Visual Accessibility and Inclusion

An Exploratory Study to Understand Visual Accessibility in the Built Environment

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Abstract— **Current research shows that visual accessibility assessment in the built environment typically considers objectively measurable parameters. However, considering subjective visual perception for architectural characteristics is extremely important. Visual perception can vary depending on environmental factors and personal factors and is particularly relevant for people with low to mild visual impairments. This explorative research studied the current state of the art of tools and systems that support the assessment of visual accessibility and investigated new ways of experiencing visual accessibility in the built environment. After identifying gaps in the current scenario, the Cambridge simulation glasses were selected as a tool to simulate visual impairments and therefore experience visual accessibility in the built environment. A pilot study was conducted by navigating a publicly accessible building and experiencing how clearly visible certain architectural characteristics were, while walking with and without wearing the glasses. The goal of this study was to understand their potential use in different settings and explore how to offer an empathic experience of visual accessibility with a low-cost tool for different stakeholders.**

Keywords- Visual accessibility; Built environment; Simulated impairment; Empathic approach; Inclusive Design

I. INTRODUCTION

Since the early cultural and social movements from the 1960's, a growing attention to designing for accessibility and for people with disabilities flourished [1]. As an example, the movement on rights for people with disabilities brought the creation of the first federal law requiring accessibility in government buildings in the USA, the Architectural Barriers Act - 1968 [2]. In the following decades, the importance of accessibility in buildings evolved and started to embrace a wider concept, expressed with the release of the Americans with Disabilities Act [3] and the emergence of disciplines, such as Universal Design (UD) [4] and Inclusive Design (ID) [5]. On a parallel path, with the increase of knowledge and awareness on accessible design, the creation of standards to support designers, engineers, and architects in developing and assessing accessible and inclusive buildings, grew [6].

Currently, the practice of assessing accessibility in built environments is carried out by professional experts, such as access consultants, auditors, or architects, who objectively measure several variables of the building and check if they comply with regulations. For a long time, the focus has been oriented towards physical accessibility, such as how a wheelchair can access a ramp or enter through a door [7] [8].

Guidance on visual accessibility of buildings is related to some objective factors that do not truly represent what people with different visual abilities could experience. For example, people with mild loss of visual acuity, and those with colour vision deficiency (e.g., colour blindness) might not have their voice fully heard when accessibility audits are carried out. Most international standards indicate dimensional features of architectural elements to regulate physical accessibility, as well as other subjects (e.g., the correct use of materials and colours to avoid glare [9]). With the advancements in human factors and usability standards, it is necessary to additionally take into consideration sensory and cognitive aspects of the visual perception, as they strongly influence the use and experience of a building [10].

Hence, there is a need to go beyond physical access, and discover what combination of tools and assessment protocols could extend the consideration of visual accessibility in the built environment, to cover the experience for people with mild visual impairments.

With this explorative research, the current state of the art of tools and systems that support the assessment of visual accessibility was studied, with a first goal to identify gaps in the current scenario, as described in Section 2 of the paper. After having identified challenges, Section 3 reports how the Cambridge simulation glasses were selected as a tool to simulate visual impairments and therefore to empathically understand visual accessibility in the built environment [11]. Section 4 of the paper reports and discusses the pilot study conducted by walking with and without wearing the glasses in a publicly accessible building and experiencing how clearly visible certain architectural characteristics were. The goal of this study was to understand their potential use in different settings and explore how to offer an empathic, immersive experience [12] of visual accessibility with a low-cost tool for different stakeholders. The final Section of the paper states the conclusion and further developments for the study.

II. VISUAL ACCESSIBILITY IN THE BUILT ENVIRONMENT

Visual accessibility is defined as the property that allows the use of vision to travel efficiently and safely through a space, by perceiving the spatial layout of key features in the environment and keeping track of one's location [13].

