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Small Living Space Prototype Design Parameters for Low-Vision Sufferers

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Abstract

Low vision is defined as chronic visual impairment that results in functional limitations, disabilities, and a vision problem that cannot be corrected by using assistive devices, drugs, or medical procedures. Attention to spatial design factors that allow people with low vision to move independently can improve their quality of life. The adaptation factor is essential in understanding the space for a person with low vision to minimize the possibility of accidents in their homes. Low vision sufferers rely on their memory or memory and their rest vision before utilizing their sense of touch in understanding space and making movements. Their ability to move in space is influenced by the legibility of the space captured through their rest vision and sense of touch. The legibility variables of the room include the clarity of the path in the layout, the geometric shape of the room, low light intensity, contrast of material and color, affordability of wall elements, and fixed position objects. These spatial legibility variables will ultimately enable low-vision sufferers to create a spatial mental map to help them move independently in the house without any accidents. This research is an experimental and participatory study to find design parameters that can help the movement of people with low vision without relying on memory or pre-existing memories. The objective is to validate spatial readability variables on a small dwelling prototype with the help of VR technology. The specified design parameters include 1) geometric layout that prioritizes path clarity; 2) affordability of wall elements and objects; 3) geometric object; 4) color contrast; and 5) fixed furniture and objects. The research involved twelve low-vision sufferer respondents aged 21 to 28 years old. This research aim to produce simple housing prototype design parameters that are friendly for people with low vision.

Keywords: low-vision, living space, design parameters, prototype

1. Introduction

Low vision is a chronic vision disorder that results in functional limitations or disabilities and cannot be corrected by using glasses, contact lenses, surgery, or drugs [1, 2]. The global population of people with low vision is predicted to be experienced by around 29% or 2.2 billion people worldwide [3]. Meanwhile, in Indonesia, around 0.79% or 2 million people experience low vision sufferers of the total population of Indonesia [4]. Low vision impairment can occur at various ages, from infants and adults to the elderly [3, 5, 6]. The cause of this disorder is due to side effects of diseases patients suffer such as age-related macular degeneration (AMD), cataracts, diabetic retinopathy, and others [1, 6, 7].

Low vision disorders in a person impact not only vision but also the psychological and social aspects of the sufferer [8-10], as well as the activities of low vision sufferers in space [11, 12]. Low vision disorders affect the sufferer's ability to understand (perceive) space, orientate, and move in space, and experience disorientation or spatial confusion [3, 12-17]. People with low vision have experienced at least one accident or more than one at home, such as falling, tripping, and bumping [14, 17]. Accidents in the house that people with low vision most often experience are in the kitchen, stairs, and bathroom areas [14, 17]. Low-vision sufferers do not lose their sight at all. In general, people with low vision can still see limitedly but experience various visual distortions (see Figure 1) caused by several cases of disease [1, 5]. Some people with low vision can still distinguish between light and dark, and some can still distinguish contrasting colors. There are also people with low vision who do not have central, side, or blurred vision. So, not all low vision sufferers see the same thing [1, 5].

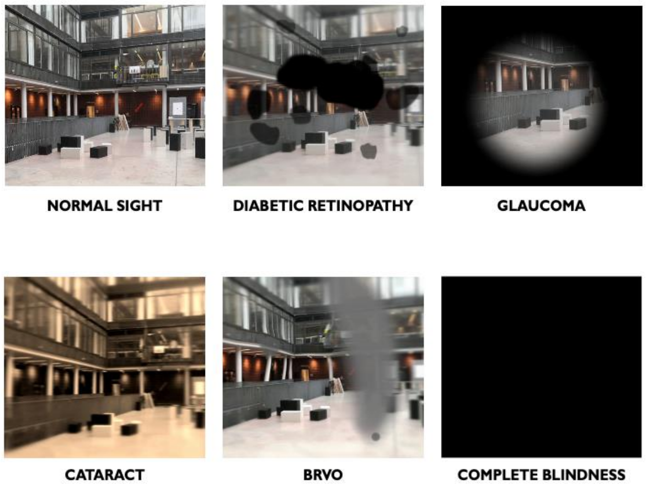


Figure 1. Low-vision sufferer distortion of vision [Source: 19]

The need for a conducive environment to support the mobility of people with low vision encourages the development of inclusive design guidelines for people with low vision [2]. These design guidelines focused on contrast sensitivity, lighting, materials and layout, and accessibility [2, 15]. The latest guide developed by the Institute for Human-Centered Design is based on planning and designing a wayfinding system for people with low vision. It is generally applied to the context of the workplace environment [11].

