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The Effect of Illuminance Artificial Light Interior on Color Difference Identification in People with Colour Vision Deficiency (CVD)

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ABSTRACT: Individuals with color vision deficiency (CVD) face challenges in various daily activities that require color identification such as selecting appropriate clothing combinations, identifying ripe fruits or vegetables, et cetera. This study aims to identify the best illuminance artificial lighting for color difference identification among individuals with CVD in Indonesia (0,7%). The research focuses on the quantitative analysis of experimental data to assess the effect of different types of illuminance artificial lighting on color perception in participant with CVD. A controlled experiment was conducted with a sample of individuals diagnosed with CVD (Deutronomali, Deutronopia, and Protonopia), utilizing a standardized color difference identification test based on Natural Color system (NCS) as the color experiment tools. The participant was exposed to different artificial lighting conditions, including various intensities (illuminance) and different color background (black or white) for each category. Quantitative data is collected, focusing on the accuracy, speed, and total steps for completing the task under different artificial illuminance conditions. Statistical analysis, including analyses of variance (ANOVA) and correlation analyses, are conducted to examine the relationship between illuminance lightings and color difference identification in individual with CVD. The results based on the analysis of duration, number of steps, and accuracy, the optimal illuminance level for identification color differences falls within the range 400-500 lux. The second-best illuminance level falls within the range 300-400 lux. In conclusion, range 300-500 lux are the best illuminance level for perceiving color variation.

KEYWORDS: Artificial lighting, Color, Color difference identification, Color vision deficiency, Illuminance, Lighting design.

INTRODUCTION

The sense of sight is crucial in human daily life, allowing individuals to receive and process information and interact with their surroundings. However, some individuals experience difficulties in perceiving colors, known as Color Vision Deficiency (CVD) or color blindness. CVD refers to the inability to distinguish certain colors or all colors, which can be caused by genetic factors carried by the X chromosome or certain diseases. There are no physical characteristics that can identify someone with CVD, so a diagnosis must be made through a color blindness test conducted by an ophthalmologist.

In Indonesia, the prevalence of color blindness was reported as 0.7% based on research conducted by Riset Kesehatan Dasar Indonesia in 2007, while globally, it ranges forms 2-5% with male-female ratio 3:1. Unfortunately, recent data regarding the prevalence of color blindness in Indonesia is unavailable. Visual Disability, including CVD, present three limitations as identified by Lowenfield (1948). The first limitation involves environmental and self-control factors, which can affect information reception and social interaction. The second limitation pertains to mobility and the challenges faced by visually disabled individuals in navigating at their environment. The third limitation concerns the level and variety of concepts, particularly for individuals with congenital disabilities who may encounter difficulties in acquiring new concepts. CVD patients also experience this third limitation due to differences in color perception compared to individuals with normal vision. Consequently, certain daily activities become challenging for individuals with CVD. For instance, a person with weak green perception may struggle to determine the freshness of red meat.

Light plays a crucial role in color perception. The retina, a structure in the eye, processes color perception by converting light energy into information received by cone cells and rod cells. Colors in objects are reflected light, and their assessment involves three qualities: hue, saturation, and brightness. Light sources in a room can be divided into natural sources, such as sunlight and moonlight, and artificial sources like electric light and candles. Artificial lighting, which is more controllable and stable than natural light, has a significant impact on color perception in a room. Luminosity and color temperature are key factors influencing color perception

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in artificial lighting, as revealed in Kruithof's research. In order to make the research results more specific and precise, this study only measures luminosity through illuminance in the experimental area. Meanwhile, the color temperature is determined using the same scale, referring to Wonyoung Yang and Jin Yong Jeon's research in 2020, which identified 4000 Kelvin as the most optimal color temperature for the learning process.

RESEARCH METHOD

This research methodology encompassed three distinct stages: data collection, experiment process, and analytical process. The process of data collection commenced with an extensive literature study, undertaken to gain insights into the perceptions of individuals affected by color vision deficiency (CVD) concerning color identification. Additionally, a phenomenon study was conducted to delve into the real-life experiences of individuals with CVD in their day-to-day activities. To ensure the efficacy of the experiment in addressing the research objectives, a pilot test was executed. This iterative process aimed to refine the experimental design and validate its appropriateness in investigating the designated research questions.