When it comes to visual accessibility in the built environment, various approaches have been studied so far. Some researchers focused on developing tools and strategies for wayfinding in the case of visually impaired people, such as the PERCEPT indoor navigation system for the blind and visually impaired [14] or the BIT kit wayfinding [15]. While the PERCEPT system provides guidance to the user towards a desired location with the support of passive radio frequency identification (RFID) tags deployed in the environment, the BIT kit includes a strategy for assessing the experience of visually impaired people in the built environment through the combination of various methods. Several similar apps or systems address indoor or outdoor wayfinding for visually impaired people [16] [17] [18]. Although these all represent advanced approaches and have important benefits in guiding users with specific visual difficulties, they present no particular guidance for the assessment and actual improvement of features such as visual acuity, clarity, or legibility for specific elements in the built environment. Research shows that most of indoor and public outdoor spaces do not provide the necessary clarity of vision for users such as older adults [19]. To approach this topic, in 2017, Motamedi et al. [20] proposed a tool that uses Building Information Modelling and Virtual Reality systems to assess sign visibility and legibility. The system simulates the movement of pedestrians and uses algorithms to calculate the visibility of signs, therefore contributing to the assessment and improvement of their placement. Similar approaches that use the "Digital Human" approach to evaluate visibility and simulate design signage can be found in literature [21] [22]. However, in these cases, there seems to be a lack of consideration for the observer's subjective experience and the different visual capabilities, therefore with no empathic involvement of users.

Furthermore, clarity of vision does not affect only signage and signs but could also affect components of the space such as staircase nosing, door handles, furniture, and a variety of other elements of the building. Thompson et al. [13] focused on mimicking the effects of reduced acuity and contrast by applying filters to calibrated High Dynamic Range (HDR) photographs of a space. Through the use of computer simulations, this approach allows the identification of potential mobility hazards and landmarks that might go unrecognized by low vision individuals. However, the complexity of the algorithm makes it rather hardly accessible to the general audience belonging to different age groups [19] [23].

An additional challenge concerns people with colour blindness, who experience difficulties in distinguishing certain hues and shades. To overcome this issue, the Adobe Accessibility Tools [24] provide designers with the opportunity to check a specific combination of colours against three most common types of colour blindness such as deuteranopia, protanopia and tritanopia, and therefore experience a simulated view of how a specific colour combination may appear. Although particularly useful to simulate how specific colour contrasts are perceived by users, it is limited to a combination of five colours and it addresses the pre-design process, being strictly applied through computer simulations.

In order to have a sense of what is accessible, currently visual accessibility regulations and guidelines tend to define specific objective parameters for visual accessibility, such as lighting and contrast levels, text size and spacing. The Canadian Accessibility criteria introduces, together with various physical-dimensional criteria, information regarding the colour-contrast values that need to be considered during the design process [25]. The Design Guidelines for the Visual Environments instead, highlight that people with low vision often experience the loss of contrast sensitivity [26]. Therefore, contrasting values should be used to define elements within a space, such as an edge of a step, level change or an object in the pathway.

To this end, CROMOCON is a tool developed to measure colour contrast values with the goal to understand the visibility level of objects, texts or building components for an impaired person before and after manufacture or installation [27]. The tool, composed by a Light Reflectance Value (LRV) meter, is based on a study that identified five key factors which affect visual capabilities, namely the visual ability of the observer, tonal contrast difference of the object to background, lighting intensity, projected width and height of the object, and distance from the object to viewer. The contrast between surfaces in a building is measured as the difference between 2 LRVs (Light Reflectance Value), by taking into consideration the previously mentioned factors [28]. The CROMOCON appears to be very useful for building features like stair nosing, however it seems less intuitive for use with more complicated features such as text or icons on signage for wayfinding. It represents a rather partial objective evaluation, without empathically offering the experience a person with visual impairments might have in a specific space, to the person without an impairment.

The state-of-the-art research highlighted the complex interaction between environmental variables and people capabilities, as well as a lack of specific bespoke design requirements for wayfinding in a space, making visual accessibility in the space hard to achieve. To this end, Arditi notes that there are several variables that determine the legibility of a sign (e.g., viewing distance, typeface, x-height, stroke thickness, intensity and directionality of lighting, foreground colour, background colour, etc.). These variables interact in complex ways, so it is not possible to ensure the legibility of a sign (for a specified degree of visual-acuity loss) by setting pass/fail threshold values for each of these variables [29].

Instead, Arditi makes the case that human observers with simulated impairments can assess the legibility of a sign, which provides a simple and practical method that takes account of all of these variables [29]. He proposes simulating impairment by adjusting the viewing distance. This has the advantage of being easy to apply without any tools but requires sufficient space in the actual environment to walk considerably backwards from the normal viewing distance. Moreover, it only works if the lighting conditions do not change with this adjusted viewing distance or at different times during the day. However, in many real-life situations in the built environment, either or both of these assumptions may not be viable. Herein, we explore simulating impairments through wearable glasses, which use a similar theoretical approach, transferred into a practically viable strategy to support assessments within real buildings. Furthermore, visual accessibility in the built environment ought to consider more than just signage, and the approach of using human observers with simulated impairment readily generalises to consider all aspects of the built environment, including other features such as controls for heating, lighting and ventilation, door handles, stair nosing, to name just a few.