The results of previous studies found that participants with low vision relied on two primary sensors for their mobility inside the house, namely residual vision and sense of touch [18]. In addition to sensory, previous research also found that participants relied on memory in mobility and doing activities in the house [18]. Memory and the combination of the rest vision and sense of touch influence the participant's ability to read space while on mobility. Some variables determine the legibility of a room, namely the clarity of the path in the layout, the geometric shape of the room, low light intensity (100-200 lux), color contrast and material contrast, element affordability, walls, and objects, as well as fixed positions of furniture or objects [18]. These spatial readability variables help stimulate participants' residual vision and touch and ultimately enable participants with low vision to form a spatial mental map (spatial mental map) [18].

Because people with low vision do not completely lose their visual senses, an inclusive design guide specifically for people with low vision is developed with focuses that still rely on visual and other senses, especially the sense of touch. Inclusive design guidelines recommend the importance of contrast sensitivity, lighting, materials and layout, and accessibility [2, 15]. The ability of the rest of vision and the presence of other senses make planning and designing a wayfinding system for people with low vision important [11].

Wayfinding is a wayfinding activity that relies on sensory information from the surrounding environment to plan, process, and travel from one place to another [20]. An environment is said to have good wayfinding if it is easy to read. Environmental legibility is determined by wayfinding elements, such as paths, landmarks, districts, nodes, and edges [21]. Environmental readability will enable someone with low vision to process information into a mental map or cognitive mapping. Ultimately, it will decide how safe and easy it is to move from one point to another in an environment [22]. In order to make it easier for people with low vision to move and read space well, the environment needs to be designed to stimulate the senses of people with low vision.

The cooperation of the remaining senses of sight and touch and other senses in people with low vision helps them experience space and move in space and improve the quality of existential experience in space [23]. This combination of several senses (multisensory) can be beneficial for people with low vision in understanding space and the environment more coherently [23-26] so that, in the end, it can reduce accidents in the room and residential environment [14, 17].

This study aims to validate the spatial readability variables in a simple housing prototype (60 m2) created as a Virtual reality prototype. Validation of spatial readability variables found in previous research is essential so that this follow-up research obtains a more complete picture of residential design that can optimally utilize the rest of vision and sense of touch of people with low vision. For this reason, this simple housing VR prototype was tested on twelve respondents with low vision with various types of limitations and visual impairment.

2. Materials and Methods

This research is experimental and participatory research that combines quantitative methods and qualitative methods. Quantitative methods were used to test the prototype parameters developed by the variables found in previous research. The technique will be used to carry out a simulation test for respondents with low vision using VR prototype by an Oculus tool. Using VR prototype has some advantages and disadvantages. The advantages and disadvantages of virtual prototypes based on the evaluation results in research can be observed in Table 1.

TABLE I. THE ADVANTAGES AND DISADVANTAGES OF USING PHYSICAL COMPARE TO VR PROTOTYPE

Physical Prototype	VR Prototype
Building cost are more expensive	The trial can be carried out anywhere according to the respondent's location

Physical Prototype	VR Prototype
Testing must be carried out at the location where the prototype is built	The trial can be carried out anywhere according to the respondent's location
Requires sufficient space and is not flexible for other activities	It doesn't require a special space, can be done in any closed space and is flexible
It is difficult to change some variables such as color contrast	Prototypes can be made in a variety of contrasting colors at no additional cost
The application of all variables can be applied comprehensively	Variable light intensity and material contrast/texture cannot be applied
Visual field limitations correspond to normal vision	There are limitations to the field of view due to using Oculus

This study involved 12 respondents with low vision aged between 21 to 36 years. Respondents consisted of 8 women and four men. The twelve respondents had different low vision conditions. Five respondents had low vision since birth, another five had low vision since childhood, and two respondents had low vision as adults.

2.1 Methods

The initial prototype design used a simple layout organized sequentially from the entrance to the bedroom. The color contrast is the contrast of the primary colors to clarify the differences in door positions between walls, floors, and furniture.

This initial prototype was used for the testing and validation process for questionnaires from the FKIK Atma Jaya and the UPH team. The UPH questionnaire was prepared based on the research conceptual framework in Figure 2. Material contrast and light intensity were excluded from the path model because they could not be tested using the VR prototype. Thus, the questionnaire questions are structured based on five variables that support ease of mobility to reduce accidents and confusion and help ease recall.

The first stage of the trial began with validation carried out on six respondents with normal vision who were asked to use low-vision glasses so that they experienced difficulty seeing for the first time. This sudden condition means the respondent has not yet experienced adapting to the inability to see well. Using the glasses makes the respondent experience the same condition as a visually impaired person. Hence, the validation proses continue by testing the VR prototype. This initial testing process also provides several notes for improving the prototype. Initial prototype validation and testing activities can be seen in Figure 3.

