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ERGONOMIC PRINCIPLES IN INCLUSIVE DESIGN: ADDRESSING THE NEEDS OF VISUALLY IMPAIRED AND SIGHTED USERS

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Abstract: *This study analyzes the importance of ergonomics within inclusive design, viewed from the perspective of sighted and visually impaired individuals, based both on their experience in indoor and outdoor public spaces, as well as on slightly abstract factors such as intuition. To begin with, a comparative analysis is made between inclusive design, universal design, and ergonomic design, concluding that inclusive design represents a sum of the other two. All these characteristics are analyzed, developed, and translated into questions in the questionnaires and interviews addressed to the respondents. Two sessions of interviews and questionnaires were conducted. Following the first session, focused especially on the general opinion of the two groups on this subject, a discrepancy in perception and needs regarding ergonomics was concluded. However, sighted individuals show empathy when they are asked to consider the needs of the other group. The second session of questions focuses on how certain shapes and textures are interpreted through intuition. The similar results of the two groups highlight the fact that visually impaired individuals have an intuition like that of sighted individuals. These studies underline the need to integrate ergonomic solutions in public indoor and outdoor spaces. Future studies will analyze how these solutions can be integrated and will extend to more types of disabilities.*
Keywords*: ergonomic design, inclusive design, visually impaired, empathy, public space.*

1. INTRODUCTION

In the context of public spaces, inclusive design is particularly critical for individuals with disabilities. According to the World Health Organization (WHO) [1], over 1 billion people live with some form of disability, representing approximately 15% of the global population. Approximately 2.2 billion people worldwide have some form of visual impairment (Fig. 1).
The article explores the ergonomic principles underlying inclusive design, considering various types of disabilities, such as visual, auditory, motor, and cognitive impairments [2].

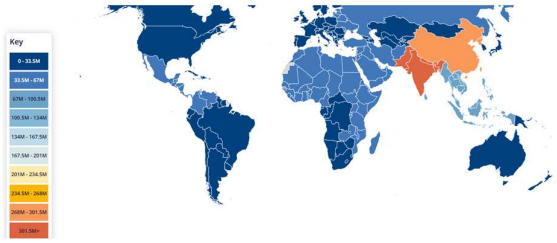

Fig. 1 No. of people affected by vision loss, 2020 [1].

This article shifts its focus towards investigating the design factors that affect impaired individuals (focused especially on visually impaired ones), while comparing their experiences with the perceptions of inclusive ergonomic design by sighted individuals. Although inclusive ergonomic design is frequently discussed, it is rarely implemented in practice, largely due to the need for more significant material resources and a broader conceptual framework.

Since creating environments that meet the requirements of this type of design often requires extra effort, many critical aspects are frequently overlooked. This article also aims to explore the views of sighted individuals, as they are typically the ones who design and develop spaces and tools that blind individuals must eventually use. By gaining a deeper understanding of these perspectives, it is possible to identify solutions that address the needs of both blind and sighted users. Overcoming these barriers has the potential to

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significantly improve the quality of life for individuals with impairments.
By the end of the article, the questions written above will be able to have a conclusive answer.

- Research Question 1 (RQ1): What is the difference in needs of ergonomic and inclusive design between sighted and visual impaired individuals?
- Research Question 2 (RQ2): At what level the needs of visual impaired people are presented in public spaces?
- Research Question 3 (RQ3): How do sighted individuals observe the needs of visually impaired people and to what level are they able to meet those?

2. UNDERSTANDING THE NUANCES: INCLUSIVE DESIGN, ERGONOMIC DESIGN, AND UNIVERSAL DESIGN

Inclusive design, ergonomic design, and universal design are often mistaken for one another because they share some common accessible and user-friendly characteristics. Each of these approaches prioritizes the accommodation of various user needs and enhancing overall usability, which can create the impression that they address the same elements. However, there are some different nuances to each of them. For instance, inclusive design aims to account for the larger spectrum of users, ergonomic design seeks to make present the comfort and efficiency for human use, and universal design incorporates accessibility features from the outset to ensure usability for everyone.

