

RECOMMENDED ILLUMINANCE LEVELS FOR THE THAI ELDERLY

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Abstract

The main purpose of this project was to study the recommended illuminance levels for the Thai elderly in various specific areas. The investigation was carried out in both residential and public buildings with two main studies. The first study was aimed to determine the recommended illuminance levels for the Thai elderly in various areas in a residential building consisted of two parts. The first part explored the recommended task illuminance by having 120 Thai elderly perform a Numerical Verification Test (NVT) and evaluated the Semantic Differential Scale of various task conditions. The second part examined the recommended illuminance levels for ambient light using 316 Thai elderly evaluating their preferences in 7 different areas of nine nursing homes in Thailand. The second study investigated the recommended illuminance levels for the Thai elderly in various areas of a public building. Two types of buildings were explored: a hospital and temple. In the temple, 212 Thai elderly people were surveyed about their lighting preference in three different areas of seven Thai temples. Regarding the hospital, 203 Thai elderly participants evaluated their preferences in 14 areas of two hospitals. Results suggested the recommended illuminance levels for the Thai elderly for both residential and public buildings. The results showed that, for residential areas, the recommended illuminance for Thai elderly was higher than that of the international standard of around 50 lux for task illuminance and around 100-400 lux for ambient illuminance. However, the difference was greater for the illuminance levels of the public building.

Keywords: Visual performance, recommended illuminance, Thai elderly

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Introduction

With the increase in age of 60 years old and older, people experience major physical changes with their visual system. These conditions include the increased absorptance of the crystalline lens, reduced range of accommodation, reduced pupil size and increased scattering of light. These physical changes can cause a large reduction in reading ability and comfort: a reduction in retinal illuminance, a reduction in contrast sensitivity, and an increase in intraocular scatter that reduces retinal image contrast and increases the glare sensitivity in the elderly eye (Boyce, 2014).

Suitable lighting, particularly the illuminance level and the Non-Image Forming effects, can help compensate the decline in an elderly person's ability to see. On the other hand, inappropriate lighting, such as dimly-lit environment can further diminish their sight. In the past 10 years, several studies examined the effect of illuminance on visual performance and preference of the elderly in both laboratory and in field survey studies (Davis and Garza, 2002; O'Connor *et al.*, 2005; Evans, *et al.*, 2010; Lewis and Torrington, 2013). Nowadays, the recommended illuminance levels for the elderly mostly follows the United States and European standards and recommendations; for example, ANSI/IESNA Recommended Practice-28-2007 Lighting and the Visual Environment for Senior Living (IESNA, 2007), ANSI/IESNA Recommended Practice-28-2016 Lighting and the Visual Environment for Senior and Low Vision Population (Revised) (IESNA, 2016) and the IESNA Lighting Handbook (Tenth edition): Reference and application (IESNA, 2011). However, the illuminance values in these references were obtained from studies with elderly with differences in eye colour and with a culture different from Thai elderly people.

Past research on illuminance and visual task performance of Thai elderly subjects is limited. Tuaycharoen and Kornisranukul (2013) reported a series of experiments that were related to lighting for the Thai elderly. Several of these experiments examined the effects of illuminance, background, and Correlated

Colour Temperature (CCT) on measurements of the reading performance of the Thai elderly. In another experiment, the effects of view content were examined for the discomfort glare for Thai elderly people. Their analysis showed that for the Thai elderly, illuminance and CCT significantly affected the NVT measure and all subjective measures (Tuaycharoen and Kornisranukul, 2013). The results also showed that the degree of naturalness of view and its horizontal stratification (the upper layer of sky, the middle layer of urban/natural elements, and the lower layer of foreground) affected the discomfort glare for the Thai elderly. A natural view with three horizontal layers still displayed the best performance in reducing discomfort glare from a window.

In their next study, they examined the effect of five factors from interior lighting on the visibility of the Thai elderly. These factors comprised 1) task illuminance, 2) CCT, 3) luminaire type, 4) room surface colour, and 5) the presence of the window view. The experiment was carried out in a 3×3×2.5 m laboratory chamber without the context of the room with 82 Thai elderly as subjects. The age range of the subjects was 61-82 years old and their average age was 72 years old. The experiment consisted of the study on visual performance, visual comfort and visual preference. The results of this study suggested that the best visibility for the Thai elderly's 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 outside view (Tuaycharoen *et al.*, 2016).