The experiment process utilized a quasi-experimental design with a within-group design due to subject availability. The research subject's area divides into two experimental groups: green type CVD and red type CVD. Each group undergoes three experimental categories of color based on the Nature Color System (NCS): blackness, whiteness, and chromaticness. Each session consists of five levels of illuminance (100-200 lux, 200-300 lux, 300-400 lux, 400-500 lux, and 500-600 lux), aligning with the Indonesia National Standard (SNI-6197) on energy conservation. Criteria for subject selection include having CVD, no history of other visual impairments, epilepsy, or mental disorders, and no history of serious illnesses. A medical color-blind test conducted by an ophthalmologist is required, and subjects must be aware of their CVD and willingly participate in the experiments.

The analytical process encompassed a comprehensive examination of the obtained data, involving the comparison of duration, accuracy, and the number of steps within the experiment. Statistical analyses were performed utilizing the widely adopted ANOVA methodology. The analytical investigation sought to discern the optimal level of illumination in artificial lighting that would facilitate effective color difference identification. The findings derived from this meticulous analysis will be comprehensively explicated and deliberated upon in the results and discussion section of the research report, providing valuable insights and contributing to the broader body of knowledge in the field.

Fig 1.1: photo of the arrangement method and experimental tools used *(source: personal).*

RESULT AND DISCUSSION

The experiment stage represents the culmination of the research process, refined through the findings derived from CVD identification and pre-experimental stages, also known as pilot test. During this stage, the research subjects were subjected to five distinct lighting conditions, determined in accordance with the illuminance levels as outlined in the research method section. The analysis and discussion of the results within this stage were organized into several subsections, encompassing the total duration of task completion at each illuminance level, the number of steps necessary to accomplish the given task at each illuminance level, and the frequency of error encountered at each illuminance level. The primary objective of this study is to determine the optimal illuminance level at which individuals with CVD can effectively discern variations in colors.

Duration

The result of the experiment unveiled fascinating insights into the relationship between illuminance levels and the duration of work required by participants. Across all the different levels of illuminance examined in the experiment, the average working duration ranged from 575,48 seconds to 619 seconds. These findings shed light on the impact of lighting conditions on task performance and

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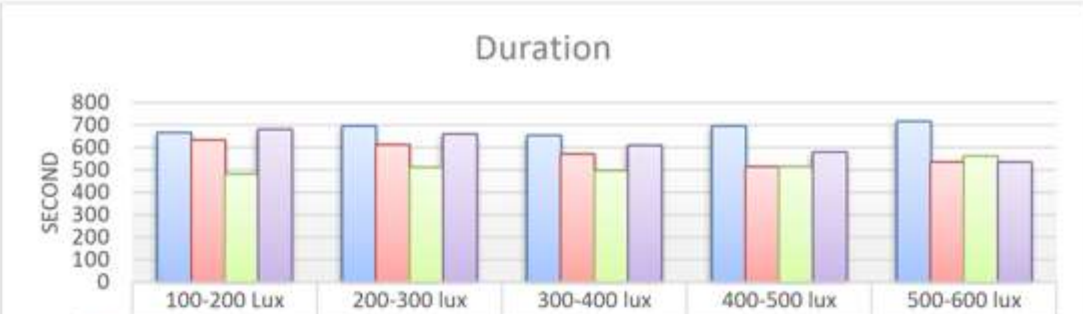
productivity. Among various illuminance categories tested, it was intriguing to observe that the shortest working duration was observed under light conditions of 300-400 lux and 400-500 lux. Surprisingly, both categories exhibited a negligible difference of just 6 seconds in average duration. This suggests that participants were able to accomplish their tasks efficiently and swiftly under these moderate levels of illuminance.

On the other end of the spectrum, the longest duration was recorded under an illuminance level 200-300 lux, totaling 619,0075 seconds. This finding implies that participants took more time to complete their work subjected to lower levels of illuminance. It is important to note that this longer duration may be attributed to reduced visibility and potential eye strain experienced under such dim lighting conditions.



