Task lighting for Thai older adults: Study of the visual performance of lighting effect characteristics

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C. Namanee, N. Tuaycharoen. Task lighting for Thai older adults: Study of visual performance of lighting effect characteristics. Gerontechnology 2019;18(4):215-222; https://doi.org/10.4017/gt.2019.18.4.003.00 The purpose of this project was to study a variety of task lighting conditions in order to identify the most favourable conditions for visual performance and subjective preference as judged by Thai older people in which the bedroom context was chosen for the research. There were two sessions for this purpose. The first session aimed to observe the effect of lighting on the visual performance of Thai older adults. The impact of the lighting variables was also examined, including illuminance, correlated colour temperature (CCT), and lighting output characteristics on the measurements of the Numerical Verification Test (NVT). Twenty-four Thai older adults participated in the experiment. The second session explored the effect of illuminance, CCT, and lighting output characteristics based on a subjective assessment. The results showed that the Thai older adults believed illuminance and CCT significantly affected the NVT measure as well as other subjective measures. The results also showed that, for the bedroom, 1,250 lux appeared to produce the highest visual performance while 750 lux at a CCT = 6,500 K and up/down light output characteristic (40/60) was the most preferred by the Thai older adults.

Keywords: Visual performance, correlated colour temperature, illuminance, Thai older adults

Introduction

Visual impairment increases with age, which can result in unnecessary loss of independence and a diminished quality of life for many older adults. This condition limits what they can do in their daily lives including the activities that provide their emotional and social well-being, as well as the actions that can increase their rate of falls and fractures. Lighting is one of the important factors that can create a suitable environment for the older people. Good lighting can help compensate for a decline in an older person's ability to see and provide needed comfort. Many studies relating to the visual performance of the older adults have continued to be an important topic over the years. Most research has strongly revealed the effect of illuminance and showed that older people need higher illuminance than younger people to keep their vision efficient (IESNA, 2011; 2016).

Apart from the increased illuminance, there are some other parameters that affect the visual performance of the older adults, but such studies have yielded inconsistent results; such as, correlated colour temperature (CCT) (Janosik & Marczak, 2016; Maher, 2017; Yamagishi et al., 2006; 2008).

Yamagishi et al. (2006) investigated the reading performance of older and younger people under four different light sources of the CCT in a range from 2,300 K to 11,000 K. The results of the study showed that white LED lighting was superior to that of a fluorescent lamp and incandescent lamp and could provide legibility for elderly people. In a later study by Yamagishi et al. (2008), they examined the effects of the CCT with the strengths of 2,500 K, 5,000 K and 8,200 K on the visual performance of elderly people under the white LED lighting. The results of the study suggested that 5,000 K LED lighting was suitable for the visual performance of older people.

In addition, Janosik and Marczak (2016) investigated the effect of warm and cool lighting on the visual performance of older workers. They found that the light of a higher CCT generally improved the visual performance of older people. Moreover, it should be applied at workstations of older people, especially where colour discrimination is demanded. The results of their study showed

Figure 1. The bedroom setting and apparatus used in the experiment. Experimental setting for the reading task in the bedroom (left); furniture setting for sleeping and relaxation area in the bedroom (right).

that older people discriminated hues much better at cold light illumination (CCT = 6,500 K) than at a warm one (CCT = 2,700 K), in spite of the same colour rendering index (CRI) of the two types of fluorescent lamps. Although achromatic and monochromatic visual tasks (the Bourdon test results and the Landolt C eye) were performed with similar accuracy, independently of the CCT, both the objective results were slightly better for cool light.

Maher (2017) also explored which CCT of artificial light assisted adult individuals to see better in an achromatic task light setting and which four CCTs they preferred utilizing a tunable LED lamp. The finding of this study showed that older subjects performed best in the 4,100 K CCT in all four achromatic tests - the Minnesota Low-Vision Reading Test (MNRead) time, MNRead errors, NVT number time, and NVT number errors. The older subjects made the fewest errors and read the fastest under a 4,100 K LED lamp.