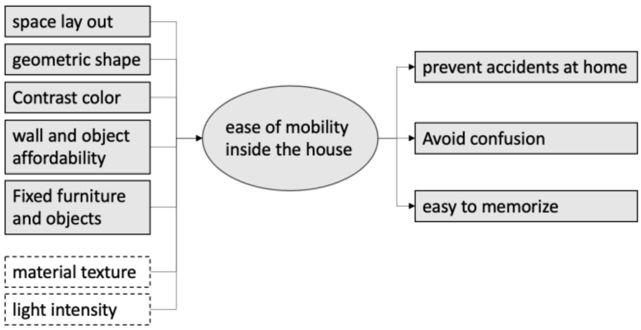


Figure 2. Research conceptual framework

Figure 3. Validation and intial prototype testing (Source: authors)

The testing process on the initial prototype revealed several findings:

a. All objects in the bathroom must be fixed, especially in wet areas. Soap and shampoo must be in the form of a dispenser with a fixed position

b. The position of furniture tucked into bends cannot be immediately recognized, so a more dominant contrasting color or more apparent geometric shape is needed.

c. The refrigerator cannot be recognized because recognizing geometric objects requires a certain distance. The dominant gray color of the refrigerator requires a frame of another color to be recognized.

d. The sink and closet can be easily recognized even though they are both white because of the contrasting wooden brown sink legs, which act as markers. This could be a guide to other designs, including refrigerator frames

e. Although there was no difficulty finding the switch, there was difficulty in pressing the light switch. The switch needs to be touched; the difficulty is felt because the respondents cannot know the distance without being able to touch it

f. Detailed objects such as reading, kitchen utensils, and other detailed activities require real objects (cannot use VR)

g. In the VR simulation, the height of the floor level can only be recognized by the color contrast. For more detailed tests on the floor, real objects must be used.

h. Material textures can only be done through simulation with real objects

i. Respondents could not feel any difference in light intensity

Based on the results of the initial trials and the validation process, several modifications were made to the prototype.

a. The prototype was designed in two variations of color contrast: sharp contrasting colors and contrasting colors with a more natural palette.

b. Utilizing lists or frames with more color contrast can easily be used as markers for movement paths

c. Using frames on refrigerators can make it easier to recognize objects

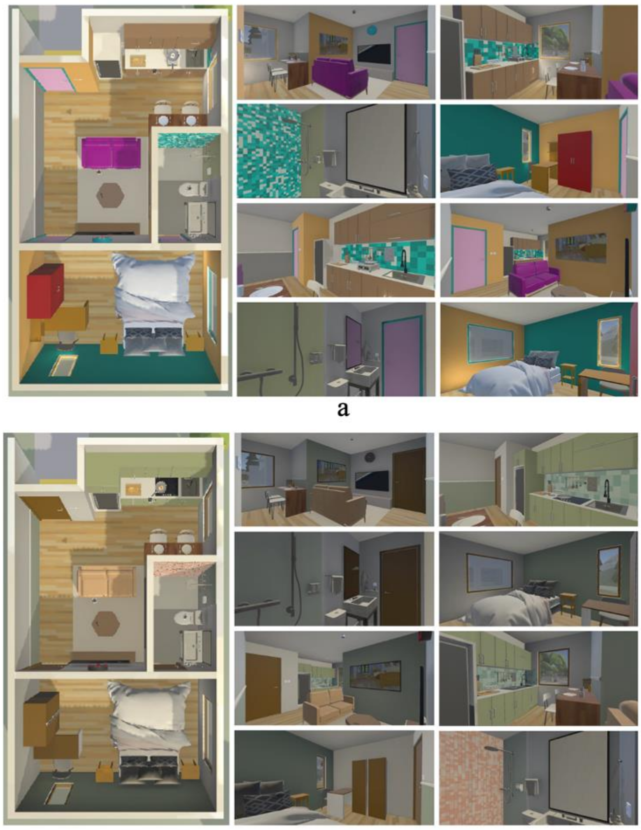
d. Do not place shelves in areas that tend to be hidden behind other objects

e. Placing fixed objects for accessories in the bathroom

Respondents were asked to test two simple housing prototypes using virtual reality technology (See Fig 5a) . The two prototypes have different contrasting colors. The first prototype uses a contrast color with a more assertive primary color (See Fig 4a), while the second prototype uses a more neutral contrast color (See fig 4b). The purpose of distinguishing the two prototypes is to see how the respondents respond to contrasting colors more suitable for their daily conditions.

