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นางสาว สิโนรส สมิทธิคุณานนท์

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ปีการศึกษา 2552

PERCEIVED LIGHTNESS IN DIFFERENT ILLUMINATION SPACE THROUGH VARIOUS SIZES OF APERTURE

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A Thesis Submitted in Partial Fulfillment of the Requirements
for the Degree of Master of Science Program in Imaging Technology

Department of Imaging and Printing Technology
Faculty of Science
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Thesis Title	PERCEIVED LIGHTNESS IN DIFFERENT ILLUMINATION SPACE THOUGH VARIOUS SIZES OF APERTURE
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Field of Study	Imaging Technology
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สิโนรส สมิทธิคุณานนท์ : ความสว่างที่รับรู้ในที่ที่มีความสว่างต่างกันผ่านช่องเปิดขนาดต่าง ๆ. (PERCEIVED LIGHTNESS IN DIFFERENT ILLUMINATION SPACE THROUGH VARIOUS SIZES OF APERTURE) อ. ที่ปรึกษาวิทยานิพนธ์หลัก : รศ. พรทวี พึ่งรัศมี, อ. ที่ปรึกษาวิทยานิพนธ์ร่วม Prof. Mitsuo Ikeda, 56 หน้า.

งานวิจัยนี้ได้ทำการศึกษาเกี่ยวกับผลของขนาดช่องเปิดต่อความสว่างที่รับรู้ในพื้นที่ที่มีความสว่างต่างกัน โดยการใช้ห้องทดลอง 2 ห้อง ซึ่งปรับความสว่าง (illuminance) ให้ต่างกัน ที่ผนังกั้นระหว่างห้องทั้งสองมีช่องหน้าต่าง เพื่อให้ผู้สังเกตที่นั่งทดสอบในห้องด้านหน้าสามารถมองผ่านไปยังห้องด้านหลังได้ และใช้อุปกรณ์หน้ากากควบคุมพื้นที่การมองเห็นห้องด้านหลัง แผ่นทดสอบที่ใช้มี 2 รูปร่าง ได้แก่ รูปร่างสี่เหลี่ยมจัตุรัส (A) และสี่เหลี่ยมจัตุรัสที่ตัดมุมออก (B) ซึ่งเป็นลักษณะที่ดัดแปลงมาจากการทดลองของกิลไครสต์ โดยรูปร่างและการจัดวางแผ่นทดสอบเป็นสิ่งกำหนดการรับรู้ตำแหน่งของแผ่นทดสอบ การทดลองได้ให้ผู้สังเกตพิจารณาความสว่างที่รับรู้ (perceived lightness) ของแผ่นทดสอบทั้งสองเมื่อมองผ่านช่องเปิดขนาดต่าง ๆ และบอกค่าความสว่างที่รับรู้เป็นร้อยละความขาวและความดำ ซึ่งมีค่าจาก 0 ถึง 100 โดยทำการทดลองในสภาพจริง และทดลองซ้ำกับในภาพถ่ายของห้องทดลอง ผลที่ได้คือเมื่อผู้สังเกตถูกจำกัดการมองเห็นเพียงในห้องด้านหน้า แผ่นทดสอบทั้งสองจะมีความสว่างที่รับรู้เหมือนกัน แต่เมื่อใดที่ผู้สังเกตมองเห็นห้องด้านหลังซึ่งมีความสว่างต่างกัน เพียงเล็กน้อยความสว่างที่รับรู้ของแผ่นทดสอบทั้งสองจะมีค่าต่างกัน โดยความสว่างที่รับรู้จะขึ้นอยู่กับความสว่างของพื้นที่

ภาควิชา วิทยาศาสตร์ทางภาพถ่ายและเทคโนโลยีทางการพิมพ์
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ลายมือชื่อนิสิต.....สิโนรส สมิทธิคุณานนท์.....
ลายมือชื่อ อ.ที่ปรึกษาวิทยานิพนธ์หลัก.....
ลายมือชื่อ อ.ที่ปรึกษาวิทยานิพนธ์ร่วม.....

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KEYWORDS : PERCEIVED LIGHTNESS / APPARENT LIGHTNESS / RECOGNIZED VISUAL SPACE OF ILLUMINATION / RVSI

SINOROSE SMITTHIKUNANON : PERCEIVED LIGHTNESS IN DIFFERENT ILLUMINATION SPACE THROUGH VARIOUS SIZES OF APERTURE. THESIS ADVISOR : ASSOC.PROF.PONTAWEE PUNGRASSAMEE, THESIS CO-ADVISOR : PROF.MITSUO IKEDA, 56 pp.

This research aims to investigate the effect of aperture on perceived lightness in different illumination space. Two rooms were constructed to obtain different illumination space: subject room (front) and test room (back). The wall between the rooms has a window through which the subject could see the test room. The achromatic test patches had two patterns: the square (A) and the square with a corner cut off (B). These test patterns were modified from Gilchrist's experiment. Subjects could perceive the test patch in different positions with the shapes of test patterns. The masks were made for controlling the open area that subject could see through test room. Subject judged lightness of test patch, Patterns A and B through various sizes of aperture in percentage of whiteness and blackness. This research was done with real scene and a picture of the real scene that was seen through a viewing box. The results showed that when subjects were limited to see only one space, i.e. front room, the perceived lightness of both test patch patterns were the same. Whenever the subject could see even the small area of the other space illumination around the test patch, the perceived lightness of both test patches were different. The perceived lightness was determined by the recognition of the space illumination.

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Student's Signature สิโนรส สมิทธิกุลนนท์
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CHAPTER 1
INTRODUCTION

The human vision consists of three important factors: light, object and visual system. Light reflects from object and enters into the eyes that have receptors inside. Then the receptor generates the image signal from light that comes in the eyes and send it to the brain. When the brain receives the signal, it evaluates the signal to perceive. The mechanism of color perception is rather complicated and still not clearly understood. As lightness is one of the color attributes, lightness perception is part of color perception.

Not only the physical factors are used to evaluate the lightness perception but the psychological factors are also involved. Examples of the psychological factors are experience, education and attitude. In addition, the human vision has an adaptation process. Thus, the physical and appearance lightness are sometime different. For example, when we see a piece of white paper outside a room, it appears white. However, when we take that paper into a room which is dimmer, we still perceive that paper as white as before. If we measure the lightness of that paper with an instrument in those two places, the lightness values will be drastically different. The lightness is not necessarily determined by the luminance. The lightness of paper remains the same. This is called the lightness constancy. The lightness constancy is very important property of the visual system and there are many theories to explain.

In 1977, Gilchrist [1] explained the perceived lightness. The apparent lightness depended on illumination of the plane that object appeared. Later, Ikeda et al. [2-7] explained lightness perception by a concept of recognized visual space of illumination (RVSI). You can understand how the space illumination when you go into a space; dim or bright, white, reddish or bluish, by light that reflected from objects, ceiling and walls around you. This is the information of luminance of the space that you see. It means RVSI of that space is created in your brain. And then you perceive the lightness of the object in that space in relation to the RVSI.

In this research we present the comparison of apparent lightness of two different illuminant spaces using two separated rooms and two test patches modified from

Gilchrist's experiment. The test patches were designed to perceive in different spaces. The effect of aperture size of the window that the subject can see though to get the initial visual information for perceiving another space by using mask was also studied. In addition, this research is conducted in the real scene and with the photographic print of the real scene. These prints were viewed with the viewing box to perceive as the 3D pictures.

1.1 Objectives

1. To compare the lightness perceived in different illumination spaces through various sizes of aperture.

2. To compare the lightness perceived in the real scene and the 3D picture.

1.2 Scope of thesis

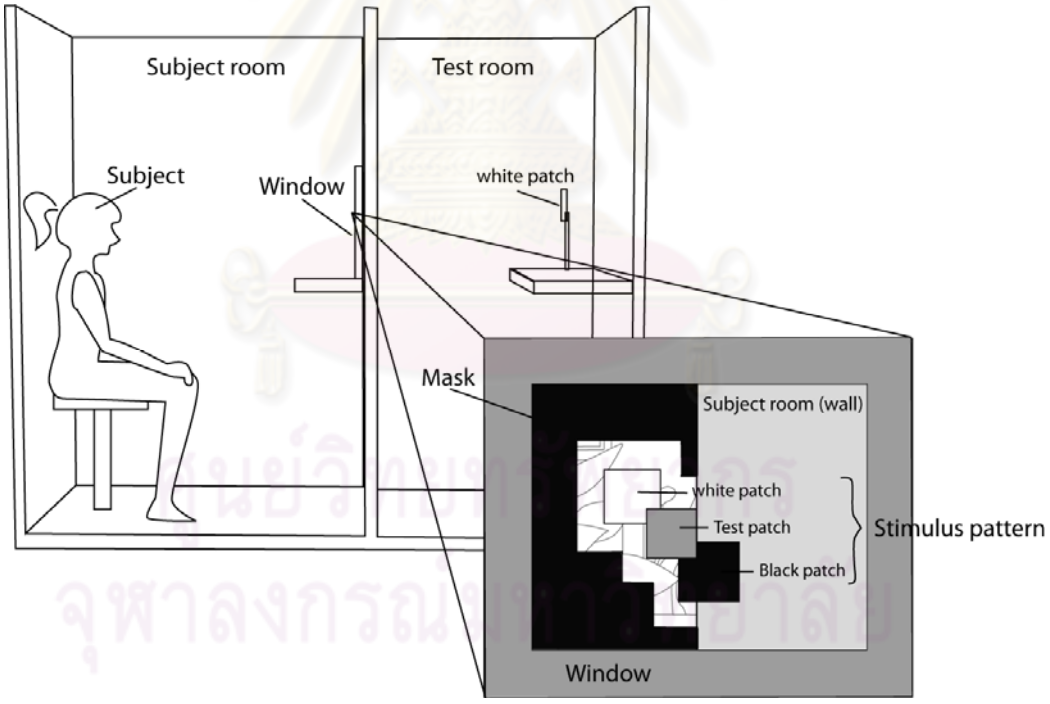

Fig.1-1 Scheme of experimental apparatuses

In this research we study the perceived lightness in difference illumination space though various sizes of aperture. The experiment can be divided into two parts. First is to find the relation of apparent lightness of the test patches to the size of aperture in the

real space. This experiment use the experimental booth that are separated into two rooms, subject room and test room as shown in Fig.1-1. The two stimulus patterns, Patterns A and B are use to test the perceived lightness. Four masks are used: W1, W2, W3 and W4, to control area of aperture. Their opened areas are 0, 17.75, 77 and 365.25 cm^2, respectively. There are three conditions used in this experiment; 10:150 lx, 150:10 lx and 100:100 lx (illuminance of subject room: test room). Next part is to find the relation of apparent lightness of the test patch to the size of aperture in the pictures seen with a viewing box. This experiment uses 18 pictures of experimental room. The illuminance of viewing box is set at about 65 lx.

1.3 Content of thesis

Chapter 1	describes background of this research, objectives and scope of research.
Chapter 2	deals with an overview of the theoretical considerations and literature review.
Chapter 3	contains the detailed description of the experimental apparatus, experimental condition and procedures.
Chapter 4	presents and discusses the results.
Chapter 5	gives the analysis, conclusion and suggestion of the thesis.

CHAPTER 2
THEORETICAL CONSIDERATION AND LITERATURE REVIEW

2.1 Theoretical consideration

Vision is one of the sensory processes of human to perceive the world by eyes. This process starts from the light get into the eyes, and then the receptors at retina generate the image signal by changing the chemistry in it. These signals are transferred to the brain which interprets into perception [8], such as shape, depth, color and lightness perception.

2.1.1 Color perception and lightness perception

Recognized visual space of illumination (RVSI)

The color appearance of an object or limited area is determined based on the recognition of illumination in the space where the object or area belongs to [5]. To have these recognitions is said that an observer has to construct a RVSI for the space in his brain. To construct the RVSI an observer has to see objects in the space and sometimes windows and luminaries. These are information to construct the RVSI and are called the initial visual information [4]. Once a RVSI is constructed in the observer's brain the color appearance of anything in the space is determined in relation to the RVSI. To explain this concept he has proposed the diagram of RVSI.

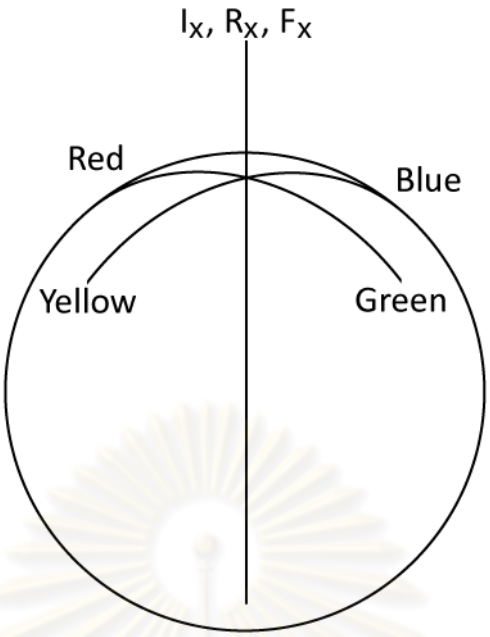

Fig.2-1 Illustration of RVSI

The concept of RVSI is illustrated in Fig. 2-1. A sphere or a circle indicates RVSI, whose size is determined by our understanding for a space how brightly it is illuminated. If we feel the space illuminated brightly, we show it by a large circle, and vise versa. All the objects in this space take positions inside the circle. The vertical axis F_x indicates the direction of the absolute neutral color and it is called the fundamental axis. Color is shown by the direction from F_x. The axis R_x, recognition axis, is the direction on which we perceive neutral color, and apparent color of an object is given by the angle from R_x to the direction on which the object locates, and by the direction from R_x. The illumination is expressed by the illumination axis I_x. Our brain positively adapt to the illumination to discount the color of illumination. The recognition axis R_x will come close to I_x.

Normally, we see objects surrounding us. Light falls on the objects and it is reflected by the surface of the objects. We see the reflected light and see the color of objects. The reflected light never exceeds the falling light on the objects. Reflection of 100 % is the maximum and we see there a very white object. In reality there is no such object that reflects 100 % of light. We see a white object for an object that reflects 90 % if the reflectance is uniform over the wavelengths. All the objects surrounding us reflect

incoming light less than 100 %. If the reflectance is zero, the object should appear really black. Such object never exists in reality. We are used to see objects, of which reflectance does not exceed 100 %. If some object presents us more light than 100 %, we can easily and quickly find it out as it is an unusual object that contradicts to our daily experience. The appearance differs from that of normal objects. It appears too bright as an object. If the light coming from the object exceeds much more than 100 % reflection, it begins to appear shining or luminous. The color is called the light source color or luminous color. These changes of color appearance are expressed as the change of color appearance mode.

The lightness apparent is presented by the distance from the bottom point along the axis. When it located near the bottom point, the perceived lightness is low. The perceived lightness is higher as it located farer from the bottom point [3,6]. All objects in the space have the reflected light less than 100%. By the concept of RVSI we say that all objects locate within the RVSI constructed. The color appearance of the light is just that of objects and surfaces in the space. If the reflected light is more than that exist the space, the color appearance is unnatural. It was called the unnatural color or light source color [9].

When the illuminance of space is increased the circle size of RVSI increases and the luminance of the object also increases by the same ratio as the circle. On the other hand when the illuminance decreased the circle size decreases and the object luminance decreased also. Thus the apparent lightness is unchanged. This phenomenon is known as lightness constancy [6].

2.1.2 Depth Perception

Depth and distance of the object can be perceived by cues from vision. There are two types of cues for perceiving the depth; monocular cues and binocular cues [10]. In this research, the subject observes with one eye so we explain only monocular cues. Monocular cues are the cues that require one eye for perceiving the information. There

are nine cues, interposition cue, aerial perspective cue, light and shade cue, linear perspective cue, texture gradient, motion parallax cue, relative size cue, relative height cue, and accommodation cue. The cue that we use to design the stimulus pattern that was used in this research is Interposition cue [10-12]. The object that placed overlap another object appears closer than the other as shown in Fig.2-2 [11].