III. An Exploratory Study to Empathically Understand Visual Accessibility in the Built Environment

Visual accessibility and inclusion in buildings are extremely important to guarantee pleasurable experiences. Wayfinding represents just one of the aspects of visual accessibility in buildings, but there are several other components of the space that might lead to exclusion depending on the visual capabilities of human beings. To support the assessment and design of visually accessible spaces, different tools are currently present in the market, however few of them can empathically offer the auditor a subjective, empathic understanding of whether an environment or object is visually accessible [12]. To bridge this gap, the Cambridge simulation glasses were selected to experience the built environment with visual impairments and understand what could be improved. The glasses were designed to offer insights into a general loss of the capacity to distinguish fine detail, such as the inability to achieve a correct focus, reduced sensitivity of retinal cells, and problems with internal parts of the eye becoming cloudy [11]. To note that they do not simulate the real condition of living with such impairment, providing a constrained experience of capability loss, and they do not convey the frustration, social consequences or coping strategies involved in living with an impairment on a daily basis [30]. The Cambridge simulation glasses, as shown in Figure 1, are composed by four pairs of identical glasses, which can be overlapped to simulate four levels of visual capacity of the user.

Figure 1. One pair of the Cambridge simulation glasses.

While one set of glasses simulates mild vision loss, if multiple glasses are worn, they can simulate more severe levels of impairment. To explore how the simulation glasses can help to assess whether indoor environments are inclusive for people with mild visual impairments, three different features present in many public buildings were examined. Staircase nosing, signage and wayfinding were object of the test, held in a publicly accessible educational building. Staircase nosing was chosen because it is covered within building regulations [31] [32]. Therefore we investigated if the glasses allowed to clearly identify the stair nosing that were compliant with these regulations, and compare to stairs that were not. Signage and wayfinding in architecture were chosen because, while in a few countries these are somehow included in the mandatory pass/fail requirements within building regulations [33] [34], there is still an exploratory curiosity behind empathically perceiving their visual accessibility from people with different visual capabilities [35]. A team of three researchers with no visual impairment examined these features multiple times, firstly without any glasses, and then repeated with 3 or 4 layers of glasses held in front of the eyes. As described within the Inclusive Design Toolkit [11], 3 pairs of glasses make the vision 0.49 logMAR worse, and 4 pairs makes the vision 0.74 logMAR worse. Given the starting visual ability of the researchers (approximately VA 6/5), this means 3 pairs simulate a level of vision ability that would be borderline for being able to drive (approximately VA 6/16), and 4 pairs simulate a level that would be registrable as partially sighted [36] (approximately VA 6/27). According to the instructions provided with the glasses, features that remain visible with 4 pairs of simulation glasses worn simultaneously should mean that the exclusion due to visual acuity issues is less than 1%.

IV. Navigating an Indoor Space with the Cambridge Simulation Glasses

While exploring the publicly accessible educational building, we found examples of stairs with and without contrasted stair nosing, as shown in Figure 2.

We found an example of wayfinding signage that had issues due to the directionality of the lighting, and another example of an informative sign that was difficult to see because of the contrast difference between foreground and background. These are both shown in Figure 3.

As this was an exploratory study, we did not seek to quantify the number of staircases that did or did not have perceivable nosing, nor to quantify the number of signs that did or did not have issues. Additionally, we did not seek to evaluate whether this particular building was better or worse than any other buildings of a similar purpose, nor to determine whether the building was compliant or not to any particular set of regulations. The examples presented in this paper were chosen solely to demonstrate the potential of the simulation glasses.

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Figure 2. Staircase case study. From left: steps with no edging strip, without glasses (a) steps with no edging strip, with simulation glasses (b), steps with yellow edging strips, without glasses (c), steps with yellow edging strip, with simulation glasses (d).

Firstly, considering stair nosing, it is known by building standards, such as the BS 8300:2018 [37], that the nosing of stairs should be clearly visible from distance. Standards also provide recommendations for operating a visual contrast between the leading part of the tread and its remainder as a supporting feature for visually impaired people [9]. The stairs without edging strips are shown in Figure 2(a), and with simulated impairment (wearing and taking a picture with 4 pairs of glasses) in Figure 2(b). The stairs that did have edging strips are shown in Figure 2(c), and with simulated impairment (wearing and taking a picture with 4 pairs of glasses) in Figure 2(d).

