrated when a tourist without knowledge of the local language in a foreign country can't find a way to read or interpret the signs in the road. This article is especially interested in situational disabilities occurring when using information systems and information and communication technology, environmental (physical, mental, and/or digital) factors disturb the interaction between the user and a digital service. The concept of Situational Disabilities has its roots in Situationally Induced Impairments and Disabilities (SIID) [14, 15], first introduced in 2003 by Sears, Jacko and Xiao [16], regarding issues occurring related to pervasive computing, where they suggest a model consisting of the human, the environment, and the application to understand and evaluate the effects of SIID. SIID are often referred to simply as situational impairments or Situational Disabilities [17-19], but Wobbrock points out that they are actually different, with impairments being features of the body itself, while disabilities are difficulties in performing a certain task [14]. For example, in a situation with cold weather, a Situational Impairment could be the inability to move fingers in an agile manner because of the cold weather, while the corresponding Situational Disability would relate the stiff fingers with the inability to use a smart phone app that requires agile finger movements, for example typing on a virtual keyboard.

We note that W3C recommends not using terms related to disability or impairment for these concepts, but instead using the term situational limitations[2] to distance the concept from disabilities and impairments that concern people's functional limitations. While this may seem reasonable from the perspective of the medical model of disability, the social model of disability highlights that disability occur in the gap between the person's abilities and the environment's requirements [20], and from this perspective, it makes sense to see SIID as legitimate types of disabilities.

Gjøsæter et al., [7, 11] discuss the differences between permanent, temporary and situational disabilities, and link these understanding in the emergency situations. "Disabilities" is taken as something that may occur to everyone who is unnecessarily a part of the vulnerable groups due to specific, situational, or temporary conditions. Moreover, the authors argue that effects of the situational disabilities may result in the same effects as those who have "traditional" disabilities. In the following, we will apply this understanding of disabilities.

2.3. The Gap Model of Disability

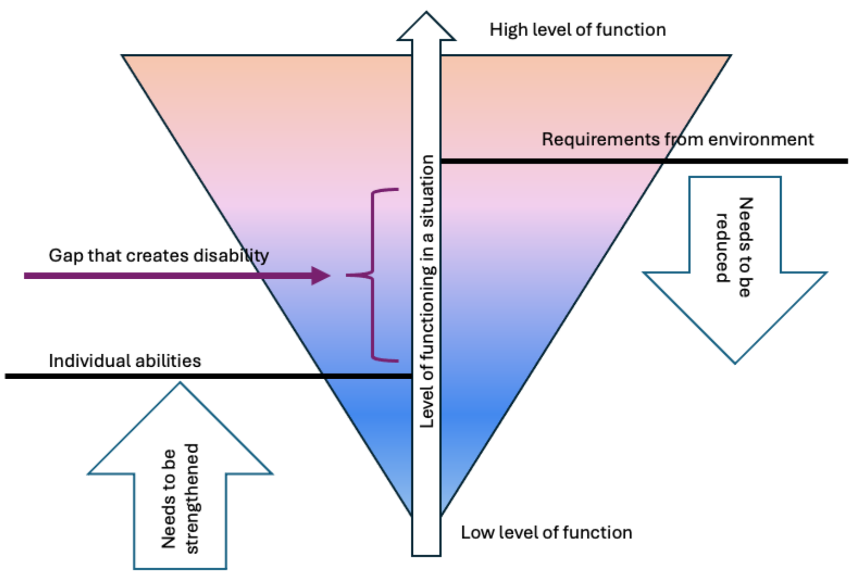

Figure 1. A common Gap model visualization inspired by visualizations in [2] and [21].

The Gap model of disability, sometimes referred to the Nordic gap or the relational model, is often visualized as shown in Figure 1, based on the visualizations in [2] and [21].The model builds on the social model of disability and presents disability as the gap between the individual abilities that needs to be strengthened, and the requirements from the environment or society, that needs to be reduced to close the gap and remove the disability. The model has been used in teaching for more than 40 years, and while the original publication is difficult to pinpoint, the gap model is frequently referred to later in Nordic scientific work on disability and Universal Design [1-4]. The gap model is also

[2] https://www.w3.org/WAI/EO/wiki/Situational_terminology

used in the definition of disability in the Norwegian Government White Paper nr. 40 on Dismantling of Disabling Barriers 2002-2003 [21].