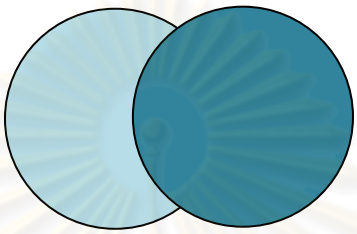

Fig 2-2 Interposition cue

2.2 Literature review

Gilchrist [1] researched perceived lightness depends on perceived spatial arrangement. There were made two rooms, divided by a wall that has a door at the central. When the subject saw through a pinhole at wall in front of the experiment room by one eye, the subject could see the back room. The front room was illuminated dimly and the back room brightly. On the dividing wall two plates are pasted one of which is a white test patch. On the back wall of the back room plate and bar were pasted. The two pattern of test patch was used. One is a square and two is a square cut out of corner. When the subject looked into the rooms through a pinhole, he saw the arrangement of patches. This test patch appeared to locate in the front room and to locate in the back room. The subject was asked to judge the lightness of the test patch. His judgment was that it was that in case of the square test patch the perceived lightness was brighter than in case of the square cut out off corner in spite of the fact that it was a same white paper placed at a same position in both cases. The appearance was perceived differently. The result showed that the perceived lightness of the test patch is governed by the luminance relationships between the patch and whatever regions are seen.

Mizokami et al. [13] researched the lightness change as perceived in relation to the size of recognized visual. The experiment box composted of two parts; front and back room. Inside the rooms were decorated with the objects, front room was dark gray and back room was light gray. So subject felt the illumination of each room was different in fact the illumination was the same. The dividing wall and the wall in front of the box had the windows for subject see the space in the box. The subject was asked to judge the lightness of the test patch at various positions in the experiment box. The results were when the position of test patch was changed from the front room to the back room, the apparent lightness of test patch was different. The apparent lightness of the patch positioned in the front room was brighter than positioned in the back room. That meaned lightness perception depended on the illumination of the space that object located.

Pungrassamee et al. [14] researched the color appearance that determined by recognition space. The experiment booth composted of two rooms; front room was for subject and back room was for test patch. The front room employed the colors illumination and the back room employed white light. There was a window at the wall between two rooms through which observer can see the test patch. Five window sizes were used. Two of them were smaller than the test patch so that the subject could see only the test patch. The subject could see the area of another room around the test patch with the other three big windows. The subject was asked to judge the color of the test patch through various sizes of the window. The result showed that when subject saw the test patch thought the two small windows, the apparent color of test patch was complementary to light source color of room. But, when the subject could see the area of the back room around the test patch, the color of test patch appears as its original. That showed the color appearance depended on the recognition of space where the object is located.

CHAPTER 3
EXPERIMENT

3.1 Apparatus

3.1.1 Experimental booth

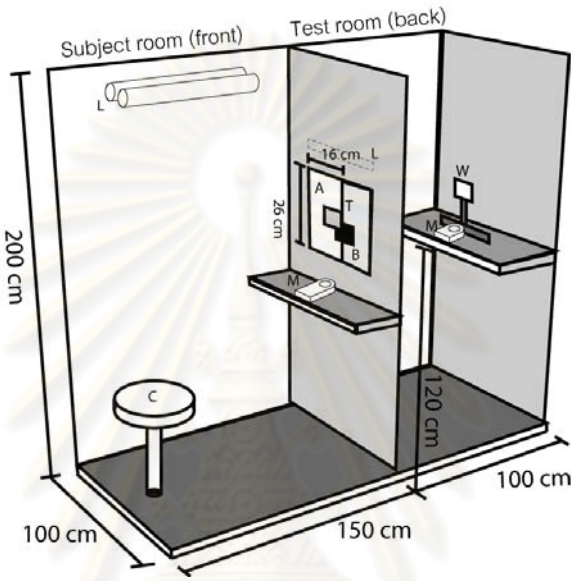

Fig.3-1 Scheme of Experimental booth; A, window; T, test patch; B, black patch; W, white patch; M, illuminometer; L, lamp; C, chair.

The experimental booth was composed of two rooms: the subject room (front); sized 100 cm wide, 150 cm long and 240 cm high, and the test room (back); sized 100 cm wide, 100 cm long and 240 cm high, as shown in Fig.3-1. There was a rectangular window (A) sized 26×16 cm^2 on the wall between two rooms. It was located at eye level of the subject when seated. The test patch (T) and black patch (B), which were a part of stimulus pattern, were attached at this window. When the subject sat on the chair (C) in the subject room he/she could see the test room through the window. In the test room, white patch, which was part of stimulus pattern, was placed. The distance from subject's eye to the windows was 130 cm and from the window to white patch was 70 cm. Both rooms were decorated with various color objects and the same achromatic wall paper which had some texture to simulate a normal living room. White and black objects such

as ceramic vase, paper and picture wall in the room were used for lightness judgment as 100% whiteness and 100% blackness. The experimental booth was illuminated by the daylight type fluorescent lamps and their intensity could be adjusted by light controller. The light intensity of subject room and test room was controlled independently. The illumination of both rooms was measured by the illuminometers (choma meter minota CL-100) that were placed on the shelf in front of the test patch and white patch.

3.1.2 Stimulus pattern

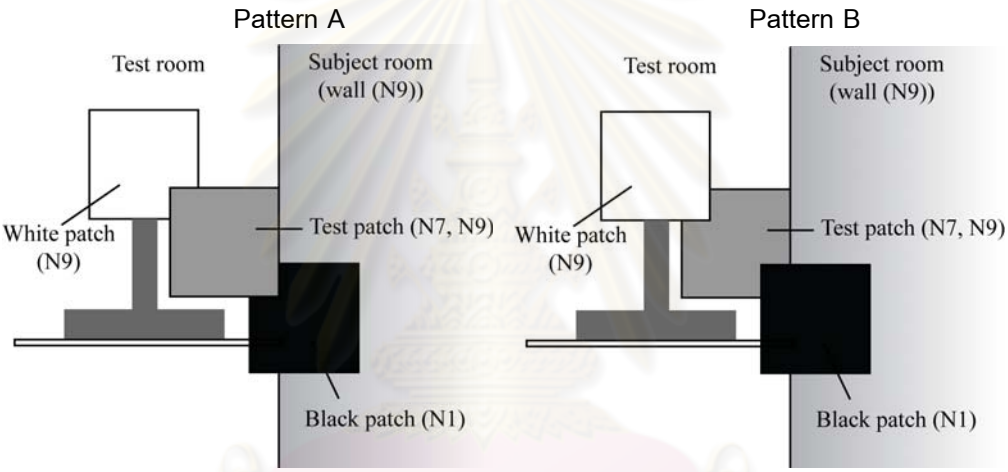

Fig.3-2 Stimulus patterns; left , Pattern A, the complete square; right, Pattern B, the square cut out off corner.

The two stimulus patterns were used in this research, namely, Patterns A and B. They were modified from Gilchrist experiment [1]. In each pattern, there were three patches: test patch, back patch and white patch, for arrangement. The test patch and a 5×5 cm^2 square black (Munsell N1) were attached at the window in the subject room. The 8×8 cm^2 square white (Munsell N9) patch was placed in the test room as shown in Fig.3-1. The test patch of Pattern A was a 5×5 cm^2 square achromatic (Munsell N7 and N9) patch. Its lower right-hand was overlapped with a corner of black patch. The Pattern B test patch was a 5×5 cm^2 square achromatic (Munsell N7 and N9) patch which upper left-hand corner was cut out off and the black patch overlapped at lower right-hand

corner as shown in Fig.3-2. When the subject looked at the test patch with one eye, he/she had to adjust the position of his/her head so that the corner of test patch fit to the corner of patch which was place in test room as shown in Fig.3-2. With this arrangement Pattern A test target appeared as it was located in the subject room and Pattern B appeared as it was located behind the white patch in the test room.

3.1.3 Mask

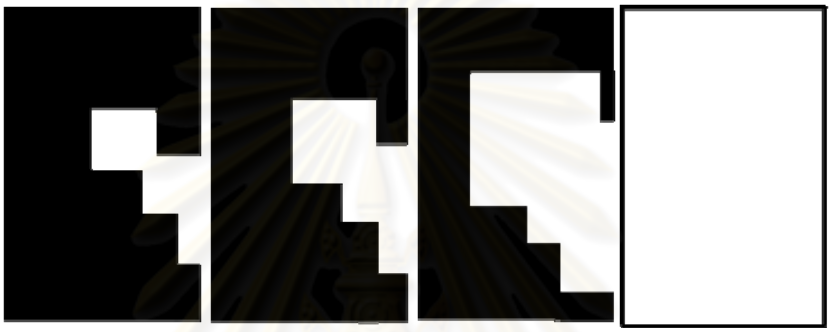

Fig.3-3 The shape of the mask ; W1, W2, W3 and W4.

Four masks with different sizes were used to control the area of aperture on the window. Their shapes were cut according to the edge of stimulus pattern as shown in Fig. 3-3. The masks were denoted as W1, W2, W3 and W4. W1 was fitted to the test patch so that the observer could not see the test room. W2 and W3 were cut to have gap 0.5 and 2 cm from the edge of the stimulus pattern; areas of apertures are 17 and 76 cm^2 respectively. W4 was the fully opened window, no mask was use; the area was 367 cm^2. The visual field of test room that subject can see when each mask was used is shown in Fig.3-4.

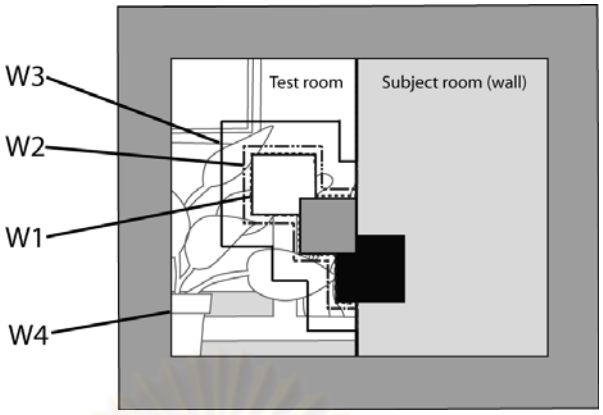

Fig.3-4 The visual field of test room that subject can see when W1, W2, W3 and W4 was used.

3.1.4 Picture

Fig.3-5 Picture of experimental room

Eighteen photographic prints of the experimental room were used in this research. Fig.3-5 is an example of pictures used in the experiment. The perspective of the print appeared the same as the real experimental room. The eighteen pictures consisted of the pictures of 2 stimulus patterns; A and B, with 3 masks; W1, W2 and W4,

in 3 conditions; the illumination of subject room brighter than test room, darker and the same, namely, Set 1, 2, and 3, as shown in Fig.3-6.

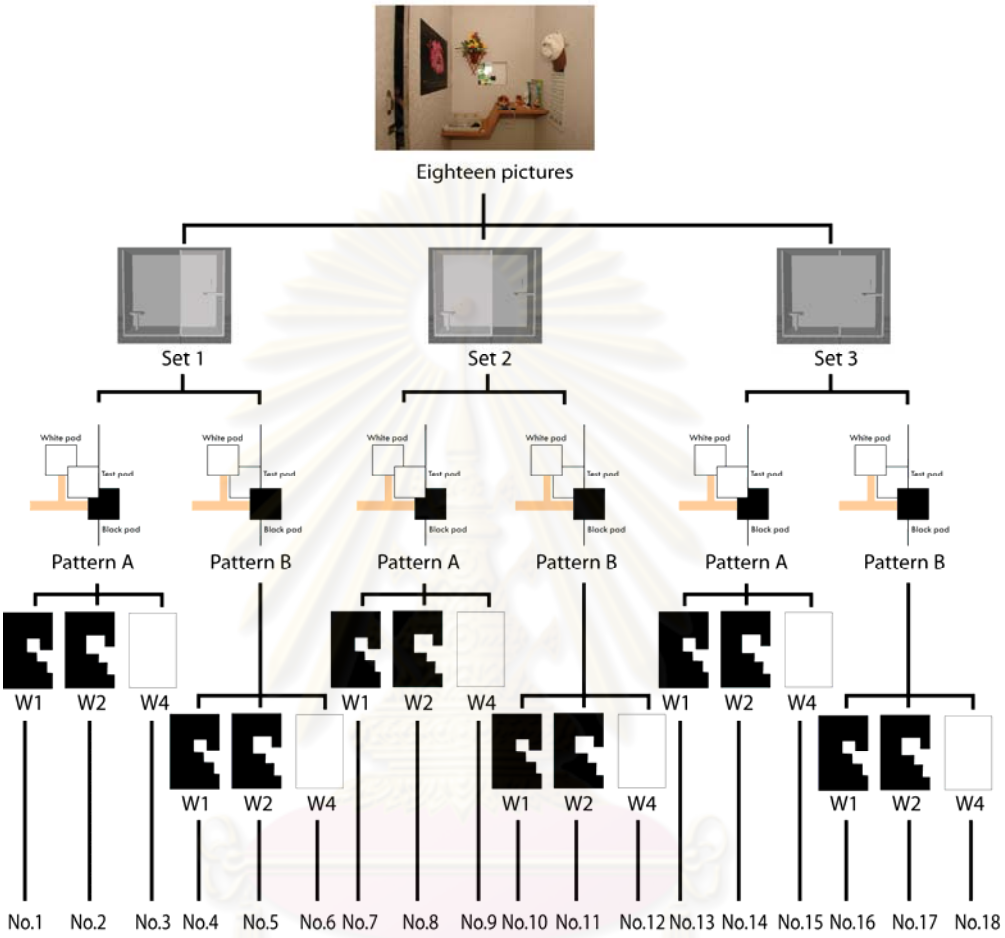

Fig.3-6 A set of 18 pictures used in the experiment

The illuminance of the subject room and the test room that use for taking the pictures of Set 1, 2 and 3 were chosen from the pictures of 15 conditions that had ratio of illuminance in the subject room to back room; 20:1, 15:1, 10:1, 7:1, 5:1, 3:1, 2:1, 1:1, 1:2, 1:3, 1:5, 1:7, 1:10, 1:15 and 1:20. When we took a picture, the camera was set to F no. 8 and shutter speed was 2 sec. Next fifteen pictures were classified into three groups according to visualization. Set 1 had appearance of the illumination of subject room being brighter than test room. Set 2 appearance of the illumination of subject room being darker than test room. And Set 3 appearance of the illumination of subject room

and test room being the same. The pictures that did not have all detail of both rooms were culled. Then only one picture having the most distinct appearance according to its desired setting was chosen from each set. The illuminance condition used for taking the chosen pictures were then use to produce the set of 18 pictures (Fig.3-6) The picture of Set 1 was taken at ratio 1:5, Set 2 was taken at ratio 5:1 and Set 3 was taken at ratio 2:1.

3.1.5 Viewing box

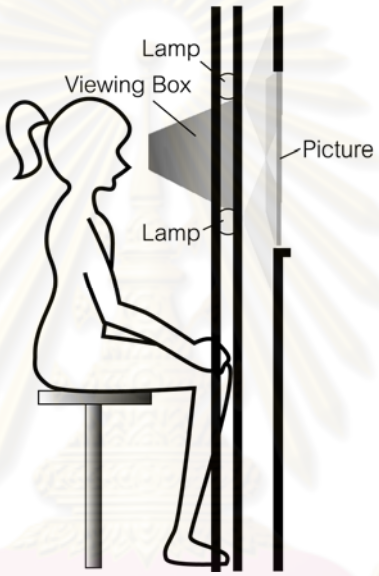

Fig.3-7 Scheme of viewing box

Viewing box was built for viewing the picture of experiment room. It limited the subject's field of view so that only the picture could be seen order to make subject perceive 3 dimensional picture. The scheme of viewing box is shown in Fig.3-7. The key point for making the viewing box was the viewing angle. It had to allow the subject to perceive the picture as the real scene. So the viewing box had to give the same viewing angle as the real scene, the relation is shown in Fig.3-8. The distance for observing was calculated by Eq.1.

