GRADUATION PROJECT

Degree in Dentistry

COLOUR MEASUREMENTS WITH DIFFERENT TYPES OF LIGHT.

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Abstract

Aesthetic restoration is a growing modern speciality of dentistry. Ever so popular due to the rapid propagation of information both scientific and commercial with the growth of social media, there are still many fields within this speciality that warrant in depth investigations. In this pilot study, we will be investigating the effects of light and illumination on the colour selection of restorative material. Twenty eight participants, of which fourteen were dental students of Universidad Europea Madrid (UEM) and University of Jordan (UOJ), as well as fourteen professional dentists practicing in Madrid and Amman most of whom were also UEM professors, were asked to use different light sources to match unidentified vita guides with labelled ones. The participants were evaluated on their ability to identify restoration colours under different lights and they were then asked to rate their experience and comfort using said lights. In the end ,it was concluded that not using additional light sources, or in other words, using natural or ambient lights, is the reliable method of choice when selecting restoration colour among our participants, with it not only being the most accurate but also the most comfortable when making selections.
Moreover, red or warm light can be ruled out for use in making colour selection as not only does it provide a challenge when it comes to accurately doing the measurements, but it also seems to be irritative for visual perception and can cause agitations that would interfere an adequate and patient colour selection, while on the other hand, blue light seemed to have less adverse effects such as irritation but did not seem to help with accuracy.
With that being said, further investigation are warranted for a multitude of other determining variables that were difficult to be kept under control in this study. Including but not limited to, biopsychosocial variables within the participants as well as physical variables that affect visual perception within this investigation.

Resumen

La restauración estética es una especialidad moderna en crecimiento de la odontología. Tan popular debido a la rápida propagación de información tanto científica como comercial con el crecimiento de las redes sociales, todavía hay muchos campos dentro de esta especialidad que merecen una investigación profunda. En este estudio piloto, investigaremos los efectos de la luz y la iluminación en la selección del color del material de restauración. Veintiocho participantes, de los cuales catorce eran estudiantes de odontología de la Universidad Europea Madrid (UEM) y la Universidad de Jordania (UOJ), así como catorce dentistas profesionales que ejercían en Madrid y Amman, la mayoría de los cuales también eran profesores de la UEM, se les pidió que usaran diferentes fuentes de luz para hacer coincidir las guías vita no identificadas con las etiquetadas. Se evaluó a los participantes en su capacidad para identificar los colores de la restauración bajo diferentes luces y luego se les pidió que calificaran su experiencia y comodidad con dichas luces. Al final se concluyó que no utilizar fuentes de luz adicionales, es decir, utilizar luces naturales o ambientales, es el método de elección fiable a la hora de seleccionar el color de la restauración entre nuestros

participantes, siendo no solo el más preciso sino también el más adecuado. cómodo al hacer selecciones.
Además, la luz roja o cálida se puede descartar para su uso en la selección de colores, ya que no solo supone un desafío cuando se trata de realizar mediciones precisas, sino que también parece ser irritante para la percepción visual y puede causar agitaciones que interferirían en el funcionamiento. selección de color adecuada y paciente, mientras que, por otro lado, la luz azul parecía tener menos efectos adversos, como la irritación, pero no parecía ayudar con la precisión.
Dicho esto, se justifica una mayor investigación para una multitud de otras variables determinantes que fueron difíciles de mantener bajo control en este estudio. Incluyendo, entre otras, variables biopsicosociales dentro de los participantes, así como variables físicas que afectan la percepción visual dentro de esta investigación.