We contrasted the literature on situational disabilities with the Gap model and a real-life scenario to formulate an extension of the Gap Model that could visually address the gaps emergent through the increasing use and dependence of digital services and cyber-physical environments.

3. Scenario Analysis

This section presents a scenario that highlights the limitations of the gap model in visualizing complex dynamic cyber-physical situations. The following scenario has been developed, discussed, elaborated and refined with university students in a bachelor level course on universal design of information systems, during special thematic discussions on situational disabilities and the presentation of the Gap Model.

Consider yourself in the scenario of needing to buy a bus ticket using a mobile app. You are in general able-bodied, but you overslept a bit and didn't have time for your morning coffee. And in addition, it is late autumn, so it is raining and there is a cold wind blowing. You are also late for the bus but hope to still catch it. Your fingers are wet, so the fingerprint reader of the phone fails to log you in to the app, and cold shaking fingers miss the buttons for the pin code three times. You are presented with a captcha, so need to select which ones of nine tiny pictures contain a traffic light. Your glasses are foggy, and you are now very stressed. You miss the bus, and you find yourself now clearly situationally disabled. Neither your abilities, the usually adequate mobile phone, nor the situation itself should be a problem, but the environment and surrounding factors combine to render you situationally disabled.

Analyzing this scenario from the perspective of the traditional gap model visualization, we find that the environment, and in the particular the weather has a strong impact on the ability to use the ticket ordering system. The combination of the too small pictures, shown on a small screen, the foggy glasses, and the stress, are however not easy to pinpoint exactly in the gap model. Is the smartphone part of the user or part of the system being interacted with? It can be argued that it is either or even totally distinct from both. While the smartphone clearly can enhance the abilities of the user, it can also introduce barriers, for instance by a lack of Universal Design of the app in use (too small pictures, maybe without descriptions), or through the impact of the environment and weather. Using the traditional gap model to analyze the scenario, factors affecting the user are displayed on the left side, while it is not clear if the inclement weather should be on the right side increasing the requirements from the system, or on the left side, reducing the abilities of the user, or perhaps both? It makes sense to consider environmental conditions in both places, since it makes the system harder to use but also reduces the capabilities of the user.

4. Towards a Cyber-Physical Gap Model

In this section, we take the previously described scenario as a starting point for developing an extended gap model visualization that better supports digital services and cyber-physical situations. First, we look at the requirements, then we propose a model and discuss its applicability to the scenarios.

4.1. Requirements for a Cyber-Physical Disability Gap Model Visualization

Based on the previous discussion as well as the theoretical background, we suggest that that the following aspects, that has a potential impact on the person's ability to achieve their purpose, should be included.

1. Diversity of user abilities and skills
2. Psychological status
3. Diversity of hardware and software affordances and limitations
4. Degree of control over different parts of the system
5. Dynamic and static elements of the environment
6. Time of day, time available to complete a task.

The Gap Model is a "gold standard" to interpret disabilities and possibilities to reduce gaps. Therefore, to avoid unnecessary competition and increase understandability we build on the existing model, and while this may lead to some compromises in expressiveness, we propose an intuitively understandable incrementally improved gap model that could potentially be a great benefit to the Universal Design community.

4.2. The Proposed Cyber-Physical Gap Model

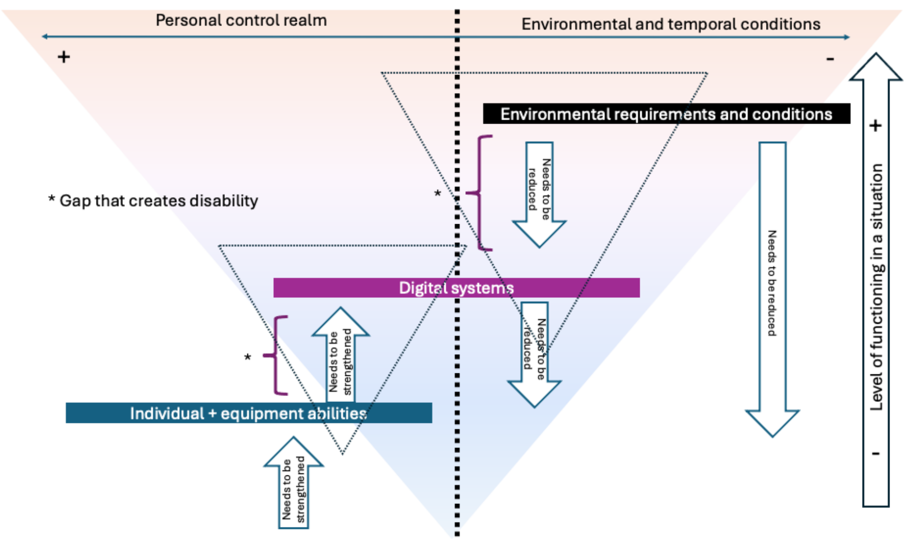

Figure 2. Proposed Cyber-Physical Gap Model. * denotes gap.