Both prototype designs apply five parameters, including sequential spatial layouts, geometric shapes of interior elements, color contrast, affordability of wall elements and objects, and the fixed position of furniture and interior objects. Respondents answered 71 questions divided into eight sections assisted by research assistants (See Fig 5b). The first section contains questions regarding the identity of the respondent and consent confirmation. Sections 2 to 5 contain questions about testing prototype parameters. Prototype trials include layout and room arrangement, geometric shapes of architectural and interior elements, color contrast, affordability of marking objects, and fixed furniture and objects. Sections 6-8 are ease of orientation or legibility questions, ease of mobility without having an accident, and ease of memorizing or imageability.

Simple residential prototype design consisting of bedroom, living room, bathroom, kitchen, and dining room. Each room has marker features as objects that people with low vision can recognize. Trials for prototype validation used two simple housing prototypes with different color palettes (See Fig. 4a,b). Respondents conducted trials using Oculus and headsets. They explored each room before being asked to answer survey questions.



a

b

Figure 4. (a) Small living space prototype with more colorful color contrast, (b) Small living space prototype with more natural color contrast (Source: authors)

a

R b

Figure 5. (a) Small living space prototype with more colorful color contrast, (b) Small living space prototype with more natural color contrast (Source: authors)

2.2 Discussion

This study conducted trials on 12 respondents with various types of low vision. The survey found that more than 80% of respondents experienced a glare sensation that disturbed their vision. As many as 75% of respondents had problems with focusing their eyesight, 58% had problems with peripheral vision, and 33% had problems with both visual focus and peripheral vision. All respondents can still do their daily activities at home without the help of others. The survey result validated five parameters applied to the prototype (See Table 2). The survey results also show the validation of the prototype through confirmation of the respondents' experiences with both prototypes (See Table 3).

TABLE II. PARAMETERS AND PRINCIPLES OF WAYFINDING FOR PEOPLE WITH LOW VISION (SOURCE: AUTHORS)

Parameters	Prototype (a)	Prototype (b)
Spatial layout	>90% of respondents can easily recognize the room layout	>90% of respondents can easily recognize the room layout
Geometric shapes of architecture and interior elements	100% of respondents could recognize architectural elements such as doors and windows. >90% of respondents were able to recognize interior elements	100% of respondents could recognize architectural elements such as doors and windows. >90% of respondents were able to recognize interior elements
Color contrast	>90% of respondents felt helped by color contrast in interior elements	>90% of respondents felt helped by color contrast in interior elements
Affordability of recognizing object as wayfinding	100% of respondents can recognize doors and window as wayfinding object 75% of respondents can recognize wall to facilitate movement	100% of respondents can recognize doors and window as wayfinding object 66% of respondents can recognize wall to facilitate movement
Fixed furniture or object	>90% of respondents can recognize object such as dinning chair or sofa as wayfinding object <75% of respondents can identify small object such as kitchen appliances or toiletries in the bathroom	>90% of respondents can recognize object such as dinning chair or sofa as wayfinding object <75% of respondents can identify small object such as kitchen appliances or toiletries in the bathroom

Source: Authors

TABLE III. RESPONDENTS' EXPERIENCE ON PROTOTYPE

Respondents' experience	Prototype (a)	Prototype (b)
Ease of orientation or legibility	100% of respondents feel at ease to find a room and ease in orientation	100% of respondents feel at ease to find a room and ease in orientation

Respondents' experience	Prototype (a)	Prototype (b)
Ease of mobility without having an accident	>90% of respondents feel safe and can mobile without having any accident	>90% of respondents feel safe and can mobile without having any accident
Ease of memorizing or imageability	100% of respondents can quickly memorize and create a mental map of the prototype	100% of respondents can quickly memorize and create a mental map of the prototype

Source: Authors

3. Conclusion

This research found that the parameters can help low-vision sufferers identify space and objects to move more easily. They can memorize the logic of space fast, which helps them avoid confusion. The prototype testing found no significant difference in response between the two types of prototypes tested. In-depth interviews found that the existence of frames on objects or lists on walls makes it easier for them to recognize the geometry of objects. Respondents also need a certain distance sufficient to recognize the geometry of large objects. Meanwhile, for small objects such as wall clocks, toiletries, and kitchen appliances, the respondents needed a sharper color contrast to be recognized. The respondents were very disturbed by glare, so white colors, such as sanitary ware in the bathroom, tended to be more difficult to recognize. White elements require a contrasting color frame or outline to make object recognition easier. The use of a Virtual reality prototype makes some limitations to the research. The research did not count light intensity and texture since it is not possible to validate through a VR prototype.

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