Furthermore, the characteristics of the light output ratio should be taken into account and may have an effect on the visual performance of the older adults. Although no study has been conducted on elderly subjects, Houser et al. (2002) investigated the human subjective response to spatial distributions of light resulting from different uplight/downlight photometric distributions in young subjects. The findings of their study showed that the room appeared

Table 1. Test lighting conditions in the experiment

Factors	Test level					
	1	2	3	4	5	6
Illuminance (lux)	250	500	750	1,000	1,250	1,500
CCT (K)	2,700	4,000	6,500			
Light output	up	down	up/down (40/60)			

Table 2. Means, standard deviations, and significance level (p-value) of the one-way repeated measure ANOVA for the NVT score

Independent variable	NVT			
	Mean	SD	F	*p*-value
CCT (K)				
2,700	34.42	8.19	2.08	0.055
4,000	***37.00***	9.37		
6,500	35.680	8.82		
Illuminance (lux)				
250	34.23	9.81	4.04	0.047*
500	36.73	8.58		
750	36.30	9.32		
1,000	35.28	8.59		
1,250	***36.93***	8.33		
1,500	35.42	8.04		
Light output characteristics				
Upward	31.12	12.34	0.081	0.922
Downward	***32.37***	14.33		
Up/down (40/60)	*32.42*	14.06		

** The mean difference is highly significant (*prob*<0.01) in the one-way repeated measure ANOVA.
* The mean difference is significant (*prob*<0.05) in the one-way repeated measure ANOVA.
Bold italic refers to the highest NVT score.

more spacious when more light was supplied indirectly. Light settings where the indirect component had a horizontal illuminance contribution of 60% or more were favoured.

However, there is little research relating to lighting that is applicable to Thai older people. Tuaycharoen and Kornisranukul (2013) found that the illuminance of 1,290 lux with a black background and high CCT (CCT = 4,100 K) produced the highest visual performance for the Thai older adults. This study investigated the effects of lighting in a living room context. A further investigation by Tuaycharoen et al. (2016) explored the effects of five factors, which were task illuminance, CCT, luminaire type, room surface colour, and the presence of a window view on the visibility of the Thai older adults. The study was carried out in a laboratory with no context. The results of their study suggested that for the best visibility for the Thai older people, the task illuminance should be 1,000 lux with a cool colour tone of light (6,500 K) and cool colour tone of the room's surface with a natural exterior view.

83243	83243
.....	.....
76475	76475
.....	.....
05023	05123
.....	.....
89236	89236
.....	.....
17958	17958
.....	.....
77426	77486

Figure 2. Sample of the Numerical Verification Test (NVT). Comparison of the five-digit number on the right lists to the left lists and mask on the difference in numbers.

From conducting a search of the information, it was found that no study of the lighting conditions for Thai older adults in a bedroom context had been undertaken. Therefore, this study aimed to examine the lighting requirements in the bedroom for the Thai older people. The main purpose of this study was, hence, to investigate the relationship between the lighting and visual performance in a bedroom context for the Thai elderly. As three factors, illuminance, CCT and light output were investigated as the main lighting factors in previous studies in Thailand and other countries, these same factors were explored again in this study.

Methods

Experiment setting

The experiment was conducted in a test room in the Faculty of Architecture, Kasetsart University, Bangkok, Thailand. This test room was located on the sixth floor of the building. All windows were covered with blank sheets of paper providing complete control over the lighting conditions for the experiment. The reason for this was that the illuminance level and lighting conditions needed to be constant.

A 1.50 m wide by 2.50 m high by 0.60 m deep testing chamber was built consisting of a luminaire with six LED lamps which individually connected to dimmers. Thus, it can produce both uplight and downlight simultaneously. Light output from all lamps in the luminaire can be dimmed up and down by using dimmers (*Figure 1*). The testing chamber was placed above a table and 75 cm above the room floor. The fixation was marked at the centre of the table; this maintained the visual size of the text constant. Subjects sat in an adjustable chair, and the illumination inside the testing chamber was provided by three individually switched lighting fixtures, which were connected to lighting control to moderate the illuminance level, CCT, and light output.

Before the experiment was started, all illuminance, CCT and light output were set using a Minolta illuminance meter and Konica Minolta XY-DC/XY-1 Chroma Metre (*Figure 1*).