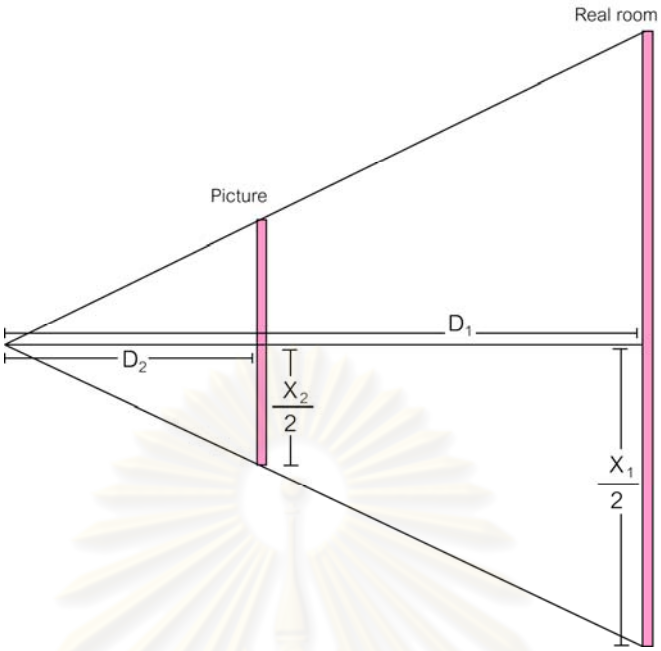

Fig.3-8 Viewing angle of the picture and the real room

$$D_2 = \frac{\frac{X_2}{2} D_1}{\frac{X_1}{2}} \qquad \text{..... Eq.1}$$

When X_1 was the size of reference object.

D_1 was the distance that observes in the real.

X_2 was the size of reference object in the picture.

D_2 was the distance that observes in the picture.

The small gap between lamps and picture (Fig.3-7) must be large enough to obtain the uniform illuminance of the picture. When the subject observed, the viewing box would be covered by the black cloth. The subject could not see anything all around.

3.2 Subject

Eight subjects; MI (male, 76 years old, Japanese), PP (female, 57, Thai), TK (female, 44, Japanese), JP (female, 31, Thai), JB (female, 26, Thai), PR (female, 26, Thai), SS (female, 24, Thai), and CJ (female, 24, Thai) participated in the experiment.

Pre-experiment

Part 1: PP, TK, JP, PR and SS

Part 2: JP, JB, PR, SS and CJ

Main experiment

Part 1: MI, PP, TK, JP and SS

Part 2: PP, JP, PR, SS and CJ

All of subjects had normal color vision. The subject MI, PP, TK, PR, SS and CJ used their right eye and subject JP and JB used left eye to observe at all part. For four subjects; JP, PR, CJ and JB, this was the first time for them to do psychophysical experiment. The subjects in the experiment were trained to judge the lightness of the test patch in the Patterns A and B by elementary color naming method. The gray scale was for practicing lightness judgment. In the experiment, the subjects could use the white and black objects in the experimental room as the reference.

3.3 Methodology

Elementary color naming method

In this research we measured the lightness of the test patch by elementary color naming method [14]. In this research, the subjects were asked to judge whiteness and blackness.

3.4 Procedure

In this research, the procedure can be divided into two steps. The first step is the preparation. It consists of processes of preparing the apparatus and finding the proper experimental condition. Step two is experiment of finding the relation of apparent lightness of test patches to the area of aperture that is separate into two parts. Part 1 is in the real space and Part 2 is in the 3D picture. The details of the pre-experiment in finding the experimental condition for use in the experimental room and in viewing box, and the main experiment; Part 1 and 2, are given in the next section.

3.4.1. Pre-experiment

3.4.1.1 Illuminance condition of the experimental rooms

3.4.1.2 Illuminance condition of the viewing box

3.4.2 Main experiment

3.4.2.1 The relation of apparent lightness of test patches to the area of aperture experiment in real space

3.4.2.2 The relation of apparent lightness of test patches to the area of aperture experiment in the 3D picture

3.4.1 Pre-experiment

3.4.1.1 Illuminance condition of the experimental rooms

The illuminance condition in experimental room could be obtained from the ratio of illuminance in the subject room to the test room that gave the maximum difference of apparent lightness between test patches of Patterns A and B. In addition, we also used this criterion for the reverse illumination experiment. So we find this ratio from the relation between apparent lightness of test patch of Patterns A and B and the ratio of illuminance between the subject room and the test room.

The relation between apparent lightness of test patch of Patterns A and B and the ratio of illuminance between the subject room and the test room can be found from pre-experiment that detail is explained as follows. Each subject was instructed to sit in subject room and look around to adapt themself to the room illumination for few minutes. The subject was told to look at the test patch with one eye which could be any side but he/she needed to use the same eye for next experiment. No chin rest was use. The subject's heads could move freely but it had to be at the position that the corner of test patch fitted to corner of white patch in case of Pattern B, and overlap the corner of white patch, in case of Pattern A at the time of judgment. The 15 ratios of illuminance between subject room and test room; 1:20, 1:15, 1:10, 1:7, 1:5, 1:3, 1:2, 1:1, 2:1, 3:1, 5:1, 7:1, 10:1, 15:1 and 20:1, and the two stimulus patterns; A and B, were randomly presented to the subject for judging the lightness of the test patches. It was observed with a achromatic test patches; Munsell N9. The subject's task was to determine the lightness of the test patch by elementary color naming method, in percentage of whiteness and

blackness. The time for judgment was not limited. There were five subjects; PP, TK, JP, PR and SS. Each subject had to repeat the experiment five times. The subjects break when they finish one session. When the experiment was completed for five sessions, the calculation was done to obtain the average of the amounts of whiteness and blackness of each test patch for in each subject.

The result of this pre-experiment, the ratio that was employed to obtain the largest difference of lightness apparent between Patterns A and B was 1:15. Detail of these experimental results in shown in section 4.1. So this ratio was used in the main experiment as Condition 1: subject room was darker than test room, the illuminance in subject room was 10 lx and in test room was 150 lx. In addition, inverse ratio was used as Condition 2: the subject room was brighter than the test room, illuminance in the subject room was 150 lx and in the test room was 10 lx. Condition 3, the illumination of subject room and test room was the same, had illuminance in the subject room and in the test room of 150 lx.

3.4.1.2 Illuminance condition of the viewing box

Illuminance of the viewing box was adjusted to look similar to the real experimental room. So we would find the condition by the pre-experiment that detail is explained as follows.

The subjects were asked to sit in the subject room and look around to adapt themselves to the room illumination for few minutes and remember lightness of the room. The subject then moved to sit in front of the viewing box and looked at the picture. The subject adjusted the illuminance of the viewing box until lightness of picture appeared similar to the experimental room. The experimenter recorded the illuminance data. Five subjects; JP, JB, PR, SS and CJ, were employed. Each subject repeated the test five times.

The average of 5 times from five subjects was 65 lx. It was used in the viewing box experiment.

3.4.2 Main experiment

3.4.2.1 The relation of apparent lightness of test patches to the area of apertures in the real space

The subjects were asked to sit in the subject room and look around to adapt themselves to the room illumination for few minutes. They were told to look at the test patch with one eye which could be any side but he/she needed to use the same eye for next experiment. No chin rest was use. The subject's heads could move freely but it had to be at the position that the corner of test patch fitted to corner of white patch in case of Pattern B, and overlap the corner of white patch, in case of Pattern A at the time of judgment. The two test patches; A and B, and four masks; W1, W2, W3 and W4, were randomly presented to subjects for judging the lightness of the test patches. It was observed with two achromatic test patches; Munsell N7 and N9. The subject's task was to determine the lightness of the test patch by elementary color naming method, in percentage of whiteness and blackness. The time for judgment was not limited. Three conditions; 10:150 lx, 150:10 lx and 100:100 lx (illuminance of subject room: test room), that were found in the pre-experiment were employed in this experiment. There are Five subjects; MI, PP, TK, JP and SS. Each subject had to repeat all five times. The subjects break when they finish one session. When the experiment was completed for five times, the calculation was done to obtain the average of the amounts of whiteness and blackness of each test patch in each subject.

3.4.2.2 The relation of apparent lightness of test patches and the area of aperture in 3D picture

The subject was asked to sit in front of a viewing box and look at the picture through the hole with one eye which could be any side but he/she needed to use the same eye for next experiment. Eighteen pictures were randomly presented to subjects for judging the lightness of test patch in the picture. The subject's task was to determine the lightness of test patch by elementary color naming method, in percentage of whiteness and blackness. The time for judgment was not limited. Five subjects; PP, JP, PR, SS and CJ were employed in this experiment. Each subject had to repeat five times and they break when they finish one session. When the experiment was completed for

five sessions, the calculation was done to obtain the average of the amounts of whiteness and blackness of each test patch in each subject.

CHAPTER 4
RESULTS

4.1 Result of pre-experiment

4.1.1 The relation of apparent lightness of test patches to the ratio of illuminance between test room and subject room

The results in 15 conditions of five subjects; PP, TK, JP, PR and SS, in pre-experiment; finding the relation of apparent lightness of test patch of Patterns A and B to the ratio of illumination between the subject room and the test room are shown in Fig.4-1(a-e). The tendency of apparent lightness of each subject was similar. The whiteness of both test patches decreased when the illuminance of the test room increased. The whiteness of test patch of Pattern A was higher than B when the illuminanc of the test room more than the subject room. And at the case of the subject room was brighter than the test room, the whiteness of both patches was the same.

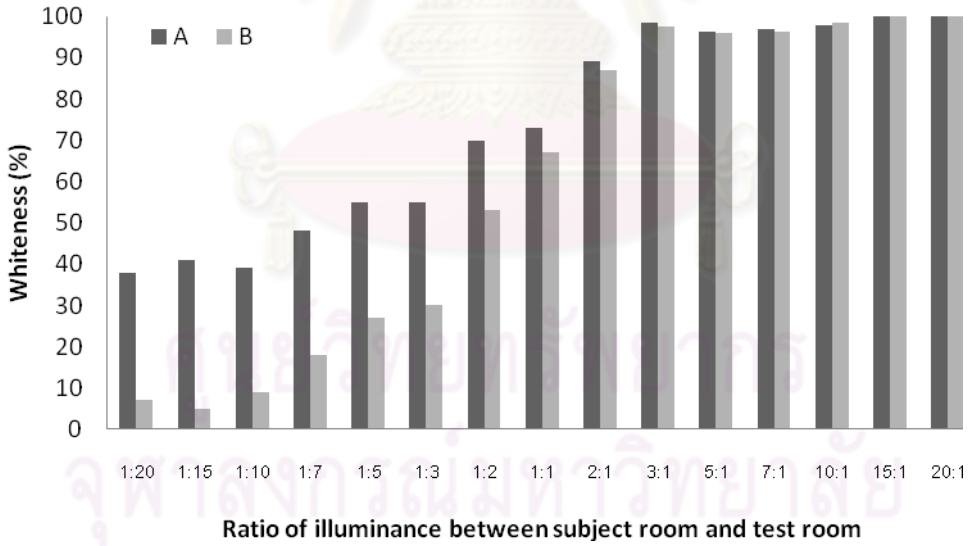

Fig.4-1a The result of apparent lightness of test patch at various ratio of illumination between test room and subject room of subject PP.

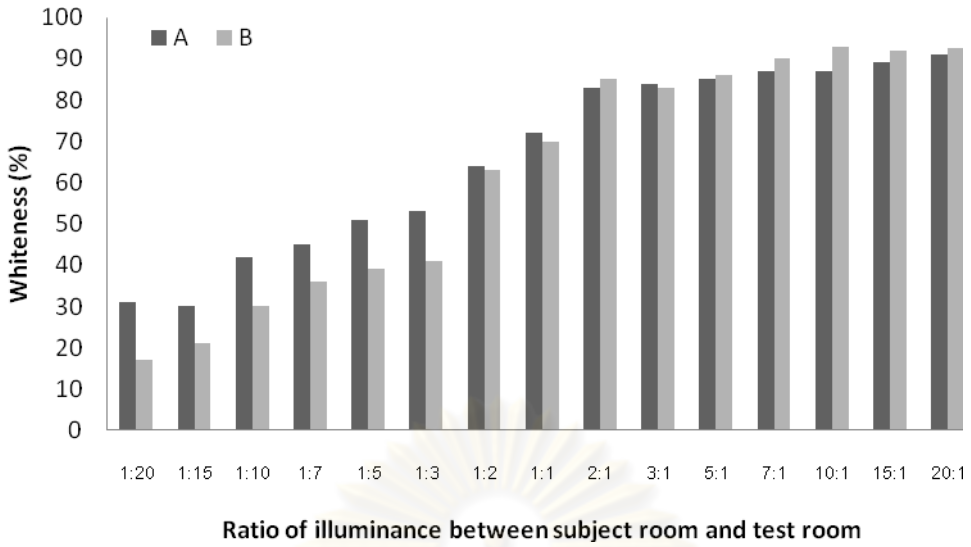

Fig.4-1b The result of apparent lightness of test patch at various ratio of illumination between test room and subject room of subject TK.

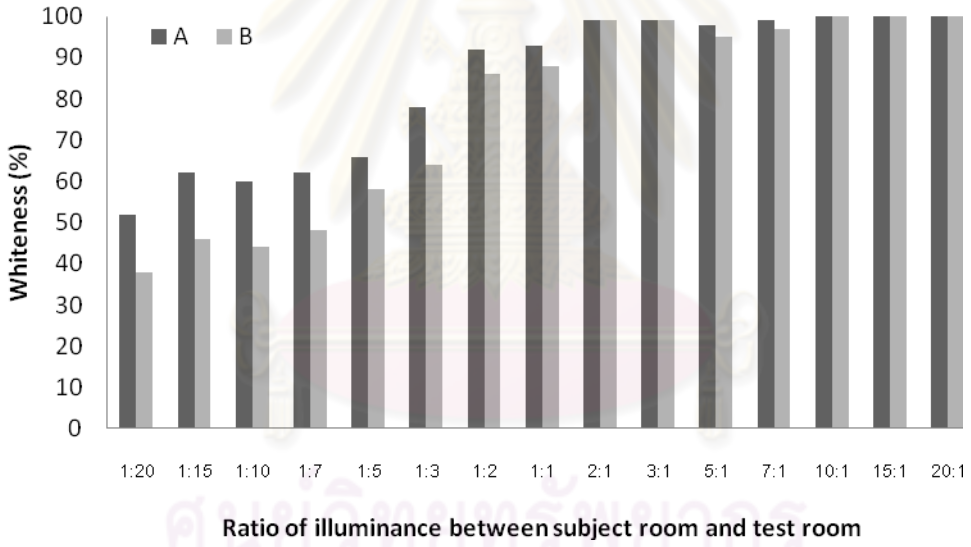

Fig.4-1c The result of apparent lightness of test patch at various ratio of illumination between test room and subject room of subject JP.