When the researchers navigated the stairs without the simulation glasses, as shown in Figure 2(a) and 2(c), no particular issues with visually identifying the edges of the steps, regardless of whether or not the steps had the high contrast edgings, were recorded. Comparatively, when the simulation glasses were worn, the edges of the steps without yellow edging strips completely disappeared, as shown in Figure 2(b). To report the subjective views of the researchers who undertook the experience, descending these steps felt “unnerving” and required “considerable concentration to place the feet on each step”. While wearing the simulation glasses and descending the stairs that did have the high contrast edges, as shown in Figure 2(d), the edges of the steps remained visible, and the experience of descending was “considerably more pleasant” and “felt safer”, as the researchers performing the experience reported. Although high contrast edging strips on stairs is part of building regulations, the glasses offered a unique empathic perspective on why these strips are so important. If an access consultant was seeking to convince someone that a set of stairs needed improving, the glasses would be an excellent tool to help build a persuasive case for change.

Considering wayfinding, Figure 3(a) shows an example of a wayfinding sign, and Figure 3(b) shows the same sign with 4 pairs of simulation glasses overlapped. The distance from the viewer and the object was constant in both cases (150cm) as well as the luminance and focal length of the camera used to take pictures.

When viewing the signage without simulated impairment, as shown in Figure 3(a), the researchers were able to identify the directions of the arrows that exist within the sign and read all of the text. The researchers noticed a bit of glare on the sign due to the lighting, but this was not unduly problematic. However, when viewing the same sign with simulated impairment, as shown in Figure 3(b), it became clear that it was considerably difficult to read. After further investigation, the researchers apprehended that this particular sign was harder to read because of the large amount of light provided by the sky light from behind the sign, which becomes considerably unhelpful. Furthermore, the casing of the sign has a slightly reflective coating, which gives further unwanted glare effects.

When considering the informative text label without simulated impairment, as shown in Figure 3(c), the researchers were able to easily read the text. However, when considering the same sign with simulated impairment, as shown in Figure 3(d), the researchers realised that this particular sign was difficult to read because there is not much

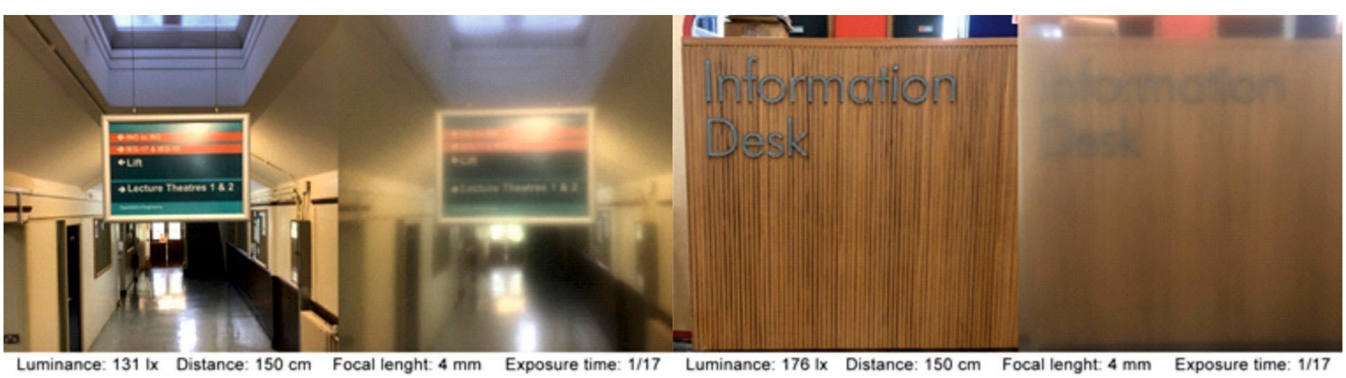

Figure 3. Signage case study. From left: signage without glasses (a), signage with simulation glasses (b), information desk text without glasses (c), information desk text with simulation glasses (d).

contrast difference between the text and its background, even though it appears considerably large.

Considering both examples, they illustrate how the legibility of a sign depends on a complex combination of numerous variables, which cover both the technical details of the sign and the contextual environmental factors.