2.1 Ergonomic design

Ergonomic Design focuses on optimizing products and environments to fit the physical and cognitive needs of users. It aims to enhance comfort, efficiency, and safety [3].

The focus is to provide comfort, efficiency and safety. To make this possible, in ergonomic design are used principles from biomechanics, anthropometry and cognitive psychology. It is usually used in the design of workplace spaces, administrative offices, equipment of medical centres.

2.2 Universal design

Universal Design aims to generate environments and products that can be largely used by most of the users [4]. It usually provides generic shapes and textures. The main purpose of universal design is on creating a design for all considering the main seven principle of this kind of design like simplicity, minimal physical effort, appropriate size etc [5]. It is commonly met in public spaces like parks, markets, city centre.

2.3 Inclusive design

Inclusive design is a mix of characteristics correlated to the designs described above. (Fig. 2) Inclusive design enhances to please a large amount of people while considering comfortable features. Product optimization is a primary specific of an ergonomic design as well as the attention on efficiency, accessibility for users and comfort are other primary characteristics too. Universal design fights for adding value by integrating simplicity, flexibility and inclusivity. However, some features of universal and ergonomic design like equitable use or cognitive load cannot be integrated in inclusive design [5]. By being focused on each of the individual needs and understanding how the solution can be integrated to meet them, a high-quality inclusive design can be created. Inclusive design comes with some compromises by default that must be faced. Most of the time the main issue is the financial aspect. To balance inclusivity with meeting as many individuals as possible individuals' needs, it usually requires more resources than usual. Although, a possible opposite compromise consists in not meeting the expectations of a greater number of people [6].

Another challenge for the designer is to be able to empathize with the actual needs of an impaired individual. Sometimes, their needs can be misunderstood. To minimize potential error, this article analyzed via questionnaires and interviews some essential insights. This approach helps creators to be better informed about specific requirements of all users.

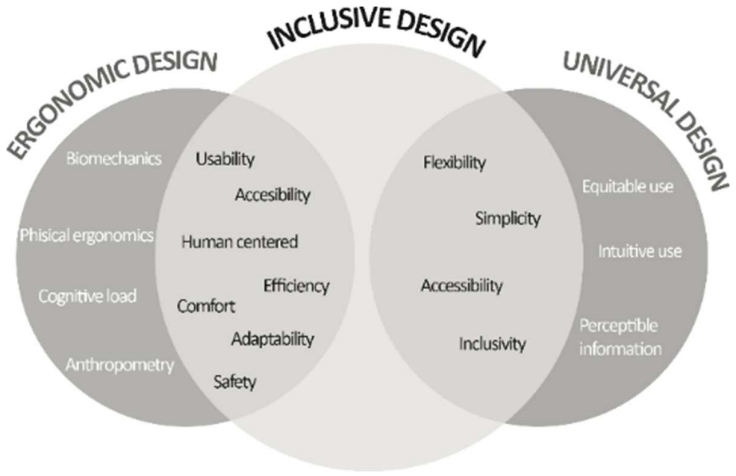

Fig. 2 Diagram with common and different characteristics between ergonomic, universal and inclusive design

3. RELATED WORK

Research on inclusive design highlights the integration of various ergonomic characteristics to ensure accessibility and usability for individuals with disabilities. One significant aspect is tactile information [7], which enhances spatial awareness and navigation for visually impaired users. Studies have shown that tactile cues, such as textured surfaces and Braille, provide essential feedback that aids in orientation and interaction with the environment. In public spaces, for example, tactile paving has been implemented to guide users safely, helping them avoid obstacles and locate key areas [8].