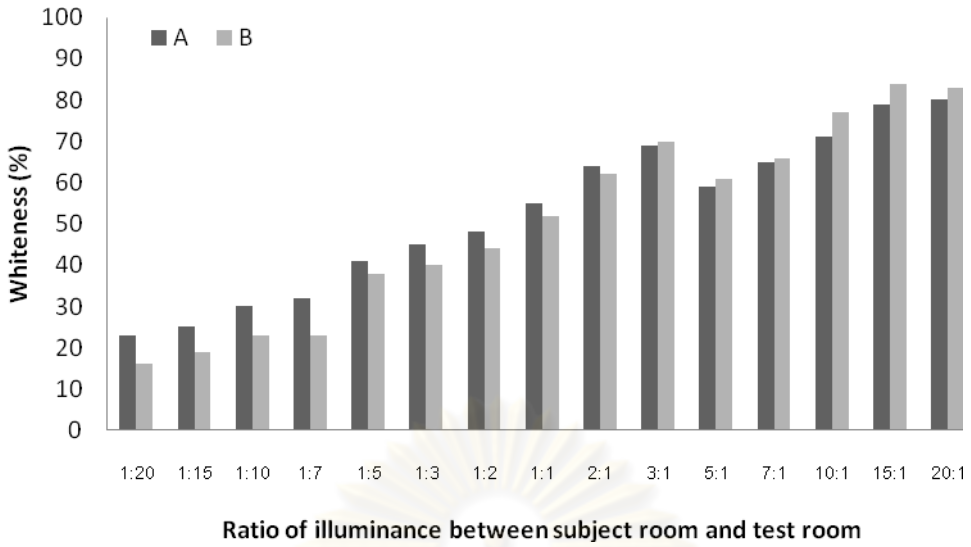

Fig.4-1d The result of apparent lightness of test patch at various ratio of illumination between test room and subject room of subject PR.

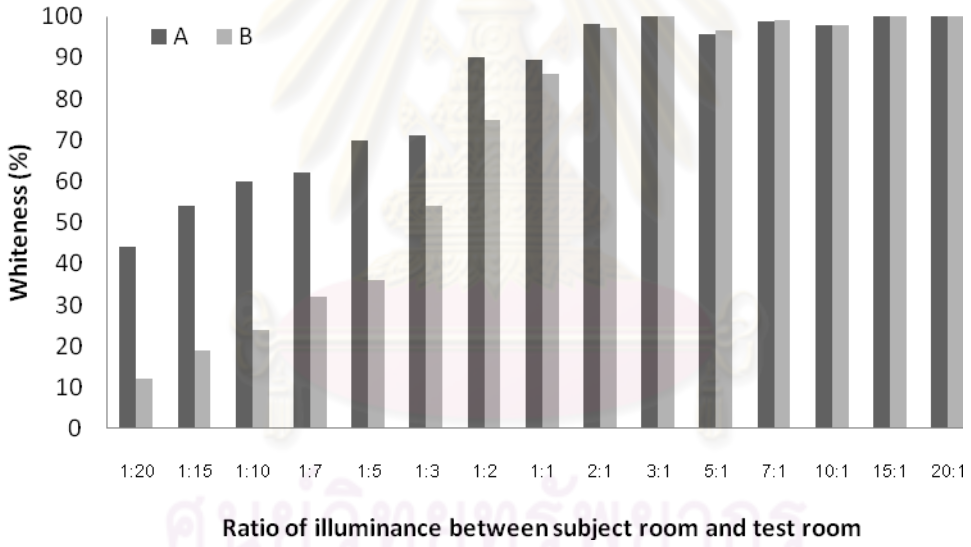

Fig.4-1e The result of apparent lightness of test patch at various ratio of illumination between test room and subject room of subject SS.

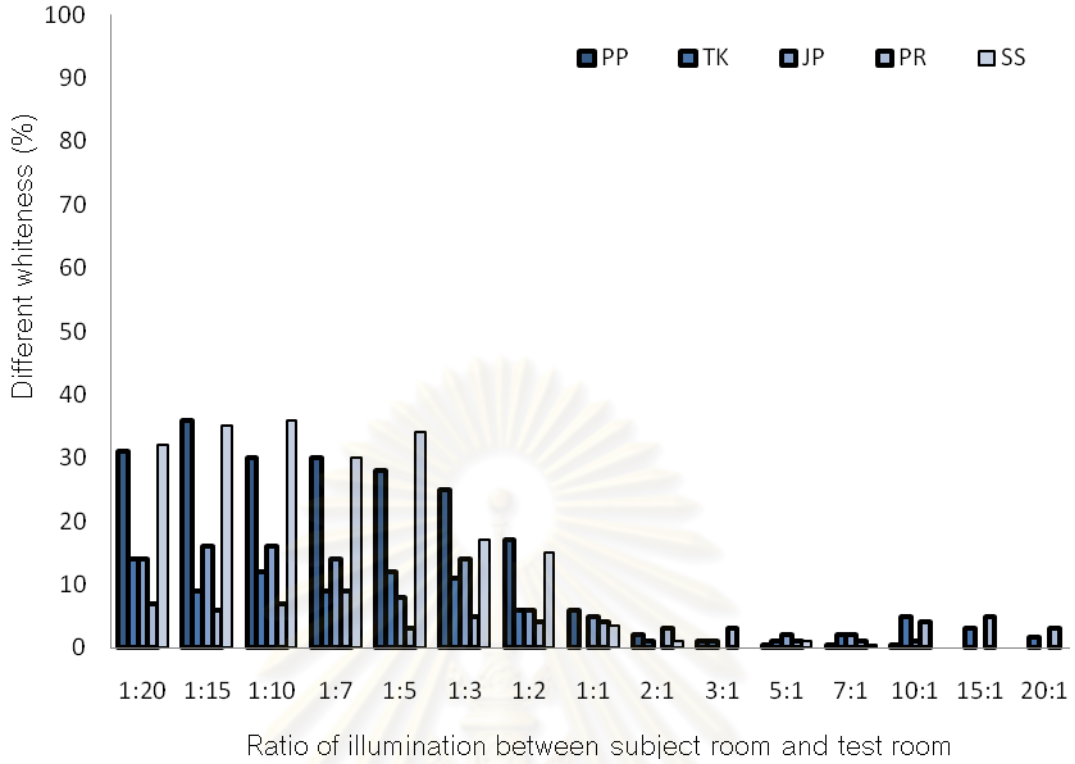

Fig.4-2 Difference of apparent lightness between test patch pattern A and B at various ratios of illuminance between test room and subject room.

The difference of apparent lightness between A and B is shown in Fig.4-2. It was clearly seen that all lines of the curves had the same tendency. When the ratio increased, the different lightness increased. From ratio 5 up, all lines became stable.

The result of this pre-experiment, the ratio that was employed to obtain the largest different of lightness apparent between Patterns A and B was 1:15. So this ratio was used in the next experiment as Condition 1: subject room was darker than test room, the illuminance in subject room was 10 lx and in test room was 150 lx. In addition, inverse ratio was used as Condition 2: the subject room was brighter than the test room, illuminance in the subject room was 150 lx and in the test room was 10 lx. Condition 3, the illumination of subject room and test room was the same, had illuminance in the subject room and in the test room of 150 lx.

4.2 Result of main experiment

4.2.1 The relation of apparent lightness of test patches to the area of apertures in the real space

In Condition 1, the test room was brighter than the subject room, the results of apparent lightness of N9 and N7 test patches of Patterns A and B from five subjects; MI, PP, TK, JP and SS, showed the similar of change as shown in Fig.4-3(a-e). At point 0 cm^2; the aperture area of W1, the whiteness curves of A and B were at the same point. The two curves dropped sharply and started to separate at the area of aperture 17.75 cm^2 (W2). Then they became stable from point 17.75 cm^2 to 365.25 cm^2. And the whiteness of B was lower than A.

The difference of the apparent lightness between Patterns A and B at various sizes of aperture is shown in Fig.4-4 and 4-5. It was clearly seen that the different lightness occurred when the test patch was seen through W2 to W4. The results of N9 and N7 were the same. But the apparent whiteness of N7 was lower than N9.

This can be explained by the RVSI concept. At W1, the subjects saw the Pattern A and B appeared in the subject room because the aperture area was completely fitted with the stimulus pattern. They could not see any part of the test room. Thus the perceived lightness of both test patches was judged based on RVSI in the subject room. Therefore the whiteness of both test patches was the same. Whenever the subject saw the stimulus patterns and some part of the test room with W2, W3 and W4 that had space around the test patch the whiteness of test patch of Pattern A and B was different. Because test patches of Patterns A and B, that design for perceive in different space, appear in the subject room and the test room respectively. In this condition, the subject room was darker than the test room, so the size of subject room RVSI was smaller than test room as shown in Fig 4-6. The luminance of both test patches was the same, so they represent at the same point. When the subject judge the lightness base on the subject room illumination, a small one, the point was nearer the edge of the RVSI than when judge base on another one. It was the cause of apparent lightness of test patch of Pattern A is brighter than the test patch of Pattern B.

In the previous experiment [14], they use to test apparent color with the area of aperture between 77 and 365.25 cm^2. The result showed that the difference of

chromaticness that changed from the original color when subject saw the test patch with 172 cm^2 area of aperture as the result that test with bigger and smaller aperture area. Thus we predicted that the result in case of apparent lightness give the same.

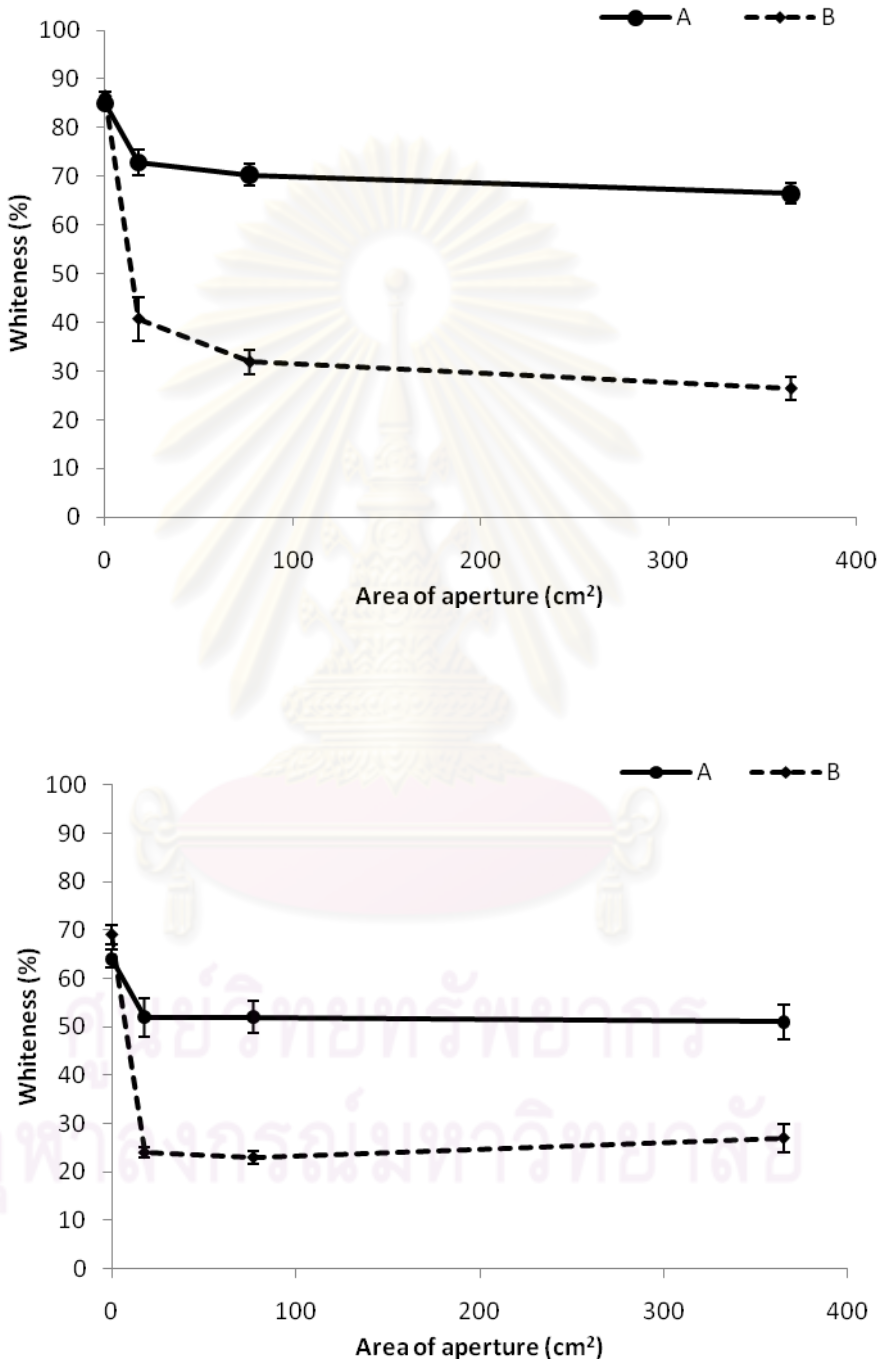

Fig.4-3a The result of apparent lightness of test patch N9 (upper) and N7 (lower) at various sizes of aperture in condition 1 of subject MI.

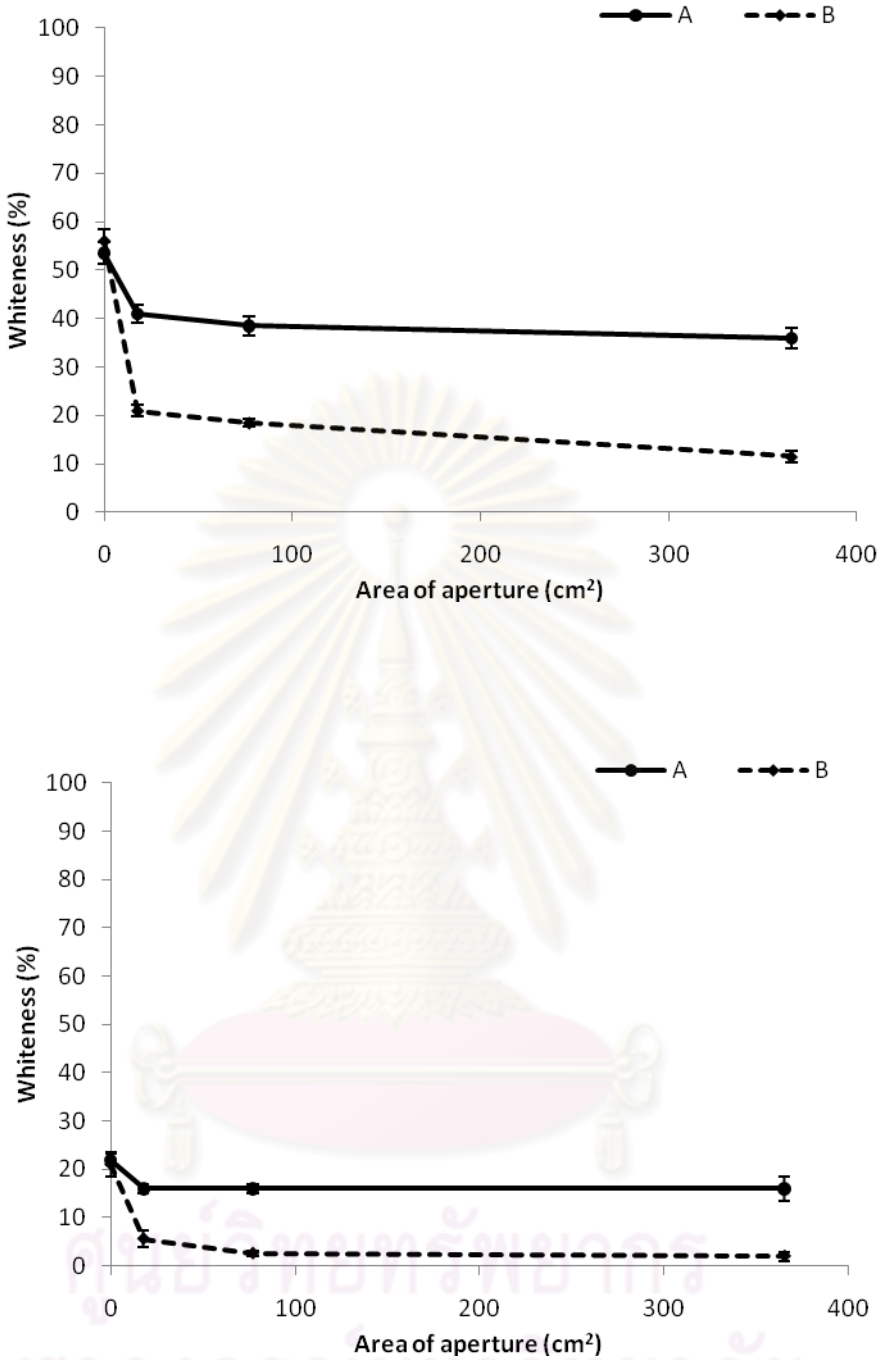

Fig.4-3b The result of apparent lightness of test patch N9 (upper) and N7 (lower) at various sizes of aperture in condition 1 of subject PP.