	100-200 Lux	200-300 lux	300-400 lux	400-500 lux	500-600 lux
A	665,76	695,23	653,29	695,08	715,56
B	632,71	612,77	570,52	513,31	533,43
C	479,33	510,1	494,05	514,31	559,47
D	679,49	657,93	609,5	579,24	534,17

Furthermore, it is noteworthy that the working duration for each participant consistently decreased as the illuminance level increased from 200-300 lux to 300-400 lux. The reduction in working duration ranged from 48 to 16 seconds, highlighting the positive effect of higher illuminance levels on task efficiency. This trend suggests that participants benefited from improved visibility and enhanced visual comfort as the illuminance increased, enabling them to complete their tasks more rapidly. Adequate illuminance levels in the range of 300-500 lux seem to facilitate optimal task performance, as demonstrated by the shorter working durations observed in these categories.

Alterations in work duration

	100-200 Lux	200-300 lux	300-400 lux	400-500 lux	500-600 lux
A	0	4	-6	6	3
B	0	-3	-7	-10	4
C	0	6	-3	4	9
D	0	-3	-7	-5	-8

Alterations in work duration can be effectively demonstrated using the percentage change ratio formula, which allows us to measure the difference between initial and final values. By employing this formula: ((V2-V1): V1) x 100, we can determine the percentage

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change, where V1 represents the initial value and V2 indicates the final value. It is important to note that if the outcome of this calculation is negative, it signifies a decrease in percentage. In such cases, a decrease in percentage can be interpreted as a reduction in the work duration, indicating superior outcomes compared to an increase in percentage.

When analyzing the data, it becomes evident that certain lighting conditions significantly influence the duration of work. Notably, the most favorable percentage change was observed within the range of 300-400 lux, where all participants experienced a decrease in duration processing. This suggests that working under lighting conditions within this range resulted in improved efficiency and productivity. The reduced work duration can be attributed to the optimized lighting environment, which likely enhanced the participants focus and performance.

Conversely, the most substantial increase in percentage change occurred at 500-600 lux, leading to a longer experimental work for most subjects (excluding subject D). The higher lux levels in this range might have caused some participants to experience decreased productivity or increased confusion, ultimately leading to a longer time spent on tasks. Moreover, the data reveals that the most significant decrease in percentage change was evident at 400-500 lux, corresponding to a remarkable -10% reduction. This implies that some participants experienced a substantial improvement in work duration within this specific lighting range.

In conclusion, the duration of work can be influenced by various factors, with lighting conditions playing a crucial role. The percentage change ratio formula allows us to quantitatively assess alterations in work duration, highlighting the impact of different lighting levels. The finding indicates that maintaining lighting conditions within the optimal range 300-400 lux can lead to decreased work duration, resulting in improved outcomes. Conversely, higher lux levels, such as 500-600 lux, may contribute to longer work duration, potentially affecting productivity. Understanding these variations can assist in creating work environments that promote efficiency, productivity, and employee well-being.

Number of steps

This experiment also aims to investigate the relationship between illuminance levels and the number of steps required. The highest value of steps, amounting to 251, was observed within the range of 500-600 lux. Interestingly, both the illuminance level of 200300 lux and 400-500 lux yielded an equal number of steps. However, a notable decrease in the number of steps was consistently observed when transitioning from the 200-300 lux level to the 300-400 lux level. The reduction ranged from 11 to 6 steps across all participants. Remarkably, the illuminance level of 300-400 lux consistently produced the fewest and most similar result across all subjects, with average ranging from approximately 220 to 240 steps. Based on the findings, it is recommended to employ an illuminance level 300-400 lux to optimize task efficiency through lighting. These results contribute to the understanding of impact of illuminance levels on human performance and can serve as valuable guidance for lighting design and implementation strategies.