Another critical feature is visual contrast, which involves the use of high-contrast environments to improve visibility for individuals with visual impairments. High-contrast color schemes and clear, legible signage have been shown to aid in accurate perception and reduce navigational challenges for low-vision individuals. For instance, research indicates that a 65% luminance contrast is necessary for elements to be "easily visible" for those with severe vision impairments, suggesting that higher contrast requirements may enhance accessibility in built environments [9]. Additionally, auditory signals are crucial in inclusive design, providing auditory feedback and alerts that help users understand their surroundings and respond appropriately to environmental changes. These signals are particularly beneficial in situations where visual information might be insufficient or inaccessible [10].

Further studies emphasize the role of assistive technology, staff training, and space accessibility in inclusive design. Assistive technologies, such as screen readers and voice-activated controls, enable users with disabilities to interact more effectively with digital interfaces and devices.

Training staff to understand and implement ergonomic principles ensures that they can offer appropriate support and foster an inclusive environment. Moreover, designing spaces that are easily accessible, with features like ramps, wide doorways, and adjustable furniture, ensures that all users can navigate and utilize facilities comfortably. These combined efforts are crucial for creating a more inclusive and supportive environment, thereby enhancing the quality of life for individuals with diverse needs [11, 12].

3.1 The key features of ergonomic design

Based on various studies [8], [9], [10], [11], the key features include several crucial aspects:

Tactile information:

- Tactile Markings: Incorporating raised elements on surfaces such as buttons in elevators, switches, and Braille on keyboards.
- Tactile Pathways: Floor markings designed to assist users in navigating through complex environments, such as institutions, market or train stations.

Visual contrast:

- High Contrast: Applying strong color differences on objects and surfaces to be able to notice boundaries and shapes.
- Adequate Lighting: Ensuring well-distributed lighting and without glare that can expand visual clarity.

Auditory Signals:

- Sound Indicators: Using audible cues at least in essential locations, such as crosswalks and elevators, to communicate direction or status changes, like indicating elevator floors.
- Audio Guidance Systems: Offering auditory guidance in public venues, such as museums or buildings, to provide instructions and directional assistance.

Space Accessibility:

- Clear Layout: Offering a space with clear and intuitive layout to avoid clutter and objects placed randomly.

Staff Training:

- Education and Awareness: Offering to the staff the information that is needed when helping individuals in need. They also must be taught how to offer respect and understanding.

Assistive Technology:

- Electronic Devices: The presence of technologies can be life changing for most of the impaired people. Using screens with special navigation applications or other assistive technologies can help them feel independent and secure.

4. RESEARCH METHODOLOGY

This article includes two research methods: interviews and two separate surveys based on questionnaires.

A total of 95 people participated in the interviews and responded to the first questionnaire, including 83 sighted individuals (SI) and 12 visually impaired individuals (VII). For the second questionnaire, a total of 85 people responded, including 68 sighted individuals (SI) and 17 visually impaired individuals (VII). The questionnaires for each group were designed to communicate similar messages for both groups. Therefore, the photographs used in the second questionnaire for sighted individuals were made accessible through detailed descriptions. The responses are presented in tables and therefore are compared using graphs for a better understanding and to draw relevant conclusions.

4.1 Interview and First questionnaire

In this study, we conducted interviews and distributed questionnaires focused on the ergonomics of inclusive design. A total of 12 visually impaired individuals participated in the interviews, providing valuable insights into their experiences and needs. They also responded to the questionnaire. Additionally, 83 sighted people participated in the questionnaire, offering a broader perspective on inclusive design. The age (Fig. 3), gender, (Fig. 4) and occupation (Fig. 5) of the participants are presented in the graphs below, illustrating the demographic distribution of our study sample.