Lighting conditions

Three parameters for the visual environment were independently varied in the experiment: (a) illuminance, (b) correlated colour temperature or CCT, and (c) light output characteristics. Six different magnitudes of task illuminance were used: 250, 500, 750, 1,000, 1,250, and 1,500 lux, which had been used in previous visual

Table 3. Difference between the mean NVT score from the pairwise comparisons

Illuminance (lux)	250	500	750	1,000	1,250	1,500
250	0.00					
500	2.61	0.00				
750	2.17	0.43	0.00			
1,000	1.16	1.45	1.01	0.00		
1,250	2.81*	0.20	0.63	1.65	0.00	
1,500	1.30	1.31	0.88	0.14	1.51	0.00

** The mean difference is highly significant (*prob*<0.01) using the Sidak *t*-test.
* The mean difference is significant (*prob*<0.05) using the Sidak *t*-test.

performance studies (Tuaycharoen et al., 2016). Three levels of distinct CCTs were used: a) CCT = 2,700 K, b) CCT = 4,000 K, and c) CCT= 6,500 K. Three different light output characteristics were explored: a) upward, b) downward, and 3) up/down (40/60). *Table 1* shows the conditions tested and the comparisons of interest. It should be noted that when the illuminance varied, the CCT was constant at 4,000 K and the light output ratio was up/down (40/60). When the CCT varied, the illuminance was constant at 500 lux and the light output ratio was up/down (40/60). Furthermore, when the light output ratio varied, the illuminance was constant at 500 lux and the CCT was constant at 4,000 K.

Human response measurements

Each of the subjects performed one task to evaluate the visual performance of each illumination condition - the Numerical Verification Test (NVT). The reason for using the NVT was that the task light was normally used in the bedroom and seemed to be a critical task in the area of the reading desk. Thus, in this condition, the authors tried to explore the lighting requirement for task lighting in this area. NVT had also been used to measure the visual performance of the reading task in many previous studies (Boyce, 2003; Davis and Garza, 2002; Maher, 2017; Yamagishi et al., 2008).

For this NVT task, the participants compared the juxtaposed lists (20 five-digit numbers) of numbers and found discrepancies. The numbers were nearly identical except for random single-digit errors (*Figure 2*). The subjects compared the lists from top to bottom, found the errors, and marked them with a pen stroke. This task used a contrast level: 100% black ink on a white background and the respective luminance ratios were 0.91.

The second task involved the completion of a subjective preference questionnaire concerning the particular illumination condition the participants were viewing at the time. The subject used a seven-step semantic differential scale to give an opinion about the lighting condition using six parameters: like/dislike, comfortable/uncomfortable, bright/dim, easy to read/difficult to read, pleasant colour of light/unpleasant colour of light, and whether the subject would or would not like to have that particular type of lighting available for everyday reading (overall preferences). The subject's response on each scale was given an integer score between one and seven, inclusive. This scale had been used in many previous studies relating to visual performance (Maher, 2017; Yamagishi, 2008).

Table 4. Means and standard deviations for the subjective preference score.

Factor	Like / Dislike		Comfort / Discomfort		Too bright / Too dim		Easy to read / Difficult to read		Pleasant / Unpleasant colour of light		Like to have lighting available for everyday life		Overall preference	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
CCT (K)														
2,700	4.78	1.73	4.96	1.84	4.75	1.53	4.78	1.68	4.46	2.00	4.78	1.89	4.76	1.77
4,000	5.03	1.53	5.25	1.43	5.32	1.31	5.28	1.44	4.96	1.53	4.89	1.45	5.12	1.44
6,500	***5.39***	1.40	***5.39***	1.64	***5.75***	0.97	***5.82***	1.09	***5.36***	1.57	***5.14***	1.67	***5.48***	1.41
Illuminance (lux)														
250	4.18	1.39	4.07	1.54	3.78	1.50	4.03	1.50	3.75	1.71	3.82	1.49	3.94	1.51
500	5.25	1.26	5.28	1.41	5.21	1.37	5.28	1.30	5.28	1.38	5.21	1.31	5.26	1.32
750	***5.61***	1.31	***5.61***	1.26	5.93	0.98	***5.78***	1.03	5.46	1.40	***5.64***	1.25	***5.69***	1.17
1,000	5.50	1.64	5.43	1.69	***6.32***	0.86	5.75	1.48	***5.57***	1.50	5.43	1.69	5.67	1.51
1,250	5.50	1.53	5.50	1.43	6.18	0.94	***5.78***	1.45	5.43	1.52	5.36	1.57	5.62	1.43
1,500	5.28	1.98	5.21	1.99	***6.32***	1.05	5.39	1.68	5.18	1.91	5.11	2.01	5.42	1.82
Light output														
Upward	4.00	1.39	4.18	1.33	3.75	1.32	4.18	1.44	3.96	1.21	3.86	1.27	3.99	1.36
Downward	3.68	1.59	3.61	1.45	3.43	1.60	3.64	1.70	3.39	1.63	3.57	1.45	3.55	1.53
Up/down (40/60)	***4.32***	1.56	***4.53***	1.71	***4.11***	1.62	***4.78***	1.59	***4.14***	1.61	***4.46***	1.53	***4.39***	1.61

Bold italic refers to the highest subjective score.