Keywords:

- Hue
- Chroma
- Light
- Illumination
- LED
- Vita-shades
- Brightness
- Electromagnetic Spectrum
- Electromagnetic Wavelength
- Colour Selection
- Opalescence
- Visual Perception
- Visual Alertness
- Visual Focus

Palabras de clave

- Matiz
- Croma
- Luz
- Iluminación
- CONDUJO
- Tonos Vita
- Brillo
- Espectro electromagnético
- Longitud de onda electromagnética
- Selección de colores
- Opalescencia
- Percepción visual
- Alerta Visual
- Enfoque visual

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Introduction

A modern and rapidly growing field of dentistry and medicine. Aesthetics or cosmetic restorative dentistry is not only a vital speciality to be studied due to its independent role in the psychosocial well-being of a patient, [26] but it is also quite advantageous to study aesthetic rehabilitation as it has been proven to motivate preventive habits and is argued to go hand in hand with preventive and periodontal oral health. [10]
It also seems to have a huge role that accompanies orthodontics, recent cross-sectional studies demonstrate that young adults have a preference for and seek orthodontic treatment as a way to preserve and improve dental aesthetics rather than as a method to fix malocclusion. [27] In facts, within that study it was concluded that: *"Patients who seek orthodontic treatment are concerned with improving their appearance and social acceptance, often more than they concern with improving their oral function or health. Results confirm the view that adolescents attribute high importance to an attractive dental appearance. Finally, gender has a significant variable in predicting the psychosocial impact of dental esthetics."[27]*
When considering aesthetic rehabilitation of one's dentition, tooth colour often tops the list of patient's priorities. Defined as the property possessed by an object of producing varied perceptions on the eye as a result of the way it reflects or emits light, [1] there are many factors that influence colour therefore, the main three being the source of light, observed object and observer. [1] In the case of a tooth, the resulting colour is due to a combination of light reflected from the enamel and light reflect and refract from both enamel and dentin. [2]

Researches also suggest other influences when it comes to how patients perceive their teeth that not only imply a certain bias based on the perception of tooth colour, but perhaps that the opposite effect can take place at times.[11] Even more studies suggest that skin tone also has a significant clinical relevance when it comes to colour selection[7] , while some studies hint at a correlation in findings where women showed brighter teeth shades than men on average. [13]

However, ever clinically relevant are the illumination and the illuminated, in other words, teeth and the light source.

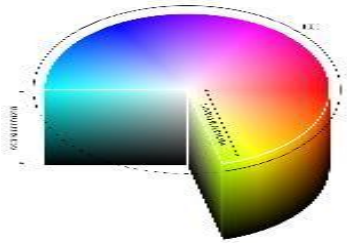
Teeth display many optical properties including but not limited to: [14]

- **Hue**
    - Defined as the dominant wavelengths from the visible spectrum that yields a perceived colour. While some authors might refer to it as the biological colour of the tooth, due to the combination of other wavelengths reflected upon perception, it has a slightly diminished clinical relevance.
      [14]
    - In the Vita Shade Guide, Hue is represented by a letter, where (A) is Reddish Brown, (B) is Orange Yellow and (C) is Grey. [12]

- **Chroma**
    - Defined as the saturation of the colour, the Chroma of a tooth comes from dentin, while the quality and quantity of the overlying enamel effects the influence of the dentin's chromatic ability as a thick enamel is more opaque for example. [14]

- **Value**
    - Defined as the sum of light reflected from an illuminated object. As light can be absorbed refracted or reflected, the value of a tooth is therefore it's ability to reflect light or brightness, where higher value results in brighter shades and lower value results in dimmer shades.[14]
    - In a Vita Shade Guide, Value is represented by a number from 0-5, with 0 being highest value and 5 being lowest. [12]

- **Metamerism**
    - *Often observed on a composite restored tooth, metamerism is a phenomenon where two objects can display a matching colour under one light source, and yet appear mismatched on another, showing an effect where the light source masks difference in values between two objects.[14]*



(Three dimensions of light. [14])

- **Fluorescence**
    - Defined as the absorption of light of a certain of wavelength and the spontaneous re-emission of light of a lower energy wavelength. In natural teeth this occurs by the absorption of ambient light and subsequent reflection of the light as visible. [14]

- **Translucency**
    - Defined as a gradient between transparent and opaque, the degree of translucency varies within both the dentin and enamel. [14]
    - In the case of central incisors enamel for example, the incisal third is more translucent than the rather opaque middle third. [14]

- **Opalescence**
    - Described as the ability of an “opal” material to refract light at varying wavelengths. In the case of enamel, it is given by the prism rod structure. [14]