Figure 2 shows the proposed Cyber-Physical Gap model that introduces the Digital Systems as a third element sitting in between the individual realm, together with supporting equipment, (left side) and environmental and temporal conditions (right side). This extended model visually distinguishes the degree an element or issue is under (left side) or outside (right side) the control of the person or user of the system. The proposed model also maintains the areas that could need to strengthen abilities and reduce environmental requirements and conditions that can be addressed in a cascading manner. By highlighting the potential for multiple gap areas, these become possibilities for staggered interventions to address the gaps.

As shown in Figure 3, the user has control over their assistive devices (e.g. glasses), the configuration of user settings of their digital equipment (e.g. such as font size or zoom), as well as protective gear against the environment (e.g. umbrella). However, on the middle can be perceived the limited control over the digital services (e.g. app) and the environment (e.g. inclement weather). The environmental conditions affect both the digital systems and the personal abilities of the user, who can meet them with digital and physical countermeasures, such as high contrast mode and easy captcha verification.

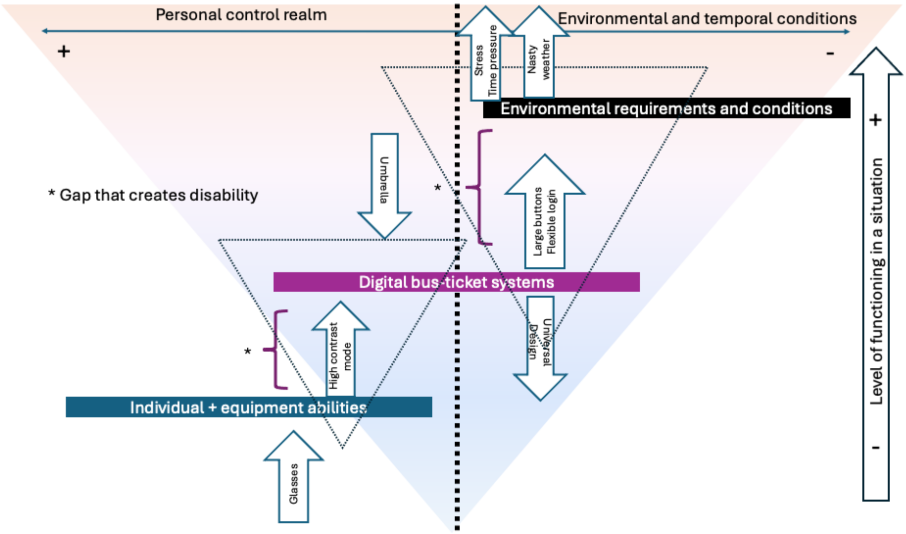

Figure 3. The bus ticket scenario visualization based on the proposed cyber-physical model.

5. Conclusions and Future Work

This study has examined the Gap Model and its applicability for Cyber-Physical situations, with a particular focus on complex situational disabilities. We find the current model to be inadequate to address the increasing digitalization of services and the subsequent disabilities and propose an extended version that explicitly distinguishes between physical and digital environmental factors, through a cascading approach for addressing disability gaps. The proposed model supports a thorough examination of digital as well as physical diversity of situations, which could support Universal Design of digital services and mediated communication platforms to be used in daily life by diverse users under diverse conditions as illustrated by the inclement weather scenario.

Future work includes a thorough examination of the proposed model with diverse users, UD-experts and -designers for validation and further evolution and elaboration, and in particular to examine and discuss more thoroughly situational disabilities potentially occurring while using digital services (for example for situational awareness or mediated communication) in crisis situations. A zoomed-in view of the cyber-physical gap model that shows individual cyber-physical equipment-enhanced abilities in detail as a stack (or rather a tree) of digital and physical (assistive) equipment use/affordances, as well as the situation broken up into cyber-physical requirements, and known as well as unknown environmental/situational conditions, is also in the works.

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