The importance of inclusivity in supporting colour-blindness
study case: Gelora Bung Karno

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Abstract. This manuscript aims to discover how people with colour-blindness see and explore open space. Proper understanding of their experience in exploring three-dimensional spaces in the creative industries should now be considered as an essential requirement, especially to create an inclusive city. This research investigated the spatial experience in public space of two respondents: one from the protanomaly and the other from the... From interviewees’ experience and field observation, the study shows that the existence of contrast and shadow is crucial to create a spatial experience for the colour-blinds by perceiving depth. The result shows how the colours used in the area are still inadequate to support their deficiency. However, they are still able to navigate themselves around the space with the help of contrast and shadows produced in the space. These findings conclude the need to improve awareness and education within the creative industries towards colour-blindness to design a space that can be fully experienced by colour-blinds.

1. Introduction
An inclusive city is a city that can be accessed by people of all ages and genders and with varying levels of physical ability. Indicators of inclusive urban development are the fulfilment of the needs of women and vulnerable groups (children, the elderly, the disabled, and women with children) to access the city. The Charter of the Network of Indonesian Mayors for Inclusive Cities in Indonesia was signed in 2017 to increase support for people with disabilities and promote inclusivity in the city [1]. However, there are visual deficiencies that are not considered because they physically did not seem disabled [2]. One of them is colour-blindness, which is known to be a deficiency to perceive colours.

Colour-blindness is known to be a deficiency in perceiving colours. People who are affected by the most deficiency unable to differentiate colours. This inability to see chroma is usually referred to as colour vision deficiency, where it is most likely to be inherited through the male bloodline, where it hit 8% of them and only less than 1% of female bloodline [2]. Colour vision deficiency establishes a range of clutters with changing degrees and types from normal vision. It occurs when light-sensitive retina cells fail to adequately respond to variations in light wavelengths, which makes colour-blind people unable to see a variety of colours. The ratio of people who are affected by colour-blindness is 1:12 for men and 1:200 for women [3].

There are three known colour-blindness categories. Each category refers to the different ability in perceiving colours, which are: red-green colour-blindness, blue-yellow colour-blindness, and complete colour-blindness. Each of these categories is being divided into different specifications. Red-green colour-blindness is known as the most common category. It is divided into four specifications. The first one is deuteranomaly; the most prevalent form of deficiency in this category. It allows the appearance of green to become redder. It is mild and generally does not interfere with ordinary activity. The second category is classified when the red colour appears greener and less bright called Protanomaly. The last
two are Protanopia and Deuteranopia; both specifications are entirely unable to distinguish between red and green [2].

According to a study conducted by Paramei, Protanomaly is a form of trichromatism where a shifted action happening to the spectral sensitivity of the long-waved cones to those of the mid-waved cones [4]. Discrimination against hue is usually less than normal discrimination against trichromats. On the other hand, Paramei also stated that Protanopia is unable to distinguish the differences between red, yellow, and green hues. People affected by Protanopia are particularly associated with loss of sensitivity towards red. They are, therefore, more likely to arise from the alteration of the long-wave cone photopigment, which causes the spectral absorption curve to completely overlap with that of the mid-wave cone [4]. So, the differences between Protanomaly and Protanopia are mostly in the way to perceive hue. In supporting that, a study stated that even though the way they see hue is different because Protanopia is the reduced form of Protanomaly, but the way luminance is being received by them is still the same [5].

This writing, therefore, will focus on the Protanomaly and Protanopia, where it occurs the most in society [3]. Protanomaly is known as red-weak and Protanopia is known as red-blind. By researching this type of colour-blindness, this paper provides a clear understanding of Jakarta’s preparedness as an inclusive city. Gelora Bung Karno (GBK) is where the observation conducted. GBK was chosen as a study case because the recent refurbishment finished in 2018, where it is supposedly supporting the Asian Games 2018 as well as Asian Para Games 2018.