Many recent studies have revealed that there were differences between Caucasians and Asians in physiological properties of the eye (Van Den Berg, *et al.*, 1991; Bergamin *et al.*, 1998) and subjective preference and performance responding to lighting properties (Revantino *et al.*, 2018). These data implies that it is difficult to directly apply recommended illuminance from previous studies to the Thai people whose physiological properties of the eyes are different from those of Caucasians. Although lighting concerns for elderly people

continues to be an important topic within the lighting community and has been studied for many years, there is no evidence relating to the recommended illuminance levels for particular areas in buildings for the Thai elderly presently available. Therefore, the main purpose of this project was to study the recommended illuminance levels for the Thai elderly in a variety of task lighting conditions. There were two main studies for this purpose - residential building study and public building study.

Methodology

Study I: Recommended Illuminance Level in a Residential Building

The purpose of this section was to explore the recommended illuminance level in residential buildings. There were two parts in this section. The first part dealt with an investigation of the recommended illuminance level for task lighting in residential building. The second part was aimed at exploring the recommended illuminance level for ambient light in residential building.

Part I: Recommended Task Illuminance Level

The main apparatus used for this experiment consisted of a portable testing chamber (3 m wide, 4 m deep and 3 m tall; painted flat black on two panels). There were six task areas to be studied: living room, administration (active), active area (day only), bedroom, bathroom (make-up/shaving area) and kitchen area. There were 11 levels of illuminance values to be tested for each area. These values were an increase and a decrease by 50 lux for five steps from the standard illuminance values obtained from IESNA (2007) (Table 1). It should be noted that ANSI/IESNA Recommended Practice-28-2007 Lighting and the Visual Environment for Senior Living (IESNA, 2007) was mainly used in this study due to the fact that ANSI/IESNA Recommended Practice-28-2016 Lighting and the Visual Environment for Senior and Low Vision Population (Revised) (IESNA, 2016)

has not been published during the time period of this study.

The ceiling panel in the chamber housed six 150W 5000 K LED lamps, each in an aluminum reflector as commonly used in task lighting equipment. One area contained one luminaire to be tested. In order to vary the task illuminance, all luminaires were connected with dimmers. A digital lux meter was installed to measure the illuminance levels on the working place for each task area. For example, for a reading task, the horizontal illuminance was measured as a point where the subject fixed their eyes on the test table (Figure 1).

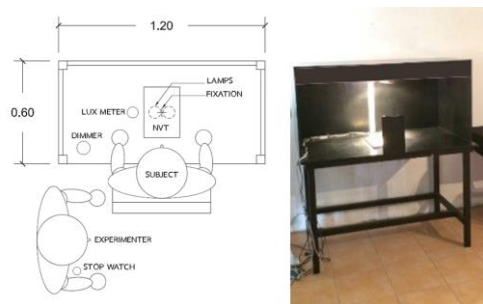


Figure1. Drawing and photograph of experimental layout and instruments for reading task in part I in study I

Testing was firstly conducted with a Thai elderly female group at the Mitraparp Female Elderly Home Care, Pathum Thani province, Thailand during December 2015. Based on the previous research and the needs of the elderly population, the main subject population for this study was limited to those aged 60 or older. All the subjects were free of visual disease; such as, colour blindness or glaucoma, cataracts and retinopathy. They also had to indicate that they were “visually-active”; that is, they regularly performed visual tasks; such as, reading, driving or sewing. One hundred and twenty Thai elderly participants aged 62 to 76 years with an equal number of males and females participated in this experiment.

The average duration of the sessions was approximately 60 min. During this experiment, only the experimental lighting as turned on in

Table 1. Test illuminance

Area	Test illuminance (lux)															
	250	300	350	400	450	500	550	600	650	700	750	800	850	900	950	1,000
Living room						✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Administration (active)	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓					
Active area (day only)	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓					
Bedroom						✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Bathroom (make-up/shaving area)			✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓			
Kitchen area	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓					

Note: ✓ means the recommended illuminance values from IESNA (2007) that were used for being a reference value for each area.