Having a better understanding of some of these optical characteristics, it is said then that the perception of tooth colour is dynamic[3], as these characteristics are given off by specific structures within the dental organ which undergo wear and integral changes with age, as concluded when lighter teeth colours where found in teenagers when compared with adults in certain researches.[13] However, these researches also conclude an influence on educational level when it comes to maintaining tooth colour, thus appreciating teeth colour was found to be a huge motive for dental maintenance. [11][13]

It is very important for dental care professionals, particularly those in the aesthetic speciality therefore to be very careful when selecting restoration colour in comparison with natural teeth while taking in account the other wavelengths reflected when perceiving tooth such as skin and gingival tone. [7][14]

Moreover, it is vital that we recognise the light source when making a colour selection not only to avoid phenomena such as metamerism or unwanted fluorescence from occurring but also to aid in the advancement of technology and restorative material when it comes to their optical characteristics in comparison to natural dentition in order to better satisfy patient's demands.

In facts, pilot studies prove that certain technologies such as VITA Easyshade Advance 4.0® to be efficient in daily clinical use in limiting the effect of different lighting source when making a colour selection. While insisting that further studies should be conducted to investigate this phenomena. [1]
Nevertheless, VITA shade guides in generals showed better adaptability under different light sources when compared with other methods of measuring and selecting colour such as spectrometry. [3]
For this reason, classical shade guides were used in this study both to maintain consistency and to maintain the relative low difficulty of using the guides under different lighting, as shown in recent studies. [3]

Hence, it is useful to attempt to collect and quantify data regarding the measurement of colour under different light sources and explain their clinical relevancy particularly in Aesthetic dentistry.

Meanwhile, in order to better critique the study, we must keep in mind the psychologyical effects of illumination and colour background, while some studies show indifference to colour temperatures of ambient light, [21] others show significant effects observed with both temperature and hue, [17,18] which will hopefully also be investigated in this study.

In elaboration, in a study where three dimensions of illumination, namely hue saturation and brightness were investigated. It was concluded that each dimension had a particular effect on visual perception via psychological stimuli. [22] To quote the authors:

"The emotion ratings showed that saturated and bright colours were associated with higher arousal. The hue also had a significant effect on arousal, which increased from blue and green to red. The ratings of valence were the highest for saturated and bright colours, and also depended on the hue. Several interaction effects of the three colour dimensions were observed for both arousal and valence. For instance, the valence ratings were higher for blue than for the remaining hues, but only for highly saturated colours. Saturated and bright colours caused significantly stronger skin conductance responses. Achromatic colours resulted in a short-term deceleration in the heart rate, while chromatic colours caused an acceleration. The results confirm that colour stimuli have effects on the emotional state of the observer."[22]

Objectives

The primary question for this study is to investigate which light is most useful and accurate when making restorative colour selection.

The secondary objectives include;

- Identifying which wavelengths allow for better identification.
- Identifying which wavelengths produce challenges when making selections.

Materials and Methods

Using Vita Guides with their identification covered and replaced with a generic label. We will expose these guides to different available lights sources mainly in the dental laboratories of Universidad Europea Madrid. A questionnaire will be provided were the task will be to match colours, an informed consent is given to and signed by all participants.

Four groups were selected, two student groups and two professional, divided according to experience level. Participants were first asked to match four unidentified vita shade guides with identified vita guides under natural light, then questioned how many they were able to correctly match and how difficult they found the process to be under said light. This process was repeated under chair lamp, warm, and cold light.

As a source for the warm and cold lights, an outdoors fifty Watt garden projector was selected and attached with a five meter extension cord for safety purposes. The projector includes fifteen colours, of which crimson (700nm wavelength) was used to represent warm light and cyan (500nm wavelength) used to represent cold light.

In order to keep most determinant variables under control. The experiment mostly took place during the same time of day at more under similar conditions, due to the size limitations and the experience requirements for participants, exceptions were made where the experiment was repeated in the private practices of some of the

participants, provided that ambient condition match that of the UEM laboratory reasonably.