1.1 Spatial perception of colour-blindness

It is no doubt that people who are affected by Protanomaly and Protanopia have a few characteristics which are different from people with normal vision, especially on perceiving their space. In visual space perception, distance becomes the most important thing because it is a supporting cue in recognizing depth. Distance is difficult to perceive by people who struggled with colour-blindness and tend to misjudge it. Spatial perception is an interesting subject that studies the relationship between individuals and their environment [6]. However, discussion on visual perception by the colour-blind people is scarce. Most studies conducted, such as research by Atli, was focused on the normal vision. The lack of discussion further exemplifies the importance of raising awareness and conversation on the matter of visual perception by people who suffer colour-blind. Understanding visual space perception is a preliminary step to explain how an individual experience the three-dimensionality around them is influenced by colour and light, including the arrangement of individual particles, each in their respective sizes and location. Each particle's apparent position determines its trajectory and distance from the observing eye's point of view [6]. In this way, distance becomes one of the visual space perception most essential attributes as it is being elaborated in the diagram below.
As mentioned before, an individual who unaware of distance does not mean that they will not be able to experience depth. It is because, in monocular depth cues, there are several identifications. There are two categories of identification. Most of them are external identifications, which are: relative size, linear perspective, aerial perspective, interposition, texture gradient, light and shade, and colours [7]. The other category is the internal identification, which is happening inside the eye with the help of the eye muscles, which is: accommodation [8].

1.2 Spatial perception of colour-blindness
It would be a mistake to think that a person who cannot determine distance fails to perceive depth. To understand the implication of distance for people who suffers colour-blindness, the knowledge of depth cues needs to be understood. Monocular and binocular depth cues are the two broad categories that depth perception being studied. In most cases, monocular cues include environmental factors, while binocular depth cues are those that are more functional in spatial vision and are affected by environmental factors too [6]. The designer must be aware of how depth changing visual perceptions and how they can be used to alter the appearance of architectural space. There are two categories of identifications. The first one is external identification, which deals with size, linear perspective, aerial perspective, interposition, texture gradient, light and shade, and colours [7]. The other category, which is internal identification, implies the way our eyes muscles work to accommodate our vision [8]. This writing will focus on the ‘Light and Shade’ and ‘Colours’ aspects because, according to the statements mentioned above, these two are main factors affecting the spatial perception of colour-blind people.

According to a study conducted by Ozorhon and Uraz, light establishes a variety of relationships with building elements. Light accommodates eyes to see shades. Moreover, Shade has taken place in the creation of a visual composition. The combination of the two later appearing of what is called shadows, where it is considered a palpable presence [9]. The existence of shadows depends on how they are cast on walls or settled in space because different conditions could create different shades, such as thin or deep and soft or sharp. Colours, however, are categorized into hue, saturation, and brightness that are displayed to the observer. Therefore, the appearance of colour is considered to be a fundamental concept to perceive space.
However, the conditioning in perceiving colours depend on the background where the colours are placed. It is understood that brightness contrast often changes depending on the change in luminance level, and therefore dark colours appear darker and lighter when the luminance level is enhanced. Some conditions should be provided equally to make a colour matching between stimuli. If the surrounding or background conditions in two settings are not the same, a shift in the perception of brightness, called simultaneous contrast, occurs in the manner of the luminance levels. Colour changes in simultaneous contrast are followed by the opposing theory of vision, which refers to the system of cones as being processed by three opposing channels: red vs green, blue vs yellow, and black vs white. Simultaneous contrast can be seen in chromatic colours, and the opposite colours mentioned above will be capable to influence each other. Therefore, people with colour-blindness in the red-green spectrum struggle to perceive street signage with red and green-based colour. However, they capable of recognising signage with blue and yellow-based colour, although they still require a higher contrast to recognise them. Colour has become an important tool in communicating. When so many people are unable to make full profits, the effective use of colour becomes a challenge not only to themselves (those who are affected), but also to those who seek to attract as large user as possible. If colours cannot be properly distinguished from each other, this may have serious consequences. For example, coloured traffic signals, road borders, and signage. Colour-blindness can also cause a lot of discomfort and confusion in daily matters. Examples include illegible road maps, buttons, and dials for parking ticket dispensers, or invisible lines on the floors of sports facilities. This is then become a challenge for designer in designing a public space because they have to include spatial issue of colour-blindness into account as part of their design.