Table 5. Results of the repeated measure analysis of the variance of the subjective preference from the effect of CCT

Subjective assessment	*F*	*p*-value
Like/Dislike	1.08	0.346
Comfort/Discomfort	0.49	0.612
Too bright/Too dim	4.24	0.018*
Easy to read/Difficult to read	3.69	0.029*
Pleasant/Unpleasant colour of light	1.90	0.155
Like to have lighting available for everyday life	0.33	0.718
Overall preference	9.10	0.000**

** The mean difference is highly significant (*prob*<0.01) using the Sidak *t*-test.
* The mean difference is significant (*prob*<0.05) using the Sidak *t*-test.

Experimental procedures

Testing was conducted in August 2018. The subjects participated in one session of approximately 30 minutes long; each of which was the same except for the order of the presentation for the test conditions and the specific test forms used. Twenty-eight Thai older people subjects aged from 62 to 76 years participated in the experiment. All were free of documented visual disease, read for at least 10 hours per week, and were Thai speakers. Fourteen subjects were male and 14 were female. Firstly, only the experimental lighting was turned on in the bedroom during this experiment. The experimental procedure was explained to the subjects, and they completed the questionnaires about their general information and signed the informed and consent forms. Then, the subjects were instructed to rest for two minutes after which they were given the NVT task. After completing the task, the subjects were asked to rest again for two minutes. Then, the subjective preference assessment was performed. The data were analysed using repeated measures with the analysis of variance (ANOVA). Pairwise comparisons were then used to verify the significance of each pair.

Results

Lighting and visual performance in the bedroom for Thai older adults

Table 2 reports the overall means, standard deviations and significance level (p-value) of the one-way repeated measure ANOVA for the NVT score. *Table 3* summarises the differences between the mean NVT score from the pairwise comparisons. It was found that illuminance significantly affected the NVT test measure ($p<0.05$) and the effect of the CCT was just below significant. The results of the pairwise comparison indicated that 1,250 lux could create the highest NVT score, and the NVT score from 1,250 lux for Thai older adults was significantly higher than that from 250 lux (*Tables 2* and *3*).

Lighting and subjective preference in the bedroom for the Thai older adults

CCT

Table 5 shows that the CCT showed a significant effect on the two subjective measures. The results of the overall preference also showed a highly significant effect of the CCT. It was found that Thai older adults preferred cool coloured light with a CCT of 6,500 K in the bedroom than other colours of light. They also felt the room was brighter and the task easier to read under a 6,500 K light (*Tables 4-6*).

Illuminance

Illuminance also had a significant effect on all six subjective measures. *Table 4* shows that Thai older adults considered the task more preferable, more comfortable, and easier to perform, as well as more likely to have lighting available for everyday life in the bedroom with illuminance of 750 lux than other illuminance levels. *Table 7* shows the "Like/Dislike", "Comfort/Discomfort", "Easy to read/Difficult to read", and "Like to have lighting available for everyday life" as the functions of illuminance. The results were highly significant for all four subjective measures ($p<0.01$).

Table 6. Difference between the mean subjective preferences from the Pairwise comparisons of the effect of CCT

CCT (K)	2,700 K	4,000 K	6,500 K
Too bright/Too dim			
2,700	0.00		
4,000	0.57	0.00	
6,500	1.00*	0.43	0.00
Easy to read/Difficult to read			
2,700	0.00		
4,000	0.50	0.00	
6,500	1.03*	0.53	0.00
Overall preference			
2,700	0.00		
4,000	0.37	0.00	
6,500	0.72**	0.35	0.00

** The mean difference is highly significant (*prob*<0.01) using the Sidak *t*-test.
* The mean difference is significant (*prob*<0.05) using the Sidak *t*-test.

In addition, there was a significant difference in the remaining two subjective measures, "Too bright/Too dim" and "Pleasant/unpleasant colour of light". With a high illuminance level of 1,000 lux, the bedroom was considered by the Thai elderly to be brighter under these two measures. They also found the colour of the light to be more pleasant than other forms of illuminance.