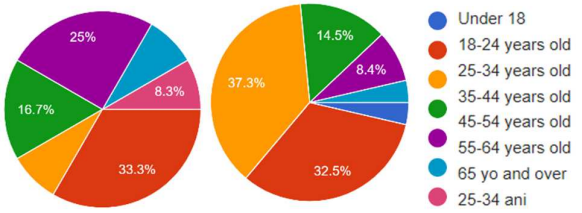

Fig. 3. Age of VII (left) vs age of SI (right)

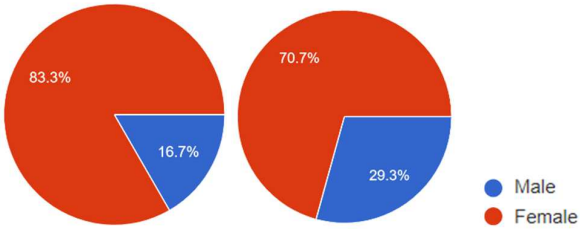

Fig. 4. Gender of VII (left) vs age of SI (right)

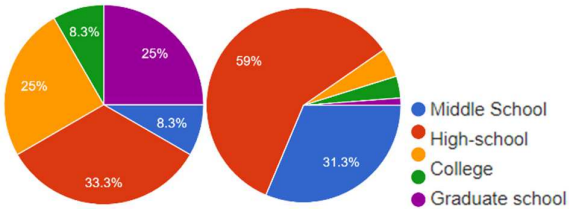

Fig. 5. Occupation of VII (left) vs age of SI (right)

4.1.1 Interview question

"What does ergonomic design mean for you?"

Expectation: The expectations for this question are that visually impaired individuals will focus on the characteristics of inclusive ergonomic design, while sighted individuals may overlook these aspects.

Answer: For both groups, ergonomic design was often an unfamiliar or difficult-to-understand term. However, the explanations provided by individuals for each group were similar, the groups themselves focused on different principles. Sighted individuals tended to describe ergonomic design as "comfortable," "efficient," "convenient," or "useful," whereas visually impaired individuals focused on aspects such as "obstacle-free spaces," "pleasant to touch," and "rounded edges."

4.1.2 First Questionnaire

Question 1: "Classify the following characteristics of ergonomic design for visually impaired individuals based on how important you consider them to be for a public space, from 1 (least important) to 5 (very important)." (research results in Fig. 6).

Question 2: Classify the following characteristics of ergonomic design based on how often you encounter them in public spaces, from 1 (never) to 5 (very often) (research results in Fig. 7).

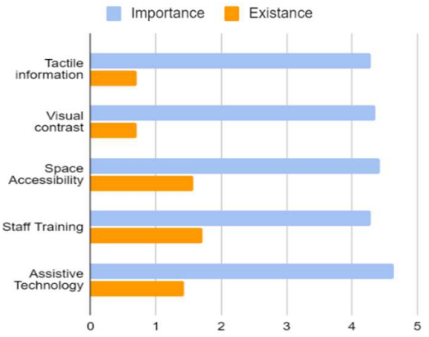

Fig. 6. Answer Q1 & Q 2: visual impaired individuals.

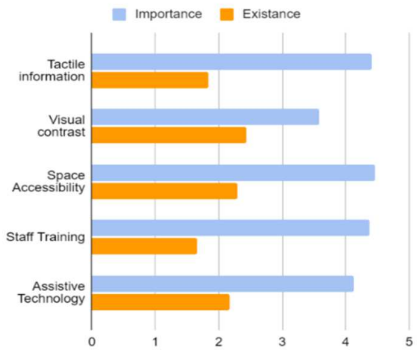

Fig. 7. Answer Q1 & Q 2: visual impaired individuals

Expectation: The expectations are that sighted individuals, when confronted with features of inclusive design, will become empathetic and adopt a perspective that aligns with the needs of blind individuals. The comparison of both groups is shown in Fig. 8 and Fig. 9.

4.2 Second questionnaire

The following questions are seeking to compare the way visual impaired people and sighted individuals understand the meaning of form and texture. The number of people who participated in the questionnaire is a total of 85, of which 68 are sighted individuals (SI) (33 fem) and 17 are visually impaired individuals (VII) (10 fem).