1.3 Visual experience of the colour-blinds

The visual experience in architecture is affected by different formal-geometric features such as size, contrast, direction, symmetry, closure, etc. and these factors are able to alter individual visual scan-paths, and affect awareness and appreciation of architectural designs [11]. The study indicates that the eye does not trace forms entirely but focuses on the overall arrangement of visual centres, major masses, and objects with distinct formal differences from the overall set. Special attention is given to elements that indicate spatial depth, such as vista. In the case of colour-blinds, the view they have received is only two dimensions of colour. Although one of their cones is weak or missing, this does not mean that they will not be able to experience dimension. The sense of depth is not just about binocular vision, and maybe seeing three colour dimensions is not just about having three kinds of cones. Finding out their inability to perceive colour and misjudgement in seeing distance, those who struggle with colour-blindness could experience space with the help of shadows and contrast. However, due to their limitation in receiving colour waves (hues), people with colour blindness depends on the brightness and saturation of an object and its background to perceive spatial depth.

Another study mentioned that the different conditions a range of hue being put will provide different sensation for the object [12]. Long-wavelength colours will appear to be in the front when a coloured object being put in front of a black background. On the other hand, if a coloured object being put in front of white background, the depth perception is reversed into seeing the short-wavelength coloured object appears in the front (figure 2). In that sense, the brightness of the background may stimulate the observer, which may have an effect on the perception of depth. Another study found that although colours are important in enhancing observer depth perception, saturation and brightness contrast are the most effective in stimulating observer depth perception. [13]. From that, it can be stated that colour-blinds still able to perceive depth even though they could not perceive the hue.

2. Methods

The technique used in this research is observational methods and is supported by an in-depth descriptive interview with each of the respondents. According to the statement by Sugiyono, the researcher is the instrument itself in qualitative research. Researchers should be validated on their own on their ability to conduct research [10]. In qualitative research, data collection is mostly conducted in the context of in-depth observation interviews and participants’ documentation [10]. The settings, direct observation, in-
depth interviewing, and review of the documentation are considered to be a fundamental method used by the qualitative researcher. In this research, the author uses direct observation supported by interviews and documentation.

Interviews were conducted by two males who visited Gelora Bung Karno (GBK) area in Jakarta in 2019. The main objective of this research was to understand how people who are affected by colour-blindness are exploring open spaces and how they navigated around the area. Interviews reveal that people who are affected by Protanomaly and Protanopia are capable of distinguishing a range of depths in open spaces. Nevertheless, their capacity to identify depth generates a variety of outcomes in the open space. Interviews reveal that people who are affected by colour-blindness are still able to navigate themselves around the space with the help of contrast and shadow. Nevertheless, their capacity to identify depth generates a variety of outcomes in an open space.

3. Result and discussion
Jakarta has already worked on creating an inclusive infrastructure. According to the Institute of Transportation and Development Policy Indonesia (ITDP) [14], the city’s spatial and design must support the mobility of various groups to be an inclusive and sustainable city. Although Jakarta tries to become an inclusive city, the government is too focused on assisting main physical deficiencies (blinds, deaf, disability) and not the one with minor disabilities, such as colour-blindness.

![Figure 2](image_url)

**Figure 2.** Colours being perceived by colour-blinds. (a) normal, (b) protanomaly, and (c) protanopia. Source: author.

To understand how people with colour-blindness explores different spaces, it is important to understand why humans form distinct boundaries between inside and outside. Human creates different boundaries surrounding them due to the fact that they need to change their environment based on their needs and goals [15]. Therefore, the distinction between inside and outside is important to fulfill the psychological necessities of human beings. Moreover, people with colour-blindness also have those necessities that need to be fulfilled, both physically and psychologically.

Open space can be defined as the great outdoor area, where it is generally associated with the environment. The environment referred to is described as the external state in which humans live. Research says that humans have a strong attachment and contact with the outdoor environment through both physical and psychological conditions [15]. Humans need an open environment to fulfil their physical and social life. However, the outside world is not always welcoming because it holds dangers and risks that might occur whenever and wherever. To anticipate dangers and risks, human creates a space that guarantees their protection from exposing themselves to dangerous threats by creating boundaries through a variety of planes, such as base plane, wall plane as well as overhead plane. In an
open space, most of the boundaries are invisible, either it was from a different levelling of the base plane or a range of trees alignment.

Humans are comfortable being surrounded by natural things, even the light [15]. That is why both respondents are preferred to be outdoors when they were told which spaces they would like to spend most of their time, when asked what factors make them prefer the open space, both responded that the amount of light in the open space helps them to see different shades and depths. This is supported by a statement saying that the combination of both light and shade will produce shadows [9] and the way those shadows cast will create different shade, whether it is light or dark. Thus, it will allow them to perceive depth.