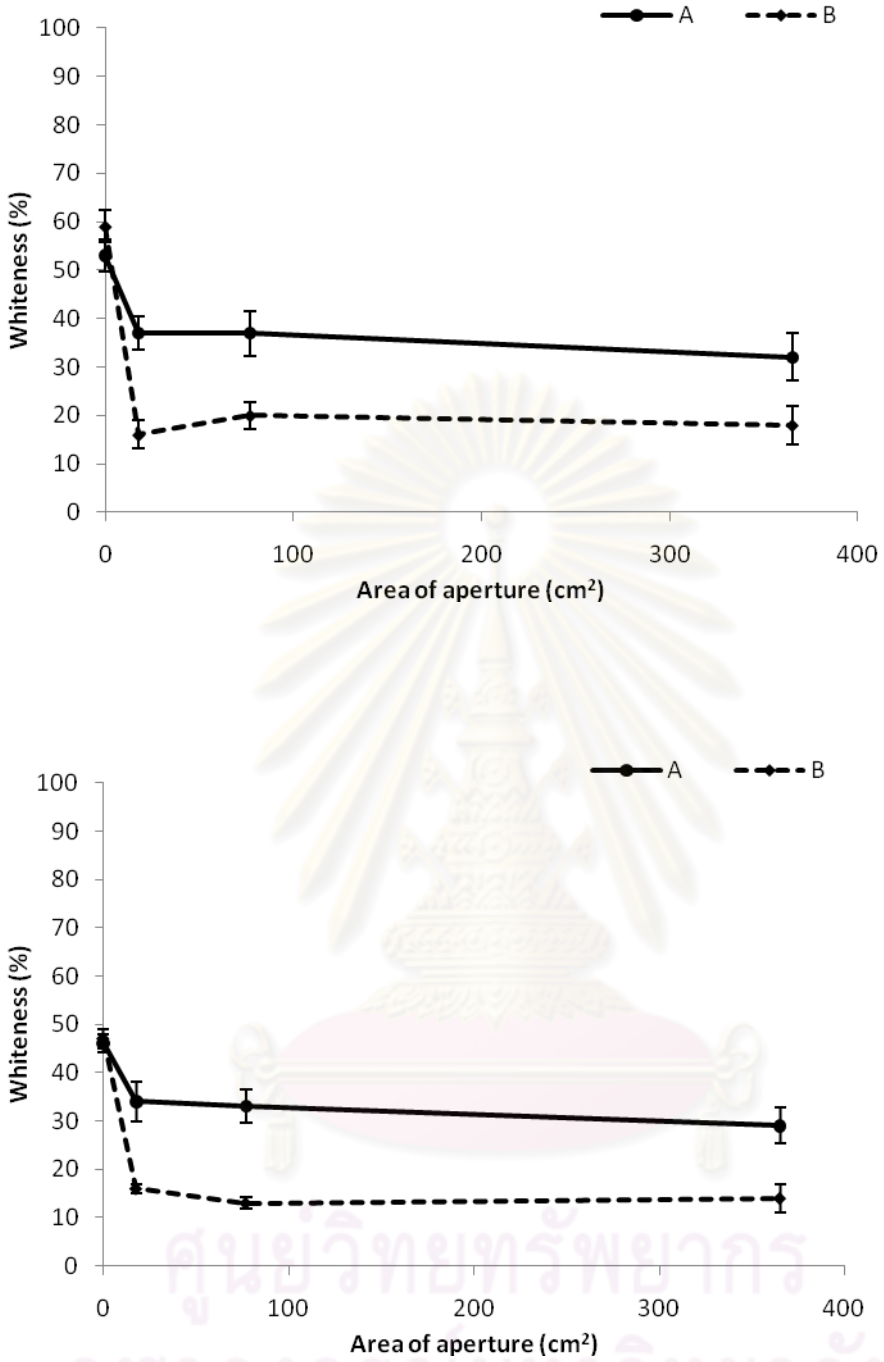

Fig.4-3c The result of apparent lightness of test patch N9 (upper) and N7 (lower) at various sizes of aperture in condition 1 of subject TK.

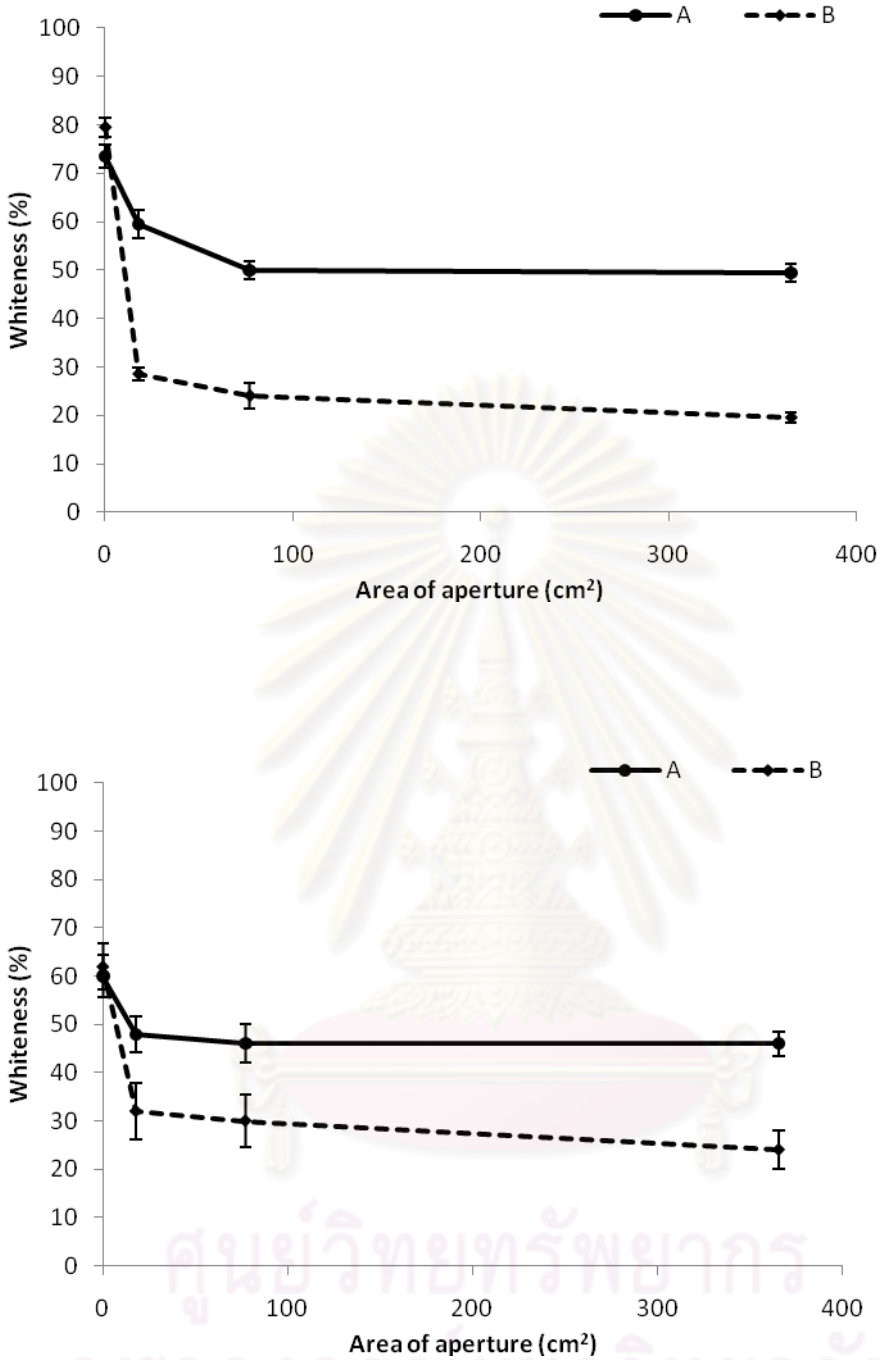

Fig.4-3d The result of apparent lightness of test patch N9 (upper) and N7 (lower) at various sizes of aperture in condition 1 of subject JP.

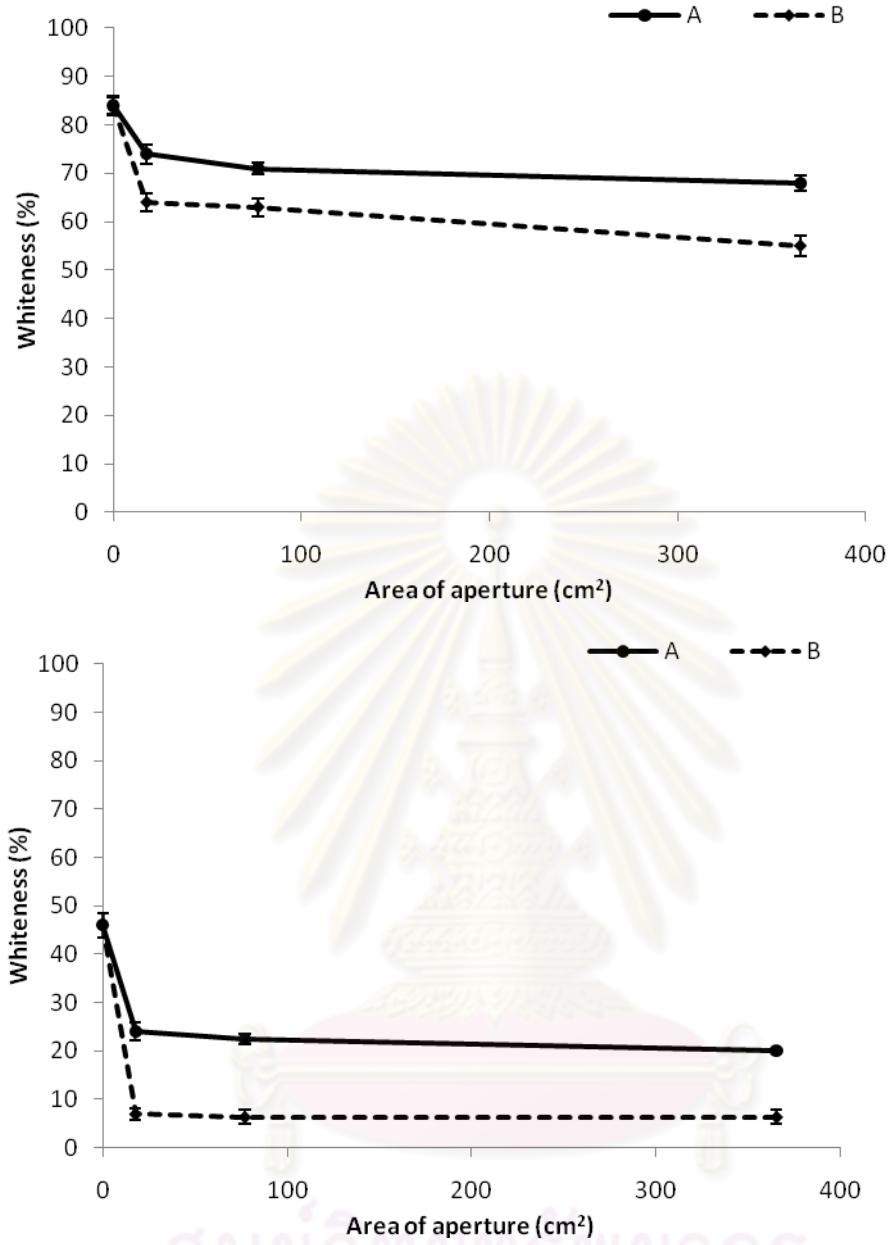

Fig.4-3e The result of apparent lightness of test patch N9 (upper) and N7 (lower)at various sizes of aperture in condition 1 of subject SS.

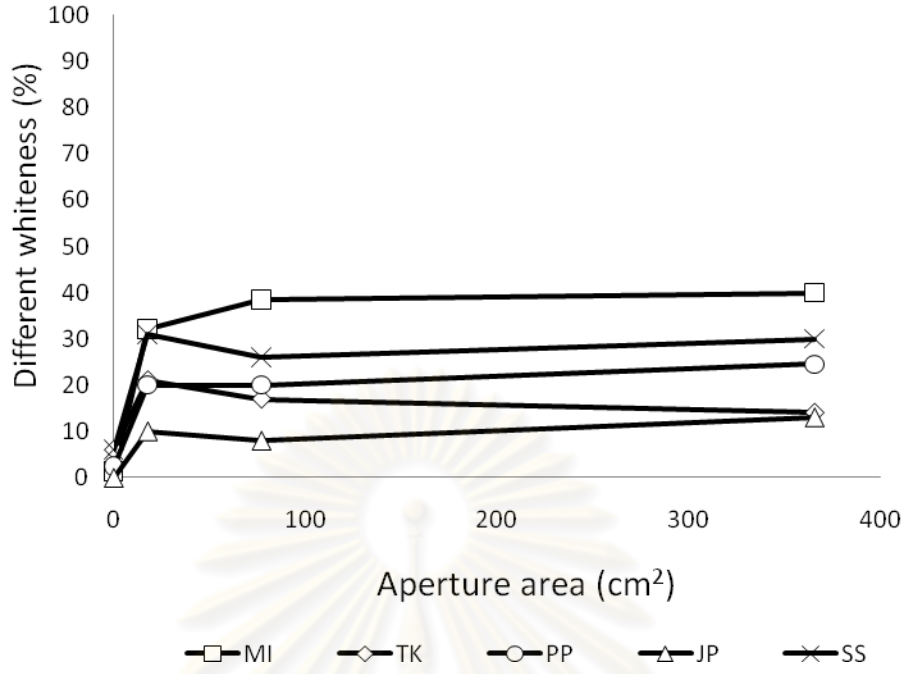

Fig.4-4 Difference of apparent lightness between N9 test patch pattern A and B at various size of aperture in condition 1.

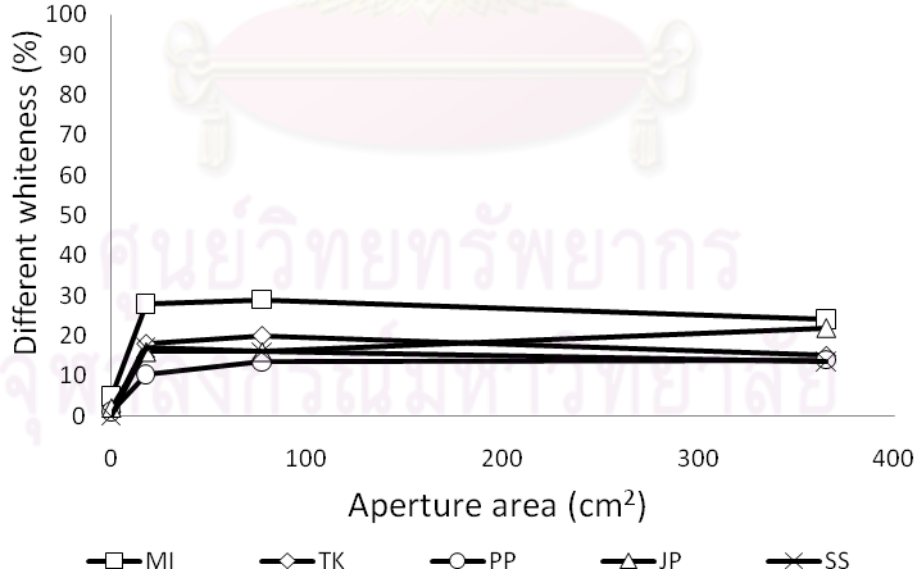

Fig.4-5 Difference of apparent lightness between N7 test patch pattern A and B at various size of aperture in condition 1.