It appears that the simulation glasses provided a method to empathically understand visual accessibility through a simple, low-cost tool that enabled all of these complex variables to be considered. It is important to highlight the fact that the assessment of the visual accessibility of features while wearing simulation glasses remains subjective. There may be situations where one assessor considers that a sign is visible while wearing four pairs of simulation glasses, yet another assessor may disagree. Partly, this may be due to different starting eyesight abilities of different assessors, but it may also be due to the subjective nature of perception and its interaction with prior knowledge of the visual stimulus.

Mandatory accessibility requirements have to be completely objective, such that there can be no doubt as to whether they are successfully met. The scope of such mandatory requirements therefore remains limited to areas where it is viable to provide a meaningful, yet objective technical specification of a feature that is compliant. Stair nosing is closer to be an example where this is possible, based on technical specifications of the width of the strip, to increase the contrast difference between the strip and the step, and the minimum level of ambient illumination.

In cases where these mandatory requirements have been developed, the glasses are not necessary to consider whether such feature is compliant. However, they remain extremely useful to communicate the benefit of meeting these technical specifications, and to make a persuasive case for change.

Furthermore, functioning effectively within indoor environments involves perceiving many features that are not completely covered through building regulations or accessibility requirements, such as wayfinding, signage, and controls for heating ventilation and lighting. The simulation glasses offer a simple method for this considerably extended set of features. This paper particularly emphasizes wayfinding and signage, as a first step towards considering an extended scope. For visual features that are not covered by mandatory technical requirements, current best practice for considering the visual accessibility of these features involves one or more of the following:

- With a **subjective experience**, it is possible to assess whether a feature of the built environment is easy to see, based mostly on personal beliefs and taste (e.g., interior designer, non-expert user).
- With a **trained subjective experience**, the subjective assessment of whether a feature is easy to see is informed through training (e.g., access consultant).
- With an **impaired subjective experience**, the assessment of whether a feature is easy to see is evaluated by persons with a particular level of visual impairment (e.g., a user with VA 6/18).
- With **heuristic guidelines**, the assessment of whether a feature is easy to see is evaluated according to whether it follows a set of best practice guidelines.

Of these currently available methods, the impaired subjective experience ought to be the most valid for truly determining the visual accessibility of these features. However, recruiting users with particular target levels of vision impairment is not straightforward. It is far easier to recruit normally sighted participants and give them a known level of visual impairment [38]. With this pilot study, we aimed to consider whether the Cambridge simulation glasses could improve these existing methods, and we discovered two additional opportunities as follows:

- With a **simulated empathic subjective experience**, the assessment of whether a feature is easy to see is evaluated by an assessor with simulated visual impairment (e.g., wearing 4 pairs of Cambridge simulation glasses).
- With a **shared empathic experience,** a person wearing Cambridge simulation glasses assesses the feature in collaboration with an impaired user.

With a **simulated empathic subjective experience**, people who have not had trained experience about accessibility can increase their awareness of how an impaired user might experience the space. This experience can be extremely engaging and informative, and it considerably improves the previous approaches that were named **subjective experience** and **trained subjective experience**. Furthermore, they can help to understand and interpret the **heuristic guidelines** and may help to pick up on issues that were not adequately covered within existing best practice guidelines.

With a **shared empathic experience**, the simulation glasses can help the communication between an architect or designer and a user with impaired vision. Such expert users can offer great insight into the issues they experience, but by experiencing these issues themselves, the architect or designer can offer great insight into how the experience can be improved, for example by choosing different colours, materials, or altering the lighting. With this approach, the shared empathic experience considerably approves on the previous approach that was named "impaired subjective experience". In advocating these opportunities for using the simulation glasses, it is vital to remember that the glasses will never cover the full spectrum of experience that visually impaired people have on a daily basis. Nevertheless, the glasses can be an informative, educational, inspirational, and experiential tool, that can leverage the power of empathy with a wider audience [12] [39].

V. CONCLUSION

Based on more than eight years of research on the use of the Cambridge Simulation Glasses for the assessment of visual accessibility of products, this paper introduces their use for examining visual accessibility in the built environment. Their potential use from stakeholders such as access consultants and design professionals can support an empathic experience of visually accessible features in the built environment. This preliminary work highlights potential benefits in raising awareness and educate stakeholders by using a low-cost tool to create a shared empathic experience across different stakeholders. Further work is planned to engage other users with the goal to explore other use cases by using these glasses and measure their benefit in daily working practice.

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