With GBK as a study case, it could cover the city scope of macro, mezzo, and micro: Indonesia as a country as macro, Jakarta as a city as a mezzo and the GBK itself as the micro. By using GBK, it allows this writing to understand different layering in identifying the inclusivity. In GBK, most of the signage or landmarks are coloured red. This condition makes both respondents, especially the ones affected by Protanopia, unable to signify where they are standing. Although the open space allows them to perceive more colours and be more comfortable because it has fewer boundaries, GBK still considered confusing for them to find their way.

Table 1. Table of factors that can be felt by colour-blinds in open space.

| Factor          | Space’s Shape | Object’s Size | Contrast | Direction | Shadow | Depth |
|-----------------|---------------|---------------|----------|-----------|--------|-------|
| Protanomaly     | v             | -             | v        | v         | v      | v     |
| Protanopia      | -             | -             | v        | -         | v      | v     |

Different situations will create different effects on people with colour vision deficiency. In this case, the different effect created by people who are affected by Protanopia is considered significant in comparison to the one who is affected by Protanomaly. There are seven factors that are being mentioned several times by respondents which told to be the affecting factors of spatial exploration (table 1).

Efforts by GBK to make the area inclusive are still insufficient. This is because some of the signs still use colours that can only be seen by those with natural vision. This was proven by the respondents’ visits to the site.

![Figure 3](image)

Figure 3. The view of depth. (a) normal, (b) protanomaly, and (c) protanopia. Source: author.

The colours seen by respondents are more likely to go into the cooler spectrum (figure 3). Around the open space, both respondents shared similar reactions. The respondent who is affected by Protanomaly stated that it was easier for him to direct himself around the space because the alignment of the trees allows him to visualized depth. He also said that the monument in the middle act as a focal point that stood as landmark. For respondent who is affected by Protanopia also said that the alignment of the tree allowing him to see depth. They also allow him to know which one is in the front and which
one is located further in the back. When this respondent is being asked about the monument, he stated that he only sees it as a monument, and does not feel directed by it.

According to the respondent who is affected by Protanomaly, the design of this space helped him to move around. The curves surrounding the space creates a movement that makes one feel directed. He also said that the different pattern on the base plane also allowed him to see the direction that space was trying to create. On the other hand, the factors listed above could not have been encountered by the respondent affected by Protanopia. While it is only claimed to be red-blind, the spectrum of shades from red to green cannot be seen by them. The GBK is assembled with vegetation as an overhead plane and invisible boundaries. It disrupts his sense of three-dimensionality, so he could not direct himself around. He said he felt he was being placed in the middle of the space that enclosing him.

![Figure 4. The view of signage. (a) normal, (b) protanomaly, and (c) protanopia. Source: detik.com (edited by author).](image)

In the case of moving around the area, only the respondent with Protanopia was affected by the signage colours. It is due to the face that most of the GBK signs are red and green, as shown in figure 4. When the signage is located near the tree, they will not be able to distinguish the signage from afar, since the colour blends in their vision. Confusion also happens with the case of the bicycle road, where it painted green while the surrounding area is dark grey asphalt. Nevertheless, it is still can be useful because the pictorial symbol of a bicycle.

4. Conclusion

In general, GBK has met several factors required in developing inclusivity in a space. The availability of ramps increases accessibility for people with physical disabilities. However, several aspects need to be considered for later development of generating inclusivity for space so that it will improve the Indonesia’s Sustainable Development Goals. Based on the research findings, GBK’s public facilities and infrastructures are not yet accommodating to its visitors suffering from colour-blindness. Colours, especially, are crucial to navigate GBK and its surrounding. Choosing a wrong colour might be dangerous for people with colour-blindness. Defining GBK as an inclusive public space might be partially correct, but improvements are surely needed, especially for citizens with unseen disabilities, such as colour-blindness.

Reflecting from GBK as study case, architects and designers in Indonesia always keen to play with a variety of colour combinations when designing a space to enhance the spatial quality of the space itself. The intended spatial quality that architects designed in a building are not fully received by the
people who are affected by colour-blindness. Moreover, it is a challenge to emphasize the immense importance of developing a well-designed space that is both practical and in line with the colour-blinds. In terms of providing the community with inclusivity, adaptation and development that will address the needs of the user and respond to the local environment should always be taken into consideration and established.

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