Another exception was made where the experiment was tried at the dental laboratory in the UOJ hospital, given that the lighting and ambient conditions relatively match those of UEM laboratory.

On the other, dental laboratories of Jordan University of Science and Technology, (JUST) were ruled out of the experiment due to differences in ambience and conditions of the campus which prevented the experimented from being repeated there without major changes in dependent variables.

These dependent variables not only included the wavelengths of the lamps used in the ambient illumination of the laboratories, but also the availability of sunlight through windows and doors as well as general temperature and room climate.

Thus, provided the use of no windows with white economy LED lamps for ambient illumination, this pilot experiment can be expanded and elaborated in future studies taking place in the UEM laboratory without any issue, as well as other laboratories when reasonably aligned with the conditions stated in this study.

Informed consent was handed to and signed by the participants before the activity. Following that, they were asked to fill a survey on how accurate they were in selecting colours and how easy they found it to be.

The results collected were then analysed and compared with recent studies regarding the effects of light and illumination in the fields of dentistry, medicine, psychology and ergonomics.

Inclusionary criteria were:

- Scientific articles investigating the effects of light in dentistry, psychology and ergonomics.
- Scientific articles available in any language which can be translated online.
- Books and established references for use in definition and introduction.

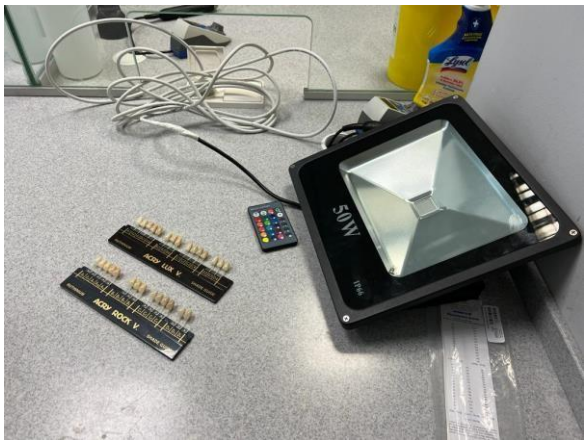
Exclusionary criteria were:

- Articles published more than ten years ago. (As of 2022)
- Commercial articles or articles only cited for advertisement reasons.

- Articles based on theory only, without any studies or references to back them up.

Pictures 1 and 2 were taken at the laboratory station during the experiment, they show all the equipment used during the activity. The colours shown on the remote control are the 16 colours available by the projector.

(Picture 1)



(Picture 2)

Results

Dental students with no clinical experience participating in the vita guide matching exercise recorded the following results:

	0 correct	1 correct	2 correct	3 correct	4 correct
Ambient Light		2			
Dental Chair Light		2			
Warm Light	2				
Cold Light	2				

When asked to rate their comfort level or difficulty when using the lights to match the guide, dental students with no clinical experience recorded the following:

	1 Very Hard	2	3	4	5 Very Easy
Ambient Light		1		1	
Dental Chair Light		2			
Warm Light	2				
Cold Light	2				

Dental students with clinical experience (policlinica) participating in the vita guide matching exercise recorded the following results:

	0 correct	1 correct	2 correct	3 correct	4 correct
Ambient Light	1	1	1	7	2
Dental Chair Light	1	1	6	4	
Warm Light	5	2	5		
Cold Light	2	3	5	2	

When asked to rate their comfort level or difficulty when using the lights to match the guide, dental students with clinical experience (policlinica) recorded the following:

	1 Very Hard	2	3	4	5 Very Easy
Ambient Light		1	1	4	5
Dental Chair Light		1	4	4	2
Warm Light	8	2		1	
Cold Light	4	3	2	2	

Professional dentists with up to five years of clinical experience participating in the vita guide matching exercise recorded the following results:

	0 correct	1 correct	2 correct	3 correct	4 correct
Ambient Light				2	2
Dental Chair Light			1	1	2
Warm Light	2		2		
Cold Light		3	1		