✓ means the illuminance values that were tested. These illuminance values were varied from the recommended illuminance values from IESNA (2007). The variation of the illuminance values was increased and decreased by 50 lux from the reference values for 5 steps. Therefore, there were 11 illuminance values to be tested for each area.

the dark room. Firstly, when the subjects entered the test chamber, they were explained the experimental procedure and completed questionnaires for their general information and completed informed consent form. Then, the subjects were instructed to rest for two minutes. Since ambient illuminance within the test room was not completely dark, this time span employed was enough for subjects' eyes to readapt in mesopic vision (Plainis *et al.*, 2005). Next, the subjects were provided the NVT task for the reading test (test task for the living area) with 11 different illuminance levels (Davis and Garza, 2002). All the sequences of illuminance levels were also systematically randomly assigned to each subject. For the other tasks, the elder subjects performed real tasks for each area and evaluated seven-point semantic differential scales to assess task performance from the lighting – difficult/easy to perform task (Evan *et al.*, 2010; Boyce, 2014). After completing each task, the subjects were asked to rest again for two minutes. Following this, the next task was performed according to each test area until completing all six tasks. After finishing the test in the Mitraparp Female Elderly Homecare, the test chamber was then moved to the Taranukro Nursing Home, Bang Khen, Bangkok where testing was performed with a Thai elderly male group during January 2016. The data were then analyzed by two steps: 1) finding which level of illuminance could create the saturation of the task performance, and 2) using the illuminance values of a decrease for five steps

to compare the saturation level to find which level significantly differed from the saturation level by using a *t*-test. This step was for obtaining recommended illuminance level for each task.

Part II: Recommended Ambient Illuminance Level

The second part in this section included a comprehensive survey of nine care homes in Thailand during February 2016 with three main measurements: 1) architectural analysis including the collection of daylighting and electric lighting techniques, 2) illuminance measurement, and 3) subjective measures of around 316 residents in these care homes. Seven areas in each residential care home were explored: 1) hallways (active hours), 2) active areas (day only), 3) bedroom, 4) dining room



Figure 2. Drawing with measurement points of an investigated area (left) and photograph of instruments (right) in part II in study I

(active hours), 5) bathroom, 6) living room, and 7) interior entry (day).

In this part, the horizontal illuminance measurements were taken at the working place of each area using a digital lux metre (approximately 1×1 m in a grid) (Figure 2). At the same time as the illuminance measurement was conducted as a point measurement, preference measures of the Thai elderly in the area were also taken using a questionnaire adapted from the National Research Council of Canada (NRC)'s Lighting Quality Scale developed by Veitch and Newsham (2000), which had been previously used in numerous studies (Newsham and Veitch, 2001; Newsham *et al.*, 2005). It should be noted that only overcast sky was explored in the study, so the effect of sunlight was controlled. After that, the relationship between the horizontal illuminance and preference from the Thai elderly was fitted using linear and non-linear regression analysis. After that, the illuminance values at percentile of 95% of Thai elderly's preference was drawn from the relationships. The recommended illuminance values for each area were obtained from the illuminance values (at percentile of 95 % of the subject preference) by increasing or decreasing within the 95% confidential interval. (Yonemura 1981; Ramasoot, 2015).

Study II: Recommended Illuminance Level in a Public Building

The purpose of this second study was to explore the recommended illuminance level for ambient lighting in a public building. Two types of public building were investigated, which were a Thai temple and hospital. The reason for investigating these types of building was because of the frequent visits by the Thai elderly.

For the study of the recommended illuminance level in a Thai temple, seven Thai temples were investigated during March - April 2016. Three main measurements were carried out: 1) architectural analysis, 2) illuminance measurement, and 3) subjective measures of around 212 Thai elderly people. Three areas in each temple were studied: 1) circulation area, 2) congregation (prayer hall and worship seating area), and 3) primary focal



Figure 3. Study areas: 1) circulation area (left) and 2) congregation area (prayer hall and worship seating area) and 3) Buddha image (right)



Figure 4. Chakkarat hospital (left) and Chokchai hospital (right)

areas (worship/Buddha image) (Figure 3). The same procedure as the study of a residential building was carried out for this part of the research.