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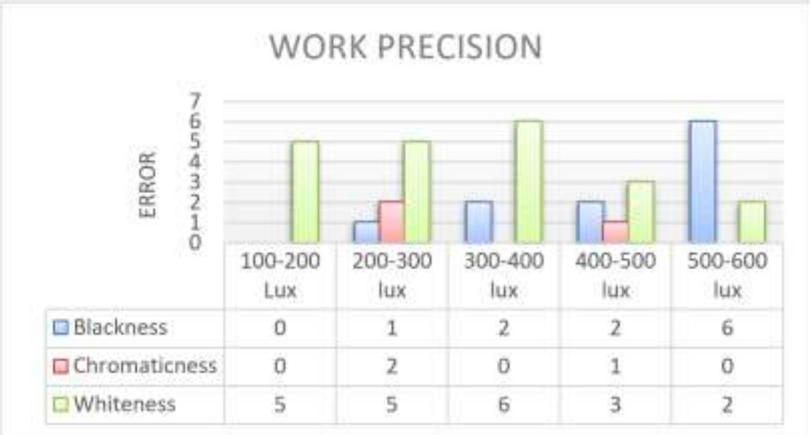
Evaluation of Work Precision

In this study, an illuminance range of 100-200 lux was examined, and the blackness and chromaticness classification demonstrated flawlessness performance, with no instances of stacking errors. This indicates a high level of accuracy and reliability in these classifications within this specific illuminance range. However, as the illuminance levels increased to 300-400 lux and 500-600 lux, the whiteness and blackness classification showed a higher occurrence of errors. Specifically, six pairs of color errors were identified in these illuminance ranges. This suggests that the precision of the whiteness and blackness classifications diminishes as the illuminance levels increase. On the other hand, the chromaticness classification consistently exhibited superior accuracy compared to the blackness and whiteness classifications across all illuminance levels.



Interestingly, the whiteness and blackness categories displayed contrasting change curves. Analysis from curve above revealed that the optimal illuminance level for precise work was observed at 100-200 lux, with the second-best level identified at 400-500 lux. These findings highlight the importance of selecting appropriate illuminance levels for different tasks to ensure optimal precision. However, it is worth noting that all other illuminance levels displayed an identical number of errors, amounting to eight errors. This unexpected outcome contradicts the previous analysis of process duration and the number of required steps.

Research has shown that illuminance levels can significantly impact visual performance and accuracy in various tasks. A high illuminance levels can improve visual acuity and reduce visual fatigue, leading to enhanced precision in detailed work. However, excessively high illuminance levels can also introduce glare and contrast issues, negatively affecting color perception and leading to errors in color classification tasks.

CONCLUSION

After carefully analyzing the data, several key conclusions can be drawn regarding the optimal illuminance levels for color variation perception. The findings indicate that an illuminance level ranging between 400-500 lux is considered optimal, considering factors such as duration, number of steps, and accuracy. Remarkably, this result is only marginally different from the illuminance level of 300-400 lux. Hence, it can be inferred that an appropriate illuminance level for distinguishing color variations exists within the range of 300-500 lux. Additionally, when the illuminance level is set at 500-600 lux, similar outcomes are observed in all three aspects: duration, number of steps, and accuracy. Although this illuminance level ranks third best among the five evaluated levels, it still provides satisfactory results.

On the other hand, an illuminance level of 200-300 lux yields the poorest results compared to the other levels. This level exhibits the longest working duration, the highest number of errors, and the greatest number of steps required. Therefore, it can be concluded that this illuminance range is not suitable for efficient color variation perception tasks. Interestingly, an illuminance level of 100-200 lux demonstrates flawless accuracy of 100%. However, it necessitates a relatively high and similar duration and number of steps, which makes it unsuitable for time-efficient activities.

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In conclusion, based on the analysis of duration, number of steps, and accuracy, the optimal illuminance level for identifying color differences falls within the range of 300-500 lux. While other illuminance levels also yield satisfactory results, they may not be as efficient or consistent. The results of this study hold significant implications for individuals with CVD in their daily lives. These implications manifest in various challenges, such as identifying ripe and unripe fruit, assessing the freshness of meat based on its color, making appropriate choices in clothing and cosmetics, and so forth. The implementation of adequate lighting within the environment can offer substantial assistance in mitigating these challenges.

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