When asked to rate their comfort level or difficulty when using the lights to match the guide, professional dentists with up to five years of clinical experience recorded the following:

	1 Very Hard	2	3	4	5 Very Easy
Ambient Light				1	3
Dental Chair Light			1	3	
Warm Light	2	2			
Cold Light		4			

Professional dentists with more than six years of clinical experience participating in the vita guide matching exercise recorded the following results:

	0 correct	1 correct	2 correct	3 correct	4 correct
Ambient Light				2	8
Dental Chair Light	1	1	3	2	3
Warm Light	7	1		2	
Cold Light		4	4	2	

When asked to rate their comfort level or difficulty when using the lights to match the guide, professional dentists more than six years of clinical experience recorded the following:

	1 Very Hard	2	3	4	5 Very Easy
Ambient Light					9
Dental Chair Light	1	1	2	3	2
Warm Light	7	1	1		
Cold Light		8	1		

Dental students in general participating in the vita guide matching exercise recorded the following results:

	0 correct	1 correct	2 correct	3 correct	4 correct
Ambient Light	1	3	1	7	2
Dental Chair Light	1	3	6	4	
Warm Light	7	2	5		
Cold Light	4	3	5	2	

When asked to rate their comfort level or difficulty when using the lights to match the guide, dental students in general experience recorded the following:

	1 Very Hard	2	3	4	5 Very Easy
Ambient Light		2	1	5	5
Dental Chair Light		3	4	4	2
Warm Light	10	2		1	
Cold Light	6	3	2	2	

Professional dentists in general participating in the vita guide matching exercise recorded the following results:

	0 correct	1 correct	2 correct	3 correct	4 correct
Ambient Light				4	10
Dental Chair Light	1	1	4	3	5
Warm Light	9	1	2	2	
Cold Light		7	5	2	

When asked to rate their comfort level or difficulty when using the lights to match the guide, professional dentist in general recorded the following:

	1 Very Hard	2	3	4	5 Very Easy
Ambient Light				1	12
Dental Chair Light	1	1	3	6	2
Warm Light	9	3	1		
Cold Light		12	1		

The overall results from the vita guides matching exercise are:

	0 correct	1 correct	2 correct	3 correct	4 correct
Ambient Light	1	3	1	11	12
Dental Chair Light	2	4	10	7	5
Warm Light	16	3	7	2	0
Cold Light	4	10	10	4	0

The overall ratings for the lights

are:

	1 Very Hard	2	3	4	5 Very Easy
Ambient Light	0	2	1	6	17
Dental Chair Light	1	4	7	10	4
Warm Light	19	5	1	1	0
Cold Light	6	15	3	2	0

Statistics:

Using the tables of results we have, we can deduce several statistics that can help us draw and conclude hypotheses:

- All participating dentists with more than 6 years of experience consider selecting colour without light as the easiest method, giving it a rating of 5. (P=100)
- All participating dentists regardless of experience had little issues selecting colour without light. (Probability of scoring more than 3 and rating it a score of 4 or higher= 100)
- Not a single participant was able to have get a full score with Warm light. (P=0)
- Not a single participant was able to have get a full score with cold light. (P=0)
- Not a single participant rated their comfort using warm light with a score of 5. (P=0)
- Not a single participant rated their comfort using cold light with a score of 5. (P=0)
- All participants regardless of experience struggled with warm light. (Probability of scoring less than 3 = 96)
- All participant regardless of experience had the least comfort with warm light (Probability of giving it a score of 4 or higher = 4)
- Participating dentist did not enjoy using cold light (Probability of rating it 4 or higher= 0)
- However not a single dentist rated cold light with a 1. (P=0)
- In general, the majority of participants had scored the highest without light. (Probability of scoring 3 or more = 82)
- In general, the majority of participants found ambient light the most comfortable (Probability of rating it 4 or higher= 88)

Discussion

Due to the size limitations of this pilot study, only hypotheses with a probability higher than 95 can be considered as definitive. With that being said, we can conclude that natural or ambient light is a reliable and the method of choice when selecting colour among experienced dentists.