4.2.1 Question 1

"The images below (Fig. 10) represent a knife handle. At which end of the handle do you intuitively feel the knife blade is located?"

Accessibility: The question has been made accessible by providing detailed descriptions of both the handle and the blade: "Imagine that you are holding a knife with its handle lying horizontally. The handle feels thinner on the left side than on the right side. Which side of the knife do you think the blade is on?" All respondents are from Romania. The average age of the SI respondents is 33.10 years old, while the average age of VII is 29.71 years old.

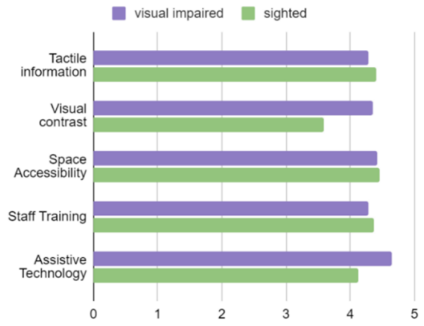

Fig. 8. Answer VII & SI about importance

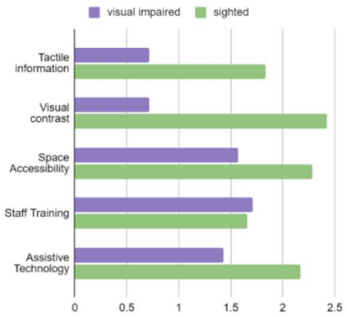

Fig. 9. Answer VII & SI about existence

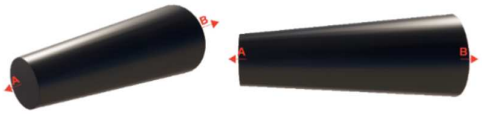

Fig. 10. Question 1: Minimal representation of knife handle;

Explanation: The question analyses the perception of gripping elements according to their shape. This analysis is necessary to understand how individuals interact with objects and comprehend their function. While a more in-depth analysis suggests what they do, considering the very short time required for using such elements, the necessity of intuition arises.

Intuition leads to a better functioning of the elements, especially in the case of elements with a danger of use. Gripping a knife and lifting it unexpectedly by the visually impaired user can create devastating problems, emphasizing the need for attention to detail.

Therefore, it is desirable that only upon gripping the handle, the user realizes in which direction the blade is oriented.

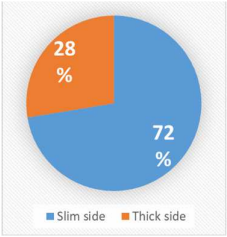

Fig. 11. Answer Q2**:** sighted people

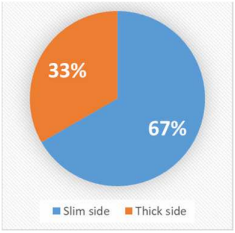

Fig. 12. Answer Q2: visual impaired

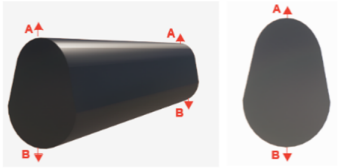

Fig. 13. Question 3: Minimal representation of knife handle.

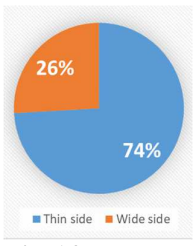

Fig. 14. Answer Q2**:** graph of sighted people

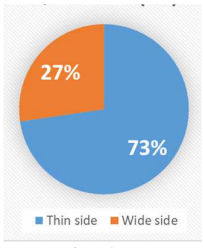

Fig. 15. Answer Q2: graph of visual impaired

With not even a second passing from gripping the knife to lifting it, the user must rely on intuition again, solving the issue of short timeframes.

Expectation: The knife blade should be in the thinner part of the handle, as the grip is better if the thicker part is held.