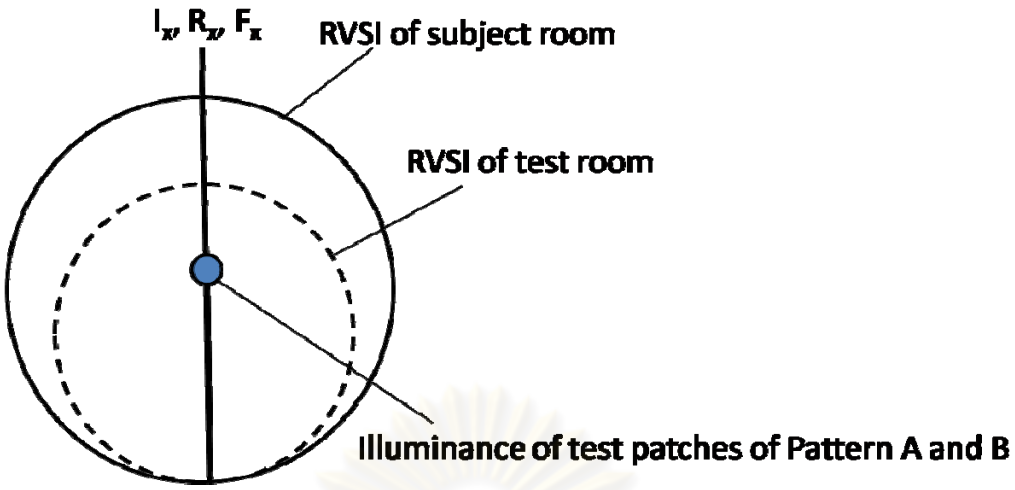

Fig.4-6 Illustration of RVSI of Condition 1.

In Condition 2, the subject room was brighter than the test room, the result of N9 test patch, the whiteness of test patch of Patterns A and B was no difference in every case. Most of the answers were 100% whiteness or close to 100%. In Fig.4-7, it was the result of subject PP. It should be remarked that the subjects comment that both test patches were very bright. And it should be notice that in this experiment, the observers complained that it was difficult to see the test patch of Pattern B to locate in the test room. Both patches appeared to locate in the same position, so the subject judged whiteness of both patches was the same.

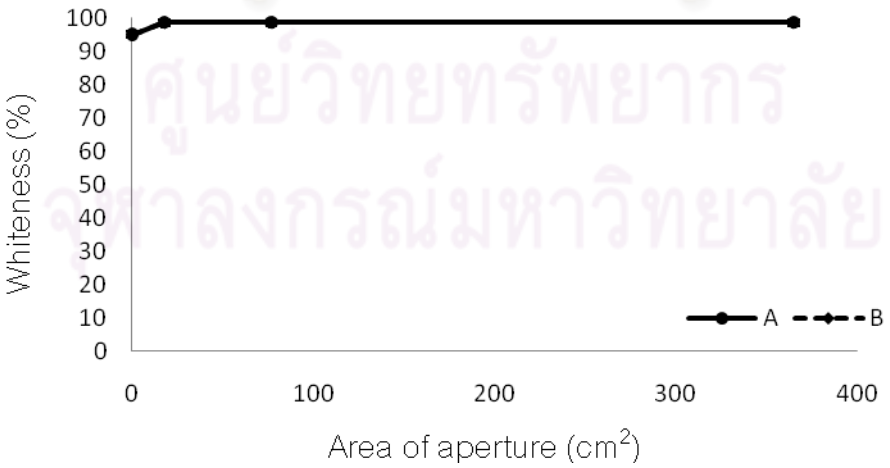

Fig.4-7 The result of apparent lightness of test patch N9 at various sizes of aperture in condition 2 of subject PP.

In the case of N7 test patch, which was darker than N9, the results of five subjects; MI, PP, TK, JP and SS are shown in Fig.4-8(a-e). The shapes of all curves were the same. The two curves of the A and B whiteness started at the same point. Then it raised and started to separate at the area of aperture 17.75 cm^2. After that it became stable from point 17.75 cm^2 to 365.25 cm^2. And the whiteness of B was higher than A.

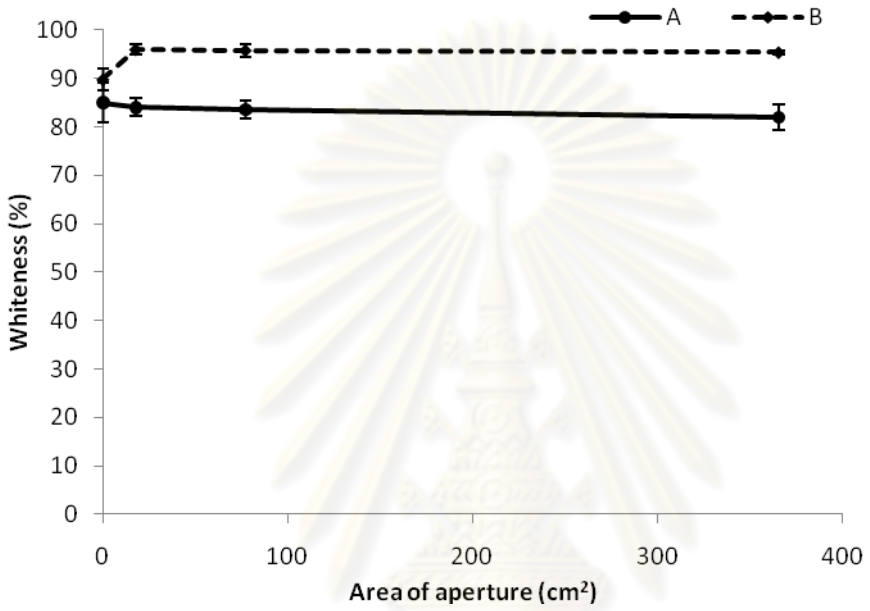

Fig.4-8a The result of apparent lightness of test patch N7 at various size of aperture in condition 2 of subject MI.

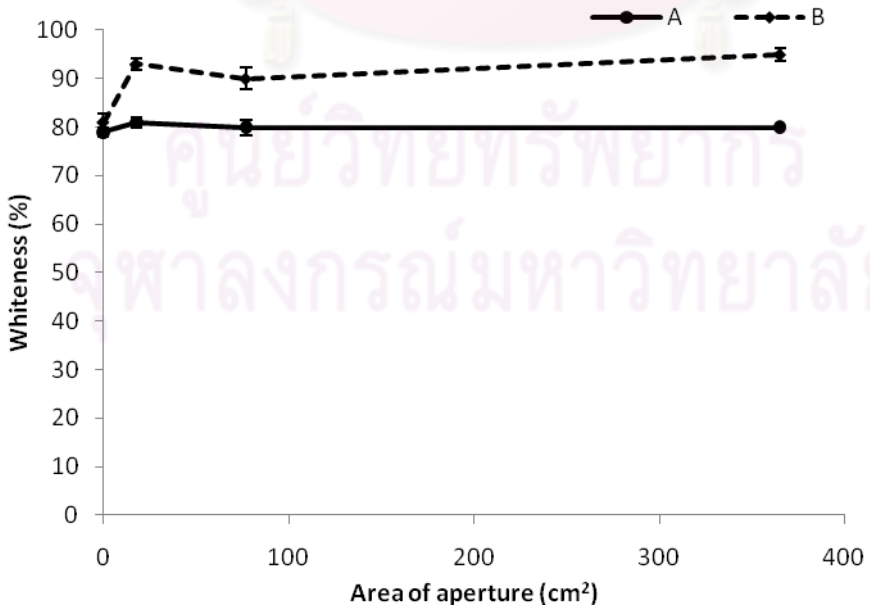

Fig.4-8b The result of apparent lightness of test patch N7 at various size of aperture in condition 2 of subject PP.

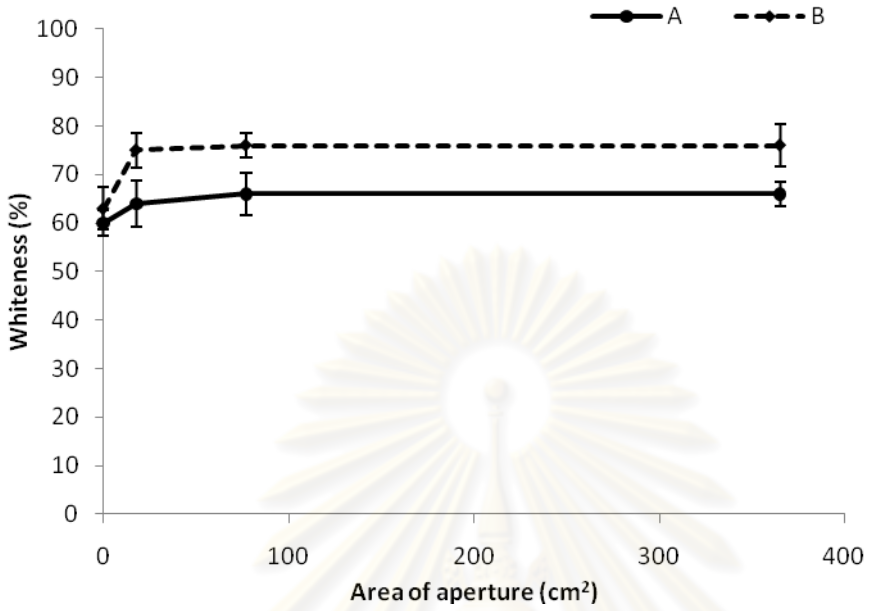

Fig.4-8c The result of apparent lightness of test patch N7 at various size of aperture in condition 2 of subject TK.

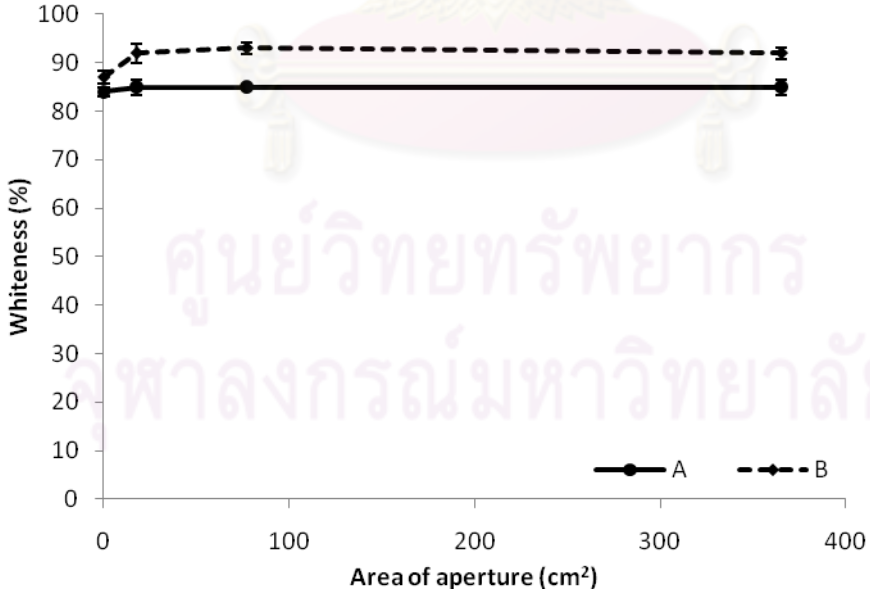

Fig.4-8d The result of apparent lightness of test patch N7 at various size of aperture in condition 2 of subject JP.

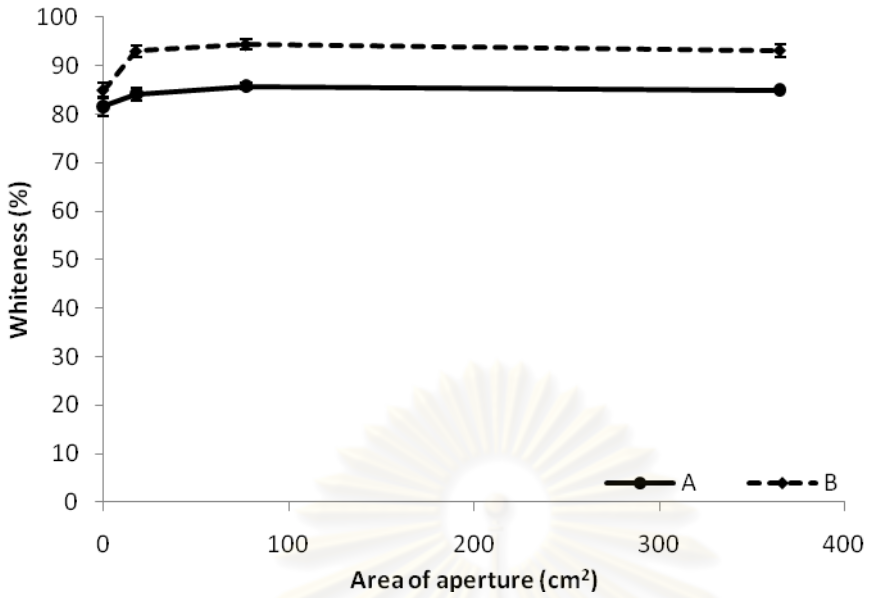

Fig.4-8e The result of apparent lightness of test patch N7 at various size of aperture in condition 2 of subject SS.

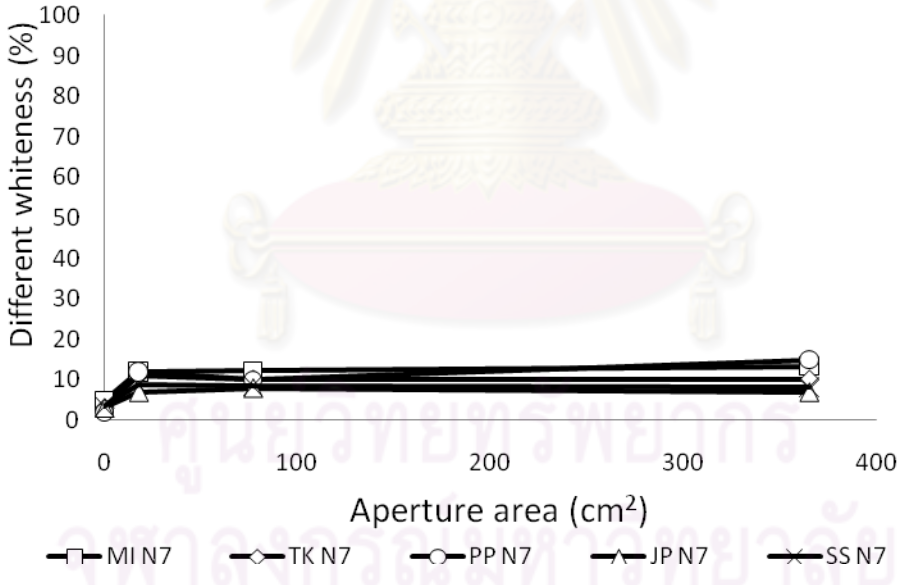

Fig.4-9 Difference of apparent lightness between N7 test patch pattern A and B at various size of aperture in condition 2.

The difference of the apparent lightness between Patterns A and B at various sizes of aperture is shown in Fig.4-9. The difference lightness occurred when the test patch was seen through W2 to W4.