For the study of the recommended illuminance level in a hospital, surveys of two hospitals, Chakkarath hospital and Chockchai hospital, were carried out during April-May 2016 (Figure 4). Similar procedure to a study of temple, three main measurements were taken: 1) architectural analysis, 2) illuminance measurement, and 3) subjective measures of around 212 Thai elderly people. Fourteen areas of each hospital were explored. For general area, study areas are: 1) interior entry, 2) escalators/moving walkways, 3) registration, 4) reading/waiting area, 5) medicine station, and 6) examination room (general). For physical therapy, study areas are: 7) examination, and 8) general area. For patient room, study areas are: 9) examination (bed), 10) reading (bed), 11) TV viewing (bed), and 12) general area. For nurses' station, study area are: 13) general area, and 14) work station.

After obtaining the data, a similar procedure to those used in the study of a residential building was carried out again in

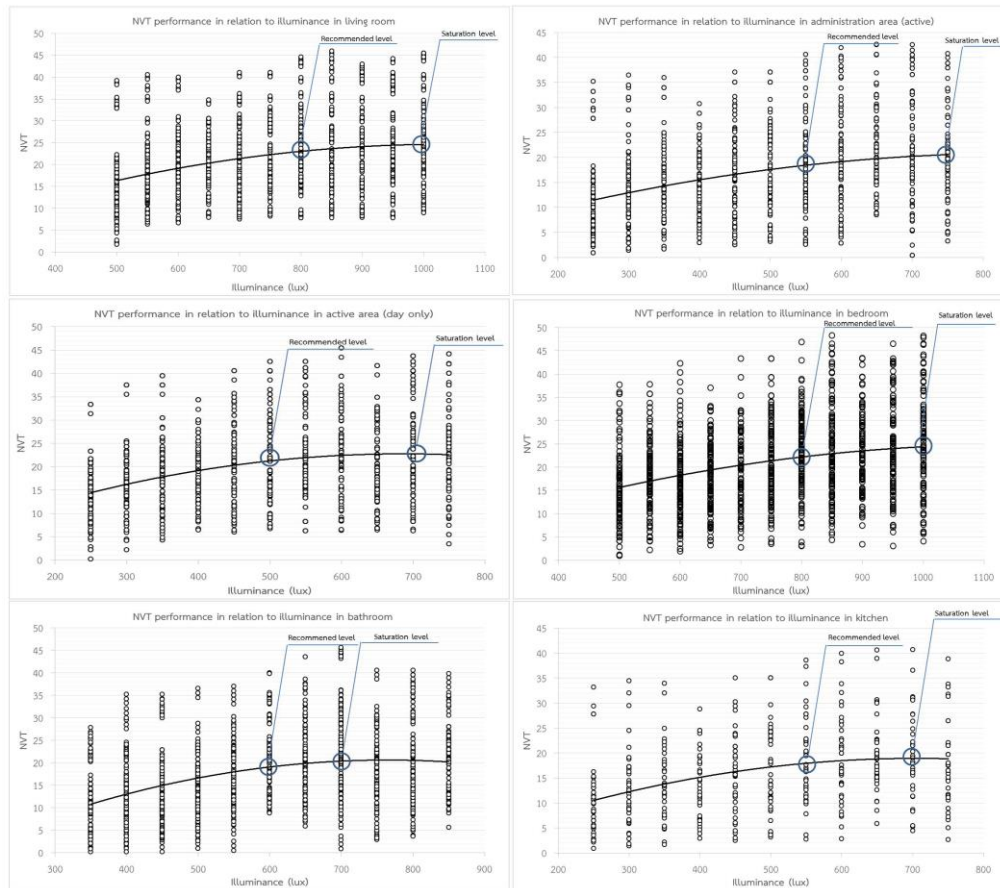


Figure 5. NVT performance in relation to illuminance, the recommended task illuminances and the saturation levels for each area in a residential building

this part to find the recommended illuminance levels in a hospital for the Thai elderly.