4.2.2 Question 2

The images in Fig. 13 depict a knife handle. The first image is a 3D representation, while the second one is a cross-section of the handle. In which direction of the handle do you intuitively feel the sharp part of the blade is located?"

Accessibility: The question has been made accessible by providing detailed descriptions of both the handle and the blade: "Imagine that you are holding a knife with its handle lying horizontally. The handle is cylindrical and feels narrower at the top than at the bottom. Which side of the knife do you think has the sharp edge of the blade?"

Explanation: Question 3 is an extension of the previous question, going even deeper, analysing both the sharp and dull parts of the blade. Once again, there are potentially greater risks of injury if the user holds the knife incorrectly, and the shape of the handle in cross-section can be a very good reference point.

Expectation: The sharp part of the blade should be directed towards the sharper end of the knife handle, while the dull part of the blade should be directed towards where the handle is more curved.

Interpretation of the answer for Q1 and Q2 (Fig. 11, Fig. 12, Fig. 14, Fig. 15): Both questions refer to a kitchen accessory that can cause significant accidents for any category of respondents. Their answers, once again similar, consider that intuitively the knife blade should be placed in the thinner part of the longitudinal section of the handle, and the cutting part of the blade facing the same direction as the thinner part in the transverse section of the handle.

Therefore, it can be inferred that the shape of these questions, whether visible or not, conveys the same message at an intuitive level. The shape of objects, elements, or accessories can indeed convey intuitive messages for their use. Another similar example where these two questions can

be applied is the door handle. For instance, the handle of a door, depending on its shape, can suggest the idea of pulling or pushing (Fig. 16).

4.2.3 Question 3

The image Fig. 17 represent textures that can be applied to various surfaces. Which of these textures, in terms of touch, do you intuitively feel suggests a hot surface and which a cold one?

Accessibility: The question has been made accessible by describing the textures, highlighting points of interest, namely, that the first texture is sharp, while the second one is smooth: "Imagine that you are feeling a surface with your hands. The left side of the surface is textured with spikes, while the right side is smooth and fine. Which side do you think might be hot and which might be cold?"

Explanation: This aspect is related to the sense of touch and how textures can alert the user about the surface temperature. This can be useful when there is a device that can generate very high or low temperatures. It can also be used in the context of a faucet to identify the direction of cold or hot water.

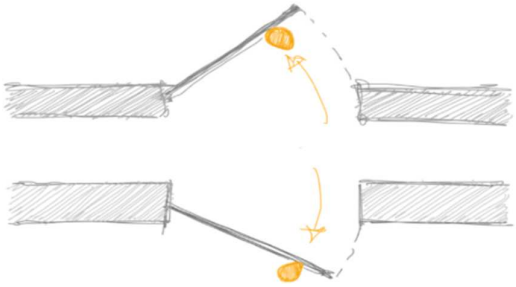

Fig. 16. Representation of the knob shape of a door that should be push.

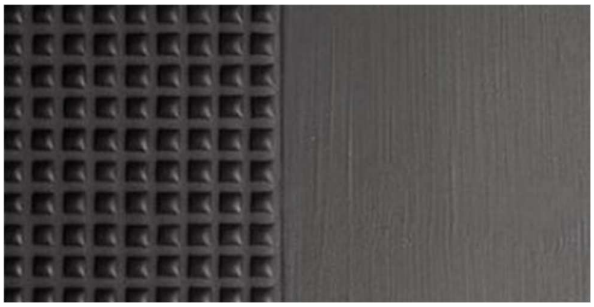

Fig. 17. Question 3: Representation of a sharp and a fine texture.