On the other hand, extremely warm light (crimson) light, can be ruled out for use as it only served to challenge dentists with experience, while students struggled when selecting colour using it even more.

Cold light (cyan) also seemed challenging for most participants, however it seems to have an advantage over warm light. No participating dentist rated it a 1, therefore all experienced participants found it slightly easier than warm. While there are no definitive hypothesis for cold light among students, the pattern of finding it slightly more convenient than warm light persists, despite not being as statistically evident.

No hypothesis was generated for the dental chair lamp, being the one light source with the most scattered results. Interestingly though, one slightly evident pattern that can be observed is that dentists with less experience had a slight preference for dental chair light, however this could either be a statistical coincidence due to the small sample size, or due to less familiarity with the shade guides.

It is significant to point out that the ambient light in the laboratory where the experiment took place seems to have a colder shift, while the chair lamp had a warmer shift.

While attempting to correlate the apparent slight cold shift observed in the results, a comparison can be made with recent similar studies in other fields where the effects of lights were measured on general visual perception and mood. There it was observed that while both colour extremities presented discomfort for the participants, red colour was concluded to be the most challenging due to more augmented negative effects compared to blue. [15]

“Red reduces visual comfort and increases the temperature of the perceptual colour. Comparison of visual assessment of blue colour with white showed that there was no significant difference in many of these cases. In general, the blue colour compared to

the red reduced the level of state anxiety, anger, fatigue, and confusion and a relative increase in happiness, peacefulness, and vigor." [15]

On the other had, blue was observed to have certain positive effects in other studies such as improved alertness, mood and cognitive function. [16] The effects of caffeine were also evaluated in that study combined with blue light, so it is worth noting that such a question was not asked in this study, but it is important to keep in mind that all data were collected during the day.

Another variable that should have been controlled but was not due to the time limitation of the study was chroma, although several saturations were available for use in the device. In a recent study measuring the effect of colour of students learning performance, *"The results showed that, although participants assessed the situation as relaxed, calm, and pleasant in the pale colour conditions, reading scores were significantly higher in the vivid colours conditions. Heart rates were significantly affected by hue; they increased in the red and yellow conditions. In addition, the results suggested that, regardless of the degree of whiteness, the hue had a significant impact on participants' emotions; blue increased relaxation and calmness feelings of participants compared to the other colours." [17]*

This practically means that although the main psychological effects come from the Hue of the light, the chroma of the illumination also has an effect, one that can be witnessed in the study, since both warm and cold lights used were vivid extremities.

Another psychological effect which warrants further studies is the status of experience, while actual experience has an established and proven effect even in this study, the slight disparity in the results witnessed between experienced students, early dentists and experienced dentists could also be credited to the pressure of performance, as well as actual experience with vita guide materials. To elaborate, a common comment among all participants in this study was that the experiment "had been interesting, but difficult." This could both mean that the pressure of being evaluated was involuntarily a variable and also that the psychological effects of colour on learning performance could have taken place, [17] meaning the experience could have negated the positive cognitive effects of blue colour or the agitative effects of red.

Focusing back to the ambient light in our experiment, the university laboratory has no windows, but has white walls as well as marble floors and desks. Hence, we can rule out the effect of the sun in our experiment, however, the room's background and slightly cooler LED illumination is worth discussing.

In facts recent studies show that brighter background and illuminance could have positive psychologically reinforcing effects that improve visual perception. [18]

Perhaps another reason warm light proved challenging in our experiment was the contrast with the bright but cold ambience in the room, which could cause confusion when selecting the restorative material. [16]

Moreover, other studies show a correlation between colour and body temperature as well as gender on alertness and visual perception. [19] Such findings are vital to be recognised in future studies, specially should this pilot investigation be repeated on a grander scale.

This perceived cold shift preference however seems to correspond with other studies investigating the effect of cold temperature on colour perception. Where under warmer ambient conditions, white colours were less well perceived than when under cooler light conditions. [20] This is something which is particularly useful to study for the field of aesthetics.