Results

Figure 5 shows NVT performance in relation to illuminance, the recommended task illuminances and the saturation levels for each area in a residential building.

Table 2 shows the recommended task illuminance for each area in a residential building obtained from NVT performance. The study indicated that for the living room, the recommended illuminance for the Thai elderly should be 800 lux. The administration

area, active area (day only) and kitchen area should have illuminance of 550 lux. The bedroom should have a value of 800 lux while the bathroom (make-up/shaving area) should have a value of 600 lux. Comparing to the IESNA recommended illuminance (IESNA, 2007), the illuminance values recommended for the Thai elderly were slightly higher (Table 2).

Table 3 illustrates the recommended illuminance for ambient light for the Thai elderly in each area of a residential building obtained from preference performance. It can be seen that, overall, the values of the recommended illuminance for the Thai elderly were higher than the IESNA values. Thus, the

Table 2. Recommended task illuminance for the Thai elderly in each area in a residential building obtained from NVT performance

Area	Saturation Illuminance Level (lux)	Recommended Illuminance for Thai elderly (lux)	Mean Difference	p-value	IESNA Recommended Illuminance (lux)
Living room	1,000	800	1.230	0.000*	750
Administration (active)	750	550	1.175	0.019**	500
Active area (day only)	700	550	0.925	0.013*	500
Bedroom	1000	800	0.314	0.012*	750
Bathroom	700	600	0.744	0.038*	600
(make-up/shaving area)					
Kitchen area	700	550	1.290	0.036*	500

Table 3. Recommended illuminance for ambient light for the Thai elderly in each area of a residential building obtained from preference performance

Area	Recommended illuminance from Linear regression at percentile of 95% (lux)	Recommended illuminance for Thai elderly (lux)	IESNA Recommended illuminance (lux)
Hallways (active hours)	453.67	450	300
Active areas (day only)	401.59	400	300
Bedroom	587.92	600	300
Dining room (active hours)	610.83	600	500
Bathroom	706.91	700	300
Living room	719.73	700	300
Interior entry (day)	1,088.27	1,100	1,000

Table 4. Recommended illuminance for ambient light for the Thai elderly in each area of a Thai temple obtained from preference performance

Area	Recommended Illuminance from Linear Regression at a Percentile of 95% (lux)	Recommended Illuminance for the Thai Elderly (lux)	IESNA Recommended Illuminance (lux)
Circulation area	549.18	550	200
Congregation area (prayer hall and worship seating area)	682.29	700	400
Primary focal areas (worship/buddha image)	1,451.72	1,450	1,000

Thai elderly require more light to perform tasks and activities in a residential building than the values recommended in the IESNA (IESNA, 2007). Moreover, the increase in ambient light from the IESNA values was about 100-400 lux (Table 3).

Table 4 illustrates the recommended illuminance for ambient light for the Thai elderly in each area of a Thai temple obtained from preference performance. The results showed that

550 lux was the minimum illuminance level for the circulation area of the temple, 700 lux was also recommended for the congregation (nave, prayer hall, worship seating area), and 1,450 lux was the recommended level for primary focal areas (worship/ Buddha image). Overall, the recommended values for the Thai elderly for tasks in temples were higher than the IESNA recommendation with a difference of about 300-450 lux (Table 4).

Table 5. Recommended illuminance for ambient light for the Thai elderly in each area of a hospital obtained from preference performance

No.	Area	Recommended Illuminance from Linear Regression at a Percentile of 95% (lux)	Recommended Illuminance for the Thai Elderly (lux)	IESNA Recommended Illuminance (lux)
General area				
1	Interior entry	709.17	700	400
2.	Escalators/moving walkways	492.57	500	100
3	Registration	770.88	800	600
4	Reading/waiting area	688.21	700	600
5	Medicine station	906.43	900*	1,000
6.	Examination room (general)	932.72	950*	1,000
Physical therapy				
7	Examination	1256.79	1,250	1,000
8	General	315.38	300	200
Patient room				
9	Examination	1,006.42	1,000**	1,000
10	Reading	433.14	450	400
11	TV viewing	179.69	200	100
12	General	145.64	150	100
Nurse station				
13	General	130.39	150	100
14	Work station	1,297.69	1,300	1,000