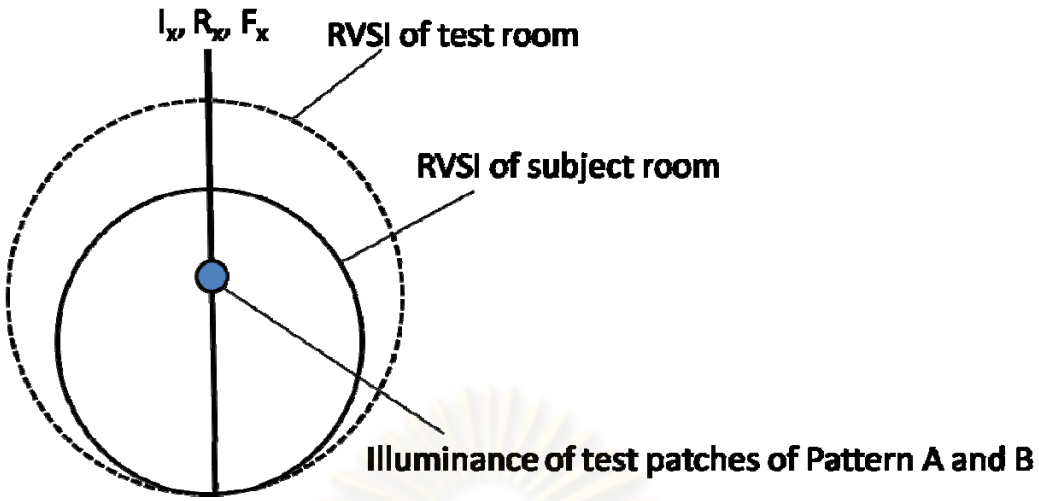

Fig.4-10 Illustration of RVSI of Condition 2.

This result can be explain with the same concept as the result of Condition 1, but it was reverse case, the illumination of subject room was brighter than the test room. So the size of subject room RVSI was bigger than test room as shown in Fig 4-10. When the subject judge the lightness base on the subject room illumination, a big one, the point, the luminance of test patches, was farer the edge of the RVSI than when judge base on another one. Thus it was the cause of apparent lightness of test patch of Pattern A are darker than the test patch of Pattern B.

Condition 3, illumination of the subject room and the test room were similar, the results of five subjects were almost the same as shown in Fig.4-11. The perceived lightness of both test patches was no difference when the subjects saw the test with the various size of aperture except subject PP and TK. the apparent lightness of PP was very different because subject PP felt that this condition like Condition 1, the test room was brighter than the subject room. So this result were similar the result of condition 1 but the effect was less.

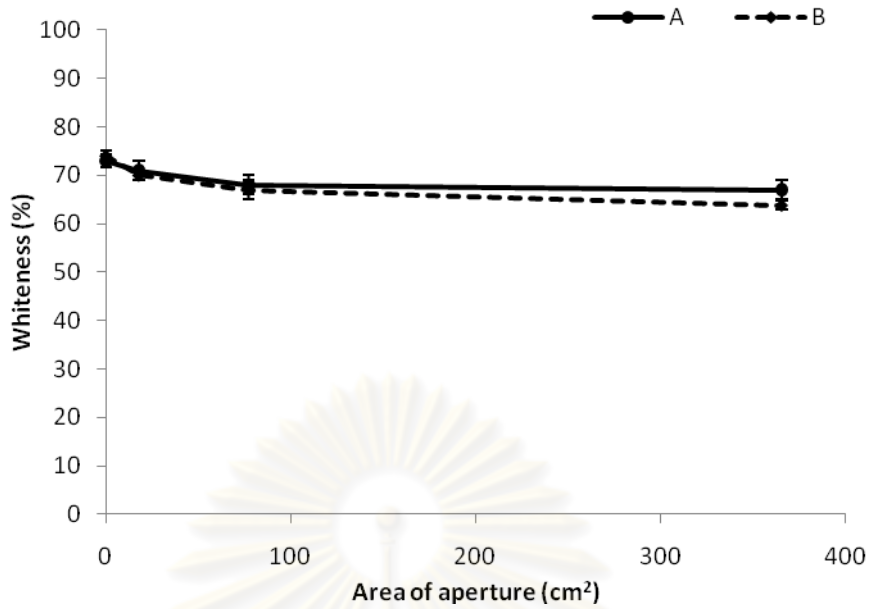

Fig.4-11a The result of apparent lightness of test patch N7 at various size of aperture in condition 3 of subject MI.

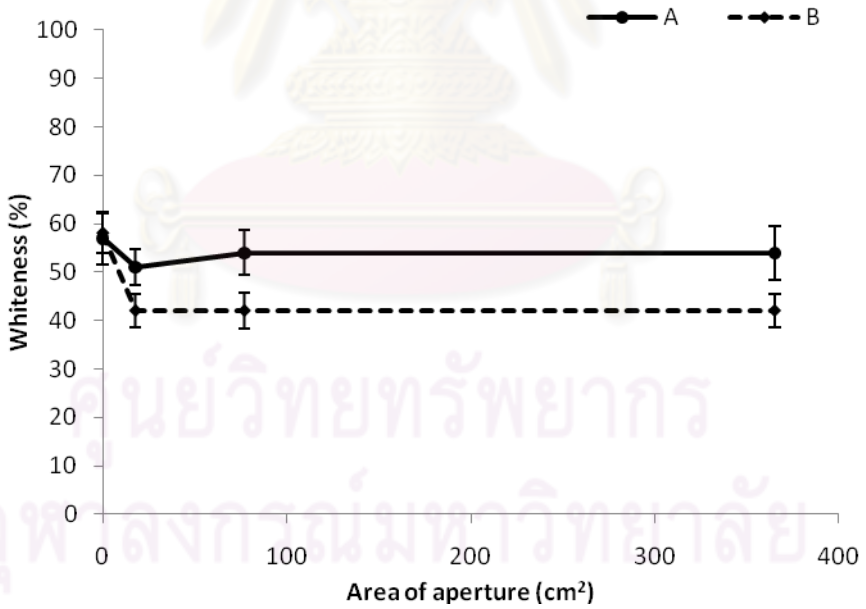

Fig.4-11b The result of apparent lightness of test patch N7 at various size of aperture in condition 3 of subject PP.

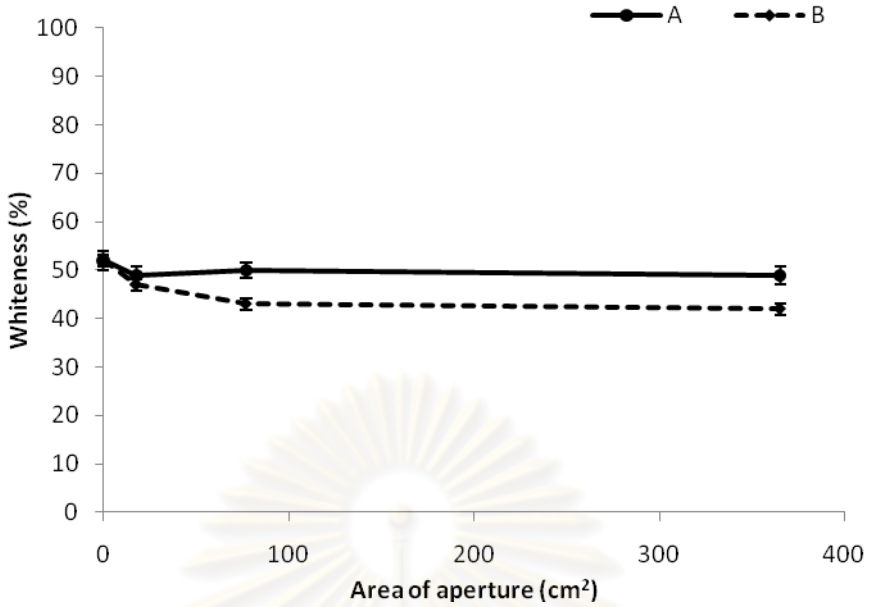

Fig.4-11c The result of apparent lightness of test patch N7 at various size of aperture in condition 3 of subject TK

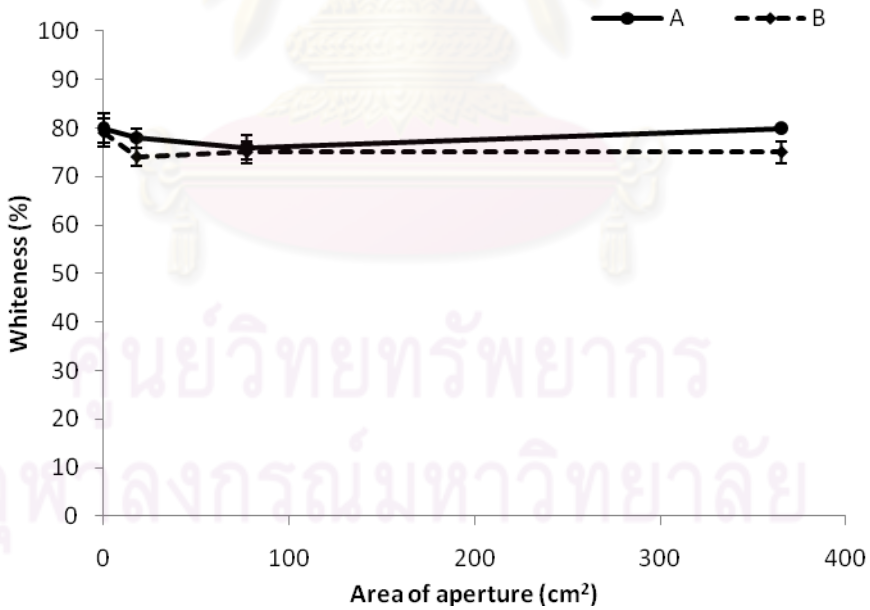

Fig.4-11d The result of apparent lightness of test patch N7 at various size of aperture in condition 3 of subject JP.

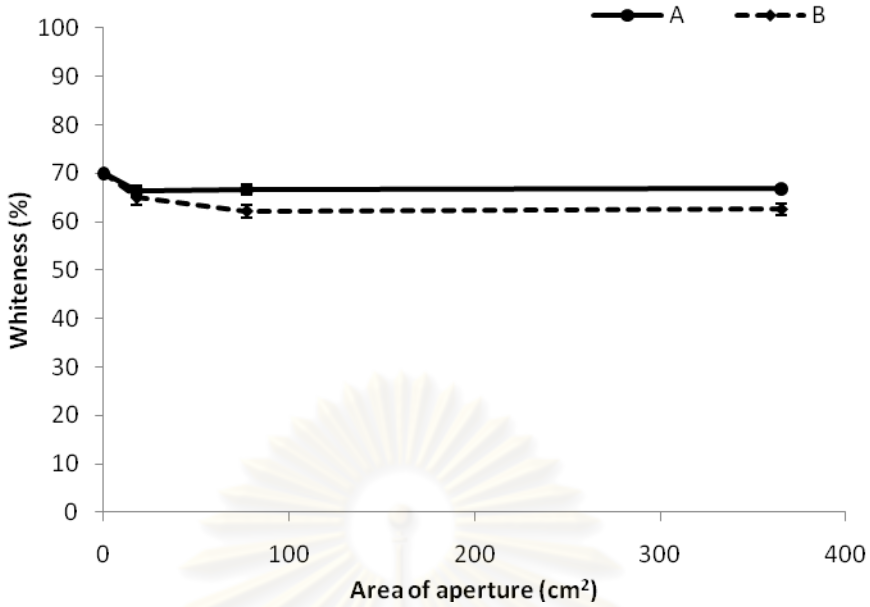

Fig.4-11e The result of apparent lightness of test patch N7 at various size of aperture in condition 3 of subject SS.

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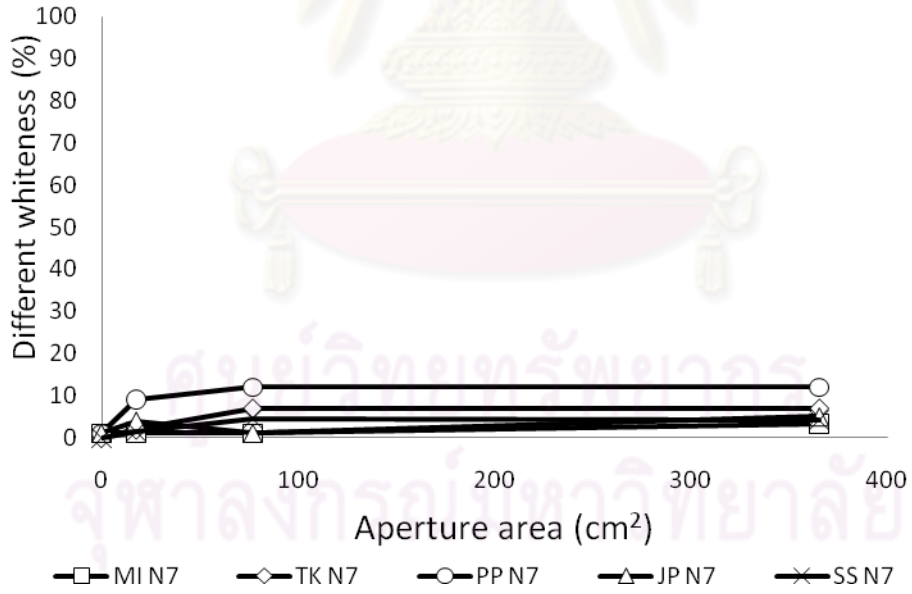

Fig.4-12 Difference of apparent lightness between N7 test patch pattern A and B at various size of aperture in condition 3.

The difference of the apparent lightness between Patterns A and B at various sizes of aperture is shown in Fig.4-12. That showed the lines were almost parallel along X-axis and they were near to 0 except that of PP and TK.

This result can be explain with the same concept as the result of Condition 1 and 2, but the size of RVSI of the subject room and the test room was the same as shown in Fig.4-13. Thus apparent lightness of the test patches were the same no matter what Pattern A, that was judge base on illumination of the subject room, or B, that was judge base on illumination of the subject room. In case of PP and TK, the apparent lightness of both test patches was different because the sizes of both rooms, that their brain constructed, were different. The sizes of subject room RVSI was smaller, like Condition 1. Thus the results were similar the result of Condition 1.

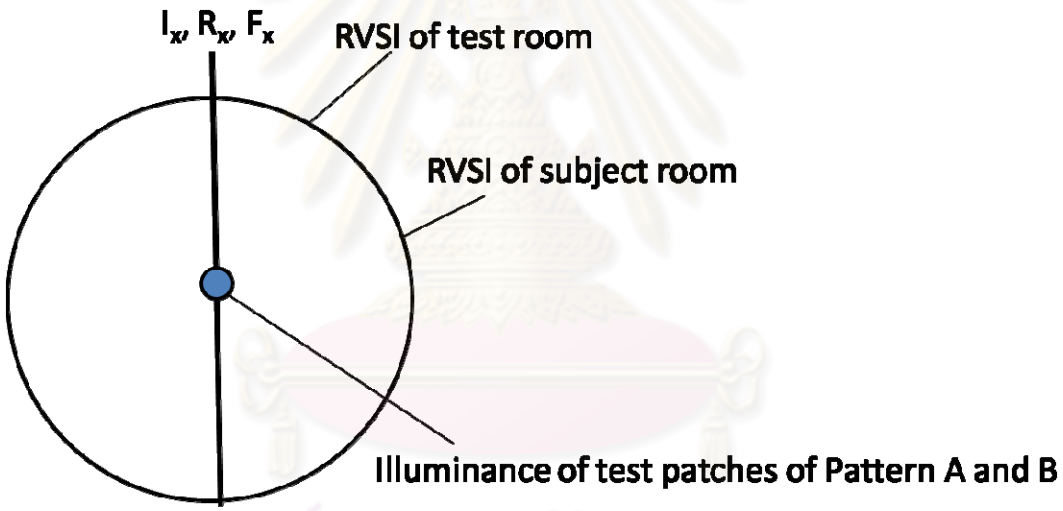

Fig.4-13 Illustration of RVSI of Condition 3.