Moreover, besides the psychological effects of colour, the social effects of colours should not be ignored either. Studies show that background colours and ambient lighting both have a direct effect on focus and perception which also could be impacted by gender, age, cultural and mood differences as well as physical variables such as hue brightness and saturation. [25]

Another issue that should be taken into registration when carrying out this study is familiarity with the Shade guides. While it is said that Classic shade guides are adequate for carrying out investigations on the effects of light in colour selection. [3] The fact that some learning curve is needed when handling shade guides should not be ruled out. While the disparity in results between students without any experiences and dental students with clinical experience can be attributed to coincidence due to a small sample size, it can also be argued that familiarity and adequacy with the equipment is a causal factor or determinant variable alongside experience with dental colours and colours of dental restorations in general.

Therefore a useful step to take into consideration when repeating this investigation on a grander scale is the prior evaluation of shade guides themselves and their properties. In elaboration, a study can be done on the shade guides themselves, testing their facility of use as well as their accuracy and repeatability, since many participants noted that guides did not seem very uniform, then it can be followed up by an investigation on the effects of the light source using the same exact tested equipment.

Not to be neglected is the dental lamp, having the most scattered results, it seems difficult to prove its utility in colour selection, it is worth noting that the dental lamps provided all had the same yellowish colour with a warm shift, thus the challenges provided by this light could also be contributed to the hypothesis that warm light could reduce accuracy. Otherwise, it could be said that the extra provided illumination of a closer lamp did not serve to aid the participants neither in precision nor comfort. Therefore, it would be relevant to investigate especially the effects of neon lights against dim lights in making selections to confirm this hypothesis too.

Combining the data we have, we cannot make a definitive conclusion nor prove a hypothesis, but we can observe a preference for ambient light among all participants, yet we cannot say for sure if an equal combination of wavelengths is the most useful or if the slightly colder shift is a clinically relevant finding.

Further studies on a larger scale should be made, variables that can be controlled better in future studied include but are not limited to:

- Homogeny of the lamps used as a source for ambient light.
- The weather forecast during the days of the experiment, due to the effects of sunlight.
- More combinations of colours of different wavelengths can be used in future studies.
- Study's population can be better divided, variables such as speciality can be used as future studies, as several Orthodontists verbally noted that they have not used shade guides in years, while Aesthetic dentists were a lot more familiar.
- Light sourced can be better isolated, perhaps the experiment can be repeated in the dark, rather than using the studied light sources in combination with ambient light.

- The equipment used can be investigated individually to determine the effects of each determinant variable and the degree of significance. For example, testing the Shade guides that are to be used prior to commencing the investigation regarding the effects of the light source.
- The effect of light intensity on colour selection should be investigated in advance and controlled during the experiment.
- Perhaps a tool can be used to better hold the guides for a more objective observation and more accurate representation of the light sources onto the guides.
- The participants were not asked about their age, or vision status, no differentiations were made between participants who wear glass and those who do not.
- Colour blindness was not a question in our study, which is vital to be taken into consideration in the future.
- All physical dimensions of lightening and illumination should be further investigated in detail prior to repeating the study in better controlled environments.
- All psychological influences of lightening and illumination should be studied and confirmed or negated prior to repeating the study in order to better understand whether such influences should be considered variables in the study.
- All social influences of lightening and illumination should be studied and confirmed or negated prior to repeating the study in order to better understand whether such influences should be considered variables in the study.

Conclusion

To conclude, further studies need to be made with better control of determinant variables and much larger sample populations. Nonetheless, to answer the question of the investigation within the realms of the study, ambient or natural light appears to be the most accurate and reliable illumination method to make colour selections. However, perhaps that is because the ambient light in this study is sourced from bright white LED lamps with a slight cold shift, thus the observed slight cold shift preference is a phenomenon that warrants further studies on a larger scale.

Moreover, we can also rule out radically warm light wavelengths such as crimson, or in other words 700nm wavelength light as a method to make accurate selection as not only did it prove challenging to both experienced and non-experienced participants, but also it seemed to be slightly irritating for the participants vision and general aura, which corresponds to previous studies investigating the effects of illumination on mood and visual perception.

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