* Recommended illuminance level for the Thai elderly was lower than the IESNA values (IESNA, 2011)

** Recommended illuminance level for the Thai elderly was equal to the IESNA values (IESNA, 2011)

Table 5 shows the recommended illuminance for ambient light for the Thai elderly in each area of a hospital obtained from preference performance. The recommended illuminance for the Thai elderly was varied according to the task areas. Most of the values recommended for the Thai elderly were higher than the illuminance values recommended by IESNA. However, some values were lower than the IESNA values; e. g., the medicine station and examination room, and one had the same values as the IESNA, which is a bed area for examination purpose in patient room (Table 5).

Discussion

Overall the results of this study also suggested that the present lighting recommendations and standards that came from the results of the experiments with people with light-coloured eyes, such as IESNA (2007), were unlikely to be used directly with Thai people; thus,

consideration should be given to those people with different coloured eyes. As such, the results of this study were consistent with many studies that demonstrated the difference in vision (Liu *et al.*, 2016; Tuaycharoen and Kornisranukul, 2013, Tuaycharoen *et al.*, 2016).

For a residential building, the Thai elderly require slightly more light to perform tasks and activities properly than the IESNA recommendation (IESNA, 2007). In addition, an increase for task light should be about 50 lux and for ambient light about 100-400 lux. However, for a Thai temple, as the area was much larger, the Thai elderly would require about 300-450 lux, which was more light than the IESNA recommendation (IESNA, 2011). In some areas of a hospital, the Thai elderly wanted equal or less light than people from Europe and North America. However, in most areas, the Thai elderly still required a higher illuminance than the international standards; such as, areas in a patient room, physical therapy and nurse station. Therefore, the difference was quite varied. This might be due

to two reasons. Firstly, a change of pupil diameter with change in illuminance between people with dark-colour eyes is larger than those with light-colour eyes. At the same illuminance level especially in high values, less light may enter into the eyes of Thai elderly (Bergamin *et al.*, 1998; Gholami *et al.*, 2018). Thus, they may require higher illuminance to perform the similar task to those with light-colour eyes. Secondly, the influence of strong solar radiation that experienced by the tropical region may take an effect. Thai elderly may get used to the higher illuminance to perform any tasks than European and American elderly.

Furthermore, there seemed to be a greater increase in illuminance from the IESNA recommendation for the Thai elderly who carried out tasks in a public building than that for a residential building. The reason for this might be due to the fact that the Thai elderly might become accustomed to performing tasks in areas in a residential building. Therefore, there may be no need to have a large amount of light to perform those tasks. On the other hand, in the public building, especially in a Thai temple, people might have to try to see things that they are not familiar with and try to concentrate for praying. The results of this present study emphasized the important effect of familiarity in elderly on scope of lighting and visibility and are consistent by previous evidences in other fields. Boger *et al.* (2013) showed that familiarity plays a substantial role in faucet usability (effectiveness, efficiency, and satisfaction) for the elderly. Besides this, the theory of familiarity can be also applied in interactions between new technologies and the elderly such as gaming and showed the positive effect on elderly behaviors (less time-consuming) (Pan *et al.*, 2015; Zhang *et al.*, 2016).

Conclusions

The purpose of this project was to study the recommended illuminance levels for the Thai elderly in a variety of specific areas in residential and public buildings. Two main

studies were undertaken for this purpose. In conclusion, the results of this study could generate new values of recommended illuminances for Thai elderly people in specific areas in both residential and public buildings. Overall, the new values of recommended illuminances for Thai elderly seems to higher than the IESNA recommendation. However, there were some limitations that need to be addressed. This study was conducted with Thai elderly people in nursing homes during the study period only. The results of this study could only be summarised by age group, gender, education and disease similar to those participating in this study. In order for the study to have more consistency, other groups of similar subjects, like Thai elderly people in private homes should be investigated.

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