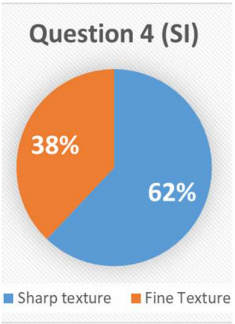

Fig. 18. Answer Q2: sighted people

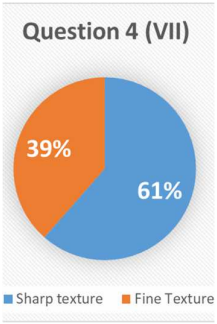

Fig. 19. Answer Q2: visual impaired

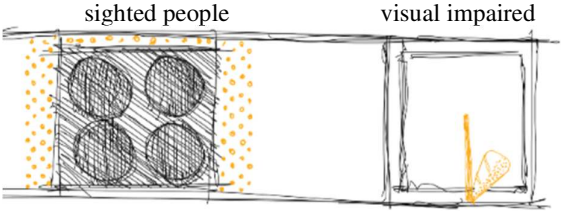

Fig. 20. Representation of the sharp texture applied on furniture/appliances to suggest hot surface.

Expectation: The expected response is to say that the sharp surface suggests it to be hot for several reasons. Firstly, the special and standardized warning sign in public spaces for visually impaired individuals represents a texture similar to the one in the image, and hot surfaces are often those that pose a danger. Secondly, at a tactile level, the sharp texture can simulate the sensation felt when burned. As for the smooth surface, it, through its reflective appearance, mimics ice, creating a sensation of cold.

Interpretation of the answer for Q3 (Fig. 18, 19)**:**

For question number 3, a majority percentage of 38% for Sight Individuals (SI), and 39% for Visually Impaired Individuals (VII), responded as expected. They consider that a rough, sharp, prickly texture suggests a hot surface, while a smooth texture implies a cold surface.

This information can also be applied in cases of danger for users, especially for hot areas such as the oven or stove. Additionally, it can be used for details such as the faucet handle to suggest the direction in which it should be turned for hot or cold water (Fig. 20).

5. DISCUSSION

Due to the analysis conducted throughout the article, we can answer the research questions posed at the beginning:

Research Question 1 (RQ1): The specific ergonomic needs identified include comfort and ease of use for sighted individuals, while visually impaired individuals prioritize spatial orientation and safety. Both groups also value tactile information and clear visual contrasts in the environment.

Research Question 2 (RQ2): Current ergonomic and universal design solutions partially meet the needs of both groups. While there is some level of awareness and implementation of inclusive design principles, significant gaps remain, especially in public spaces, where crucial features such as tactile paving and high-contrast signage are often lacking.

Research Question 3 (RQ3): Sighted individuals generally become aware of the visual impaired users needs when they are reminded to. The first series of questions showed us that they describe ergonomic needs considering theirs, but when the question mentioned the visual impaired people, they became aware of their needs instantly.

6. CONCLUSION

This study has provided valuable insights into the ergonomic principles of inclusive design, particularly for individuals with visual impairments. Through questionnaires, it was revealed that the perception of ergonomics differs significantly between sighted and visually impaired individuals. For sighted people, ergonomics is predominantly associated with comfort, whereas for visually impaired individuals, it is intrinsically linked to spatial orientation and safety. This disparity highlights the unique needs and priorities of different user groups when interacting with their environments.

Interestingly, when sighted individuals were asked to rank the importance of ergonomic characteristics for visually impaired people, they demonstrated a high degree of empathy. They recognized the crucial aspects of spatial orientation and safety for visually impaired users, indicating an awareness and sensitivity to the needs of others. Despite this empathy, both groups acknowledged the lack of inclusive design features in public spaces, pointing to a significant gap in current ergonomic implementations. Moreover, the study found that both sighted, and visually impaired individuals place similar importance on the perception of shape and texture. This suggests that these tactile characteristics are universally significant, enhancing the adaptability and interaction of users with their environments. The high level of adaptability observed among visually impaired individuals might stem from the absence of inclusive design features in public spaces, compelling them to develop heightened sensory and navigational skills.

These findings underscore the necessity for a more inclusive approach to design that incorporates ergonomic principles tailored to the diverse needs of all users (Table 1). By addressing the specific requirements of visually impaired individuals, such as enhanced tactile information and improved spatial orientation aids, designers can create environments that are not only more accessible but also safer and more intuitive for everyone.