However, the overall preference score was also the highest with an illuminance of 750 lux and the result of the ANOVA was highly

Table 7. Results of the repeated measures analysis of variance of the subjective preference from the effect of illuminance

Subjective assessment	*F*	*p*-value
Like/Dislike	3.30	0.007**
Comfort/Discomfort	3.61	0.004**
Too bright/Too dim	21.09	0.000**
Easy to read/Difficult to read	6.28	0.000**
Pleasant/Unpleasant colour of light	5.198	0.000**
Like to have lighting available for everyday life	4.79	0.000**
Overall preference	34.69	0.000**

** The mean difference is highly significant (*prob*<0.01) using the Sidak *t*-test.
* The mean difference is significant (*prob*<0.05) using the Sidak *t*-test.

Table 8. Difference between the mean subjective preferences from the pairwise comparisons of the effect of illuminance

Illuminance (lux)	250	500	750	1,000	1,250	1,500
Like/Dislike						
250	0.00					
500	1.07	0.00				
750	1.43**	0.36	0.00			
1,000	1.32*	0.25	0.11	0.00		
1,250	1.32*	0.25	0.11	0.00**	0.00	
1,500	1.11	0.03*	0.32	0.21	0.21	0.00
Comfort/Discomfort						
250	0.00					
500	1.21	0.00				
750	1.53**	0.32	0.00			
1,000	1.36*	0.14	0.18	0.00		
1,250	1.43*	0.21	0.11	0.07	0.00	
1,500	1.14	0.07	0.39	0.21	0.28	0.00
Too bright/Too dim						
250	**0.00**					
500	1.43**	0.00				
750	2.14**	0.71	0.00			
1,000	2.53**	1.11**	0.39	0.00		
1,250	2.39**	0.96*	0.25	0.14	0.00	
1,500	2.53**	1.11**	0.39	0.00	0.14	0.00
Easy to read/Difficult to read						
250	0.00					
500	1.25*	0.00				
750	1.75**	0.50	0.00			
1,000	1.71**	0.46	0.03	0.00		
1,250	1.75**	0.50	0.00	0.03	0.00	
1,500	1.36**	0.11	0.39	0.36	0.39	0.00
Pleasant/Unpleasant colour of light						
250	0.00					
500	1.53**	0.00				
750	1.71**	0.17	0.00			
1,000	1.82**	0.28	0.11	0.00		
1,250	1.68**	0.14	0.03	0.14	0.00	
1,500	1.43*	0.11	0.28	0.39	0.25	0.00
Like to have lighting available for everyday life						
250	0.00					
500	1.39*	0.00				
750	1.82**	0.43	0.00			
1,000	1.61**	0.21	0.21	0.00		
1,250	1.53**	0.14	0.28	0.07	0.00	
1,500	1.28*	0.11	0.53	0.32	0.25	0.00
Overall preference						
250	0.00					
500	1.31**	0.00				
750	1.75**	0.43	0.00			
1,000	1.73**	0.41	0.02	0.00		
1,250	1.68**	0.37	0.06	0.04	0.00	
1,500	1.48**	0.16	0.27	0.25	0.21	0.00

** The mean difference is highly significant (*prob*<0.01) using the Sidak *t*-test.
* The mean difference is significant (*prob*<0.05) using the Sidak *t*-test.

significant (p<0.01) (*Tables 7* and *8*).

Light output characteristics

Although not statistically significant for most of the subjective preference assessments, *Table 7* indicated a significant effect of the light output characteristics on the "Easy to read/difficult to read" (p<0.05), and "Overall preference" measures (p<0.01).

Table 10 shows the results from the follow-up comparison tests for the "Easy to read/difficult to read" and the "Overall preference" subjective measures as a function of the light output characteristics, respectively. The table illustrates that Thai elderly subjects preferred an up/downlight (40/60) for the light output characteristics compared to upward and downward only (*Tables 9* and *10*).

In summary, for the bedroom for the Thai elderly, lighting with up/downward (40/60) output that could create an illuminance of 750 lux with a CCT of 6,500 K produced the highest visual preference and was the most preferable by Thai elderly subjects.

Discussion

The main findings of this study resulted in the conclusion that for the best visibility for task lighting for reading in the bedroom for Thai older adults, there should be an illuminance of 1,250 lux with a luminaire contained light output (up/down) at a ratio of 40/60 with cool colour light (CCT = 6,500 K).