One of the primary limitations of this study is the relatively small number of visually impaired participants compared to the sighted participants.

Fig. 21. The power of diversity and collaboration; Source: https://bootcamp.uxdesign.cc/my-journey-towards-inclusive-design-d410e0de0370

Table 1

The characteristics of inclusive design from different perspectives: sighted and visual impaired individuals.

Group of people	Perspectives of inclusive design
Sighted Individuals	Comfortable, Efficient, Convenient, Useful
Visual Impaired Individuals	Obstacle-free spaces, Pleasant to touch Rounded edges

Additionally, the questionnaires were not standardized across both groups; visually impaired participants received oral questionnaires and descriptions of images, whereas sighted participants were given written questionnaires with visual aid. This difference in the format of questionnaire administration could potentially influence the responses and introduce bias, as the method of presentation may affect how participants interpret and respond to the questions. Furthermore, the geographical scope of the study was limited to Romania, which may restrict the generalizability of the findings to other regions or populations. Diversity and collaboration can provide new insights into the approach in inclusive design (Fig. 21) [13]; sustainability solutions could be combined and considered as suggested by [14, 15] to solve problems related to safety climate at home and at work.

Future research should expand to include other forms of disabilities, ensuring that inclusive design principles are applied universally. This holistic approach will ultimately lead to more equitable and user-friendly public spaces, benefiting society as a whole.

7. FUTURE DIRECTIONS OF STUDY

Future research should expand to include a broader range of disabilities beyond visual impairments, such as auditory, motor, and cognitive disabilities. This comprehensive approach will ensure that inclusive design principles cater to a more diverse user base.

Additionally, studies should investigate the integration of advanced technologies, such as augmented reality and haptic feedback, to enhance the accessibility and usability of public spaces. Another crucial area for future exploration is the development of standardized guidelines for inclusive design that can be universally applied across different environments.

Collaboration with stakeholders, including users with disabilities, designers, and policymakers, will be essential to create effective and practical solutions (Fig. 21).

Finally, longitudinal studies are needed to assess the long-term impact of inclusive design interventions on user satisfaction and quality of life, providing valuable insights for continuous improvement and innovation in this field.

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Principiile ergonomice în designul inclusiv: analiza nevoilor persoanelor nevăzătoare și văzătoare

Acest studiu analizează gravitatea ergonomiei în cadrul designului incluziv, vizualizat din prisma persoanelor văzătoare și a persoanelor nevăzătoare, bazat atât pe experiența acestora în spațiile publice de interior și de exterior, cât și pe factori ușor abstracți precum intuiția. Pentru început, este realizată o analiză comparativă între designul incluziv, designul universal și designul ergonomic, ajungându-se la concluzia că designul incluziv reprezintă o sumă a celorlalte două. Toate aceste caracteristici sunt analizate, dezvoltate și transpuse prin întrebări în chestionarele și interviurile adresate respondenților. Au fost realizate două sesiuni de interviuri și chestionare. În urma primei sesiuni, axată în special pe părerea generală a celor două grupuri asupra acestui subiect, se concluzionează cu o discrepanță de percepție și nevoi în ergonomie. Totuși, persoanele văzătoare dau dovadă de empatie când li se precizează să ia în considerare nevoile celuilalt grup. A doua sesiune de întrebări este axată pe modul de interpretare a unor forme și texturi prin intermediul intuiției. Rezultatele asemănătoare ale celor două grupuri scot în evidență faptul că persoanele nevăzătoare au o intuiție asemănătoare cu cea a celor văzătoare. Aceste studii stau la baza necesității de a integra soluții ergonomice în spațiile publice de interior și de exterior. Studii viitoare vor analiza modul în care acestea pot fi integrate și se vor extinde pe mai multe tipuri de dizabilități.

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