Furthermore, there was no significant effect of the CCT on the visual performance for Thai older adults in this study, but the results were just below significant. However, considering the preference results, the findings in this part showed that the CCT of cool light (CCT= 6,500 K) produced the highest

Table 9. Results of the repeated measures analysis of variance of the subjective preference from the effect of the characteristics of the light output

Subjective assessment	*F*	*p*-value
Like/Dislike	1.26	0.290
Comfort/Discomfort	2.71	0.073
Too bright/Too dim	1.40	0.253
Easy to read/Difficult to read	3.65	0.030*
Pleasant/Unpleasant colour of light	1.78	0.174
Like to have lighting available for everyday life	2.89	0.061
Overall preference	13.08	0.000**

** The mean difference is highly significant (*prob*<0.01) using the Sidak *t*-test.
* The mean difference is significant (*prob*<0.05) using the Sidak *t*-test.

visual preference in the bedroom and was significantly higher than those from warm (CCT = 2,700 K) and white light (CCT = 4,000 K) in the two subjective measures. The authors' results in this part were consistent with those of Tuaycharoen et al. (2016). The results of their study suggested that a cool colour tone of light (CCT = 6,500 K) could produce a higher preference for the Thai older people than warm (CCT = 2,800 K) and white colour of light (CCT = 4,200 K). The reason of the results in this part might be due to the fact that cool colour light can have a calming effect that may comfort and give people peace (Kurt and Osueke, 2014; Mikellides, 2017). Therefore, this would seem to make the bedroom more relaxing than another colour of light.

With regards to the illuminance effect, the results of the first session showed that illuminance of 1,250 lux created the highest visual performance for Thai older adults in the bedroom and displayed a significant difference from other illuminance conditions. The highest visual performance from the illuminance value of 1,250 lux in this present study was consistent with previous studies in the living room context that found the highest effect of the illuminance of 1,290 lux (Tuaycharoen and Kornisarnukul, 2013). Compared to the illuminance recommendation from the international standards, the Illuminating Engineering Society of North America (IESNA) suggested that an illuminance of task light for reading in the bedroom for the older adults should be 750 lux (IESNA, 2016), while it should be 400 lux for young people (IESNA, 2011). This result confirmed that older people need a higher illuminance than younger people to keep their vision efficient. Additionally, this confirmed that Thai older people need more light than older adults from the USA and Europe.

In relation to the effect of the light output characteristics, the results from the subjective evaluation in this study showed that lighting with an up/downward (40/60) output was the most preferable by Thai elderly subjects when used in the bedroom.

Conclusion

The main purpose of this study was to explore the effects of illuminance, correlated colour temperature (CCT) and light output characteristics on the visual performance in the bedroom context for Thai older people. The findings of this study arrived at the conclusion that illuminance of 1,250 lux was recommended for better visibility by Thai older adults in the bedroom. Furthermore, if there was a requirement for performing a task; such as reading, a luminaire contained light output (up/down) at a ratio of 40:60 with cool colour light (CCT = 6,500 K) should be provided for the preferred environment. However, lighting could be dimmed to an illuminance of 750 lux when there was no requirement for performing a task. Therefore, flexible lighting systems of the bedroom that provide an illuminance level and CCT controlled by the Thai elderly themselves, according to their needs and preferences, would seem to be a reasonable solution.

It must be noted that the findings presented here were limited to the experimental characteristics and conditions considered in this study. The subjects participating in the study were Thai older people living in city areas only, a group of the population with distinctive cultural, age-range and background traits. Therefore, to make a comprehensive conclusion, further research would be required for other groups of Thai older adults; such as those residing in rural areas with different cultures and backgrounds.

Table 10. Difference between the mean subjective preference from the pairwise comparisons of the effect of the characteristics of the light output

Light output	Upward	Downward	Up/Down (40/60)
Easy to read/Difficult to read			
Uplight	0.00		
Downlight	0.53	0.00	
Up/downlight (40/60)	0.61	1.14*	0.00
Overall preference			
Uplight	0.00		
Downlight	0.43*	0.00	
Up/downlight (40/60)	0.40*	0.84**	0.00

** The mean difference is highly significant (*prob*<0.01) using the Sidak *t*-test.
* The mean difference is significant (*prob*<0.05) using the Sidak *t*-test.

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