It should be notice that even the results of Condition 1 and Condition 2 agree with each other but the result in Condition 1 had more effect than Condition 2, as shown in Fig.4-14. When the spaces with different illumination appear at the same time, the subject tends to recognize the space that is brighter easier than the darker one. From the interviewed with each subject, it was difficult to see the bright test patch of Pattern B to appear in the dimmer space. The subject had to be mindful to see and judge the whiteness of test patch of Pattern B.

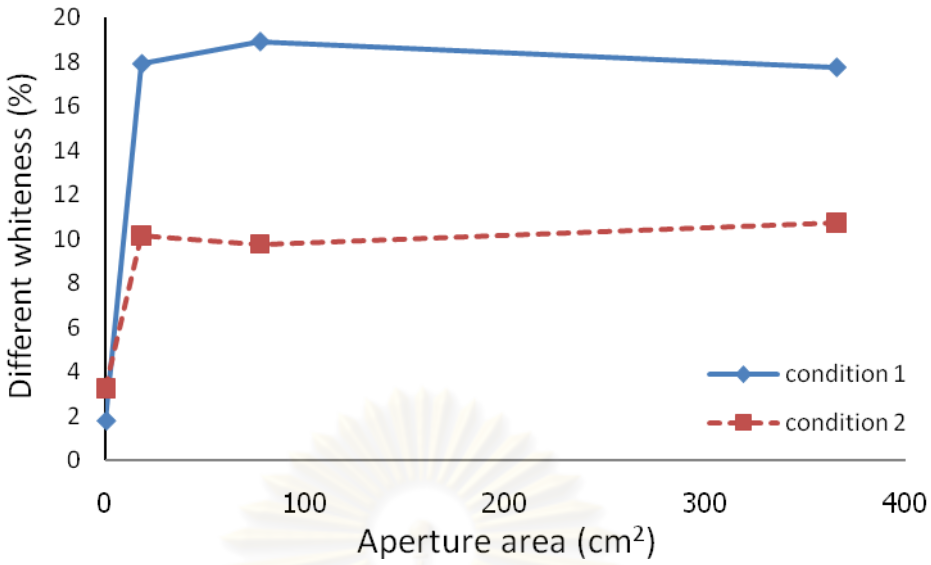

Fig.4-14 Difference of A and B whiteness in condition 1 and 2

4.3 The relation of apparent lightness of test patches and the area of apertures in the 3D pictures

In picture Set 1; the test room was brighter than the subject room, the results of apparent lightness of test patches of Patterns A and B from five subjects are shown in Fig.4-15 (a-e). They were similar in shape. At the point 0 cm^2; the aperture area of W1, the whiteness curves of A and B were at the same point or closed to each other. The two curves started to separate at the area of aperture 17.75 cm^2. Then it became stable from point 17.75 cm^2 to 365.25 cm^2. And the whiteness of B was lower than A.

The difference of the apparent lightness between Patterns A and B at various sizes of aperture is shown in Fig.4-16. It was clearly seen that the different lightness occurred when the test patch was seen through W2 to W4.

This result can be explained with the same concept as the result of Condition 1 in the experiment Part 1, even if it observes with the picture. At W1, the subjects saw the Patterns A and B appeared in the subject room because the aperture area was completely fitted with the stimulus pattern. They could not see any part of the test room. Thus the perceived lightness of both test patches was judged based on RVSI in the subject room. Therefore the whiteness of both test patches was the same. Whenever the subject saw the stimulus patterns and some part of the test room with W2 and W4 that had space around the test patch the whiteness of test patch of Patterns A and B was different. Because test patches of Patterns A and B, that design for perceive in different

space, appear in the subject room and the test room respectively. In this condition, the subject room was darker than the test room, so the size of subject room RVSI was smaller than test room as shown in Fig 4-6. And the luminance of both patches was the same, so they represent at the same point. When the subject judge the lightness base on the subject room illumination, a small one, the point was nearer the edge of the RVSI than when judge base on another one. It was the cause of apparent lightness of test patch of Pattern A are brighter than the test patch of Pattern B.

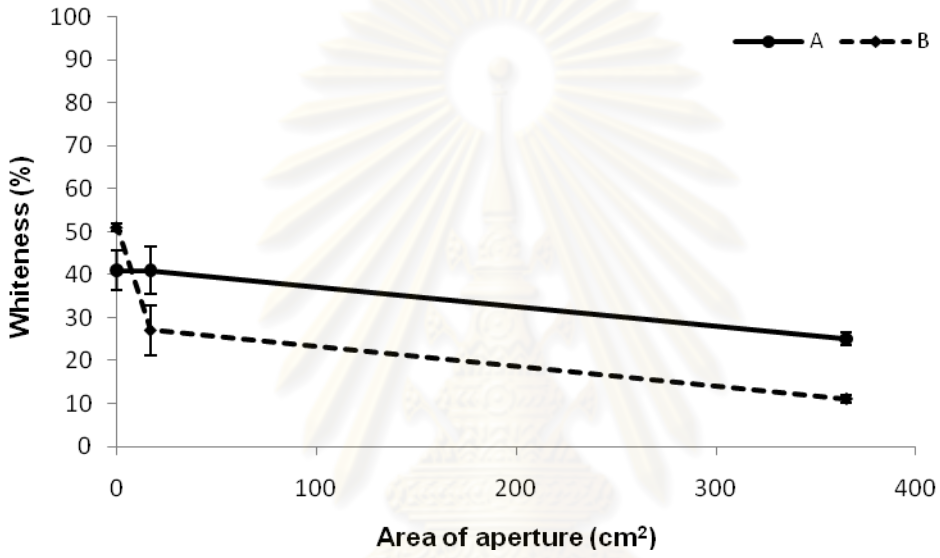

Fig.4-15a The result of apparent lightness at various size of aperture in the picture set 1 of subject PP.

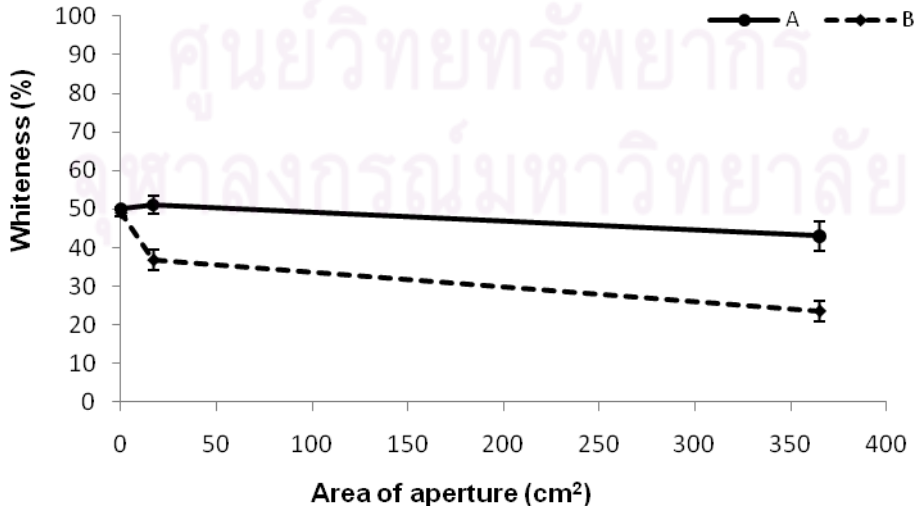

Fig.4-15b The result of apparent lightness at various size of aperture in the picture set 1 of subject JP.

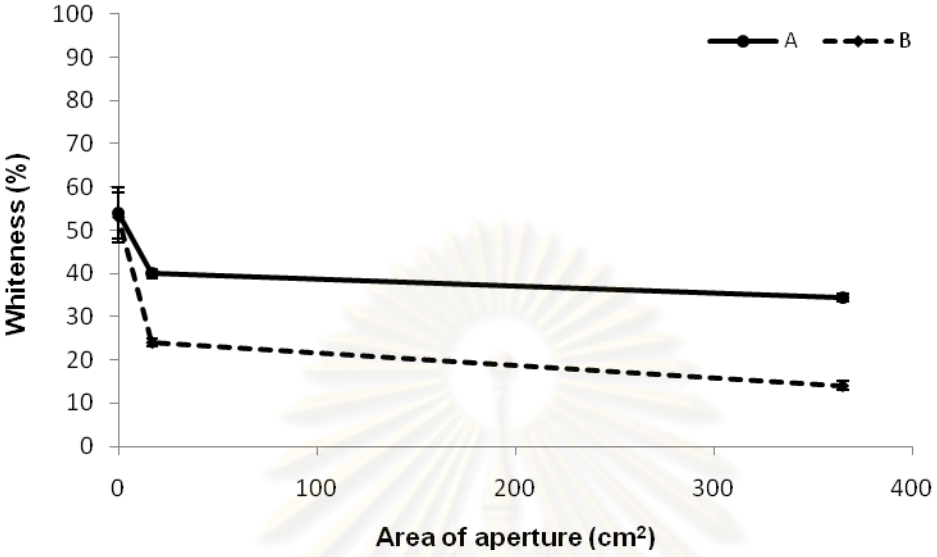

Fig.4-15c The result of apparent lightness at various size of aperture in the picture set 1 of subject PR.

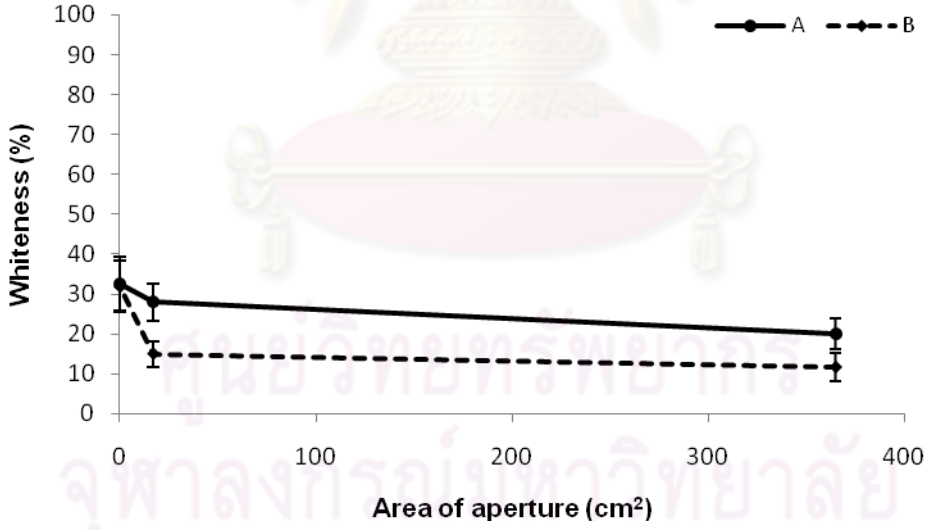

Fig.4-15d The result of apparent lightness at various size of aperture in the picture set 1 of subject SS.

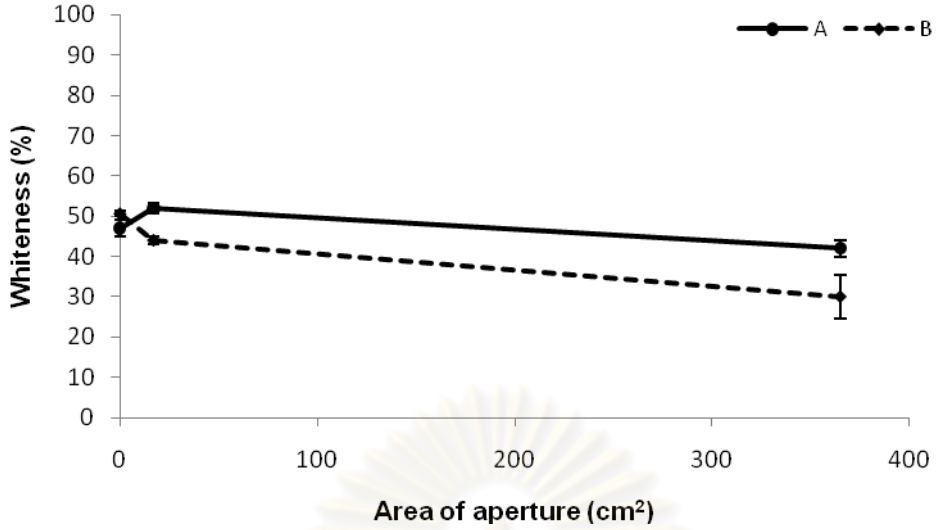

Fig.4-15e The result of apparent lightness at various size of aperture in the picture set 1 of subject CJ.

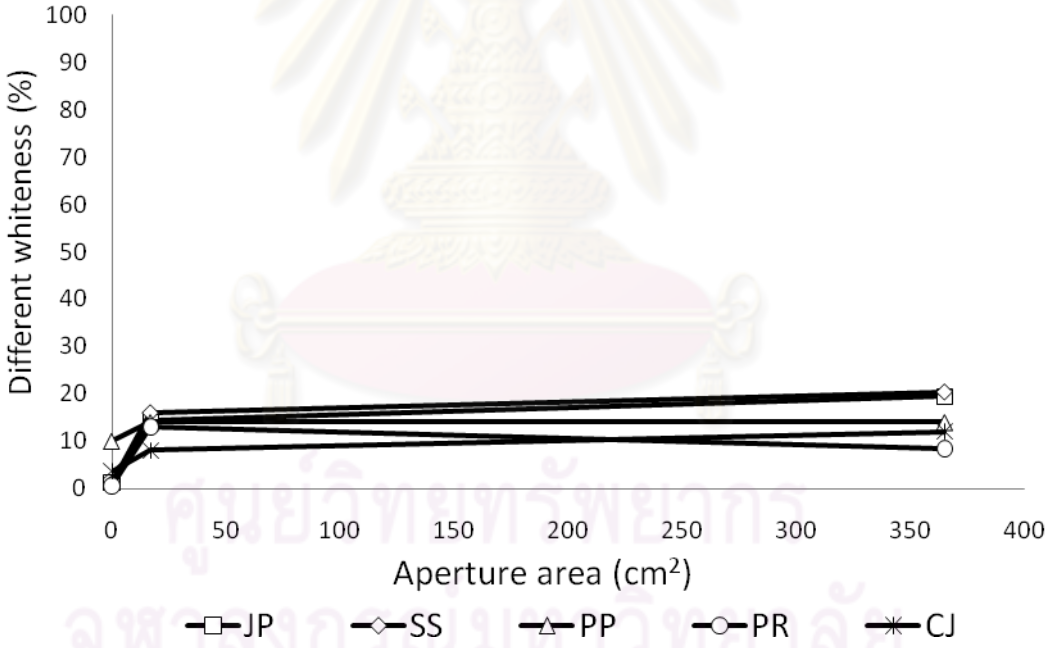

Fig.4-16 Difference of apparent lightness between test patch pattern A and B at various size of aperture in the picture set 1.

In picture Set 2; the subject room was brighter than test room, the result of five subjects are shown in Fig.4-17 (a-e). The shape of all curves was the same. The two curves of the A and B whiteness started at the same point. Then it started to separate at the area of aperture increased to 17.75 cm^2. Though some curves dropped and some raised but in both case whiteness of B was higher than that of A. And the different was very small. After that it became stable from point 17.75 cm^2 to 365.25 cm^2.

The difference of the apparent lightness between Patterns A and B at various sizes of aperture was shown in Fig.4-18. It was clearly seen that the different lightness occur when the test patch was seen through W2 to W4.

This result can be explained with the same concept as the result of Condition 2 in the experiment Part 1, even if it observes with the picture. In this case, the size of subject room RVSI was bigger than test room as shown in Fig 4-10. When the subject judge the lightness base on the subject room illumination, a big one, the point, the luminance of test patches, was farer the edge of the RVSI than when judge base on another one. Thus it was the cause of apparent lightness of test patch of Pattern A are darker than the test patch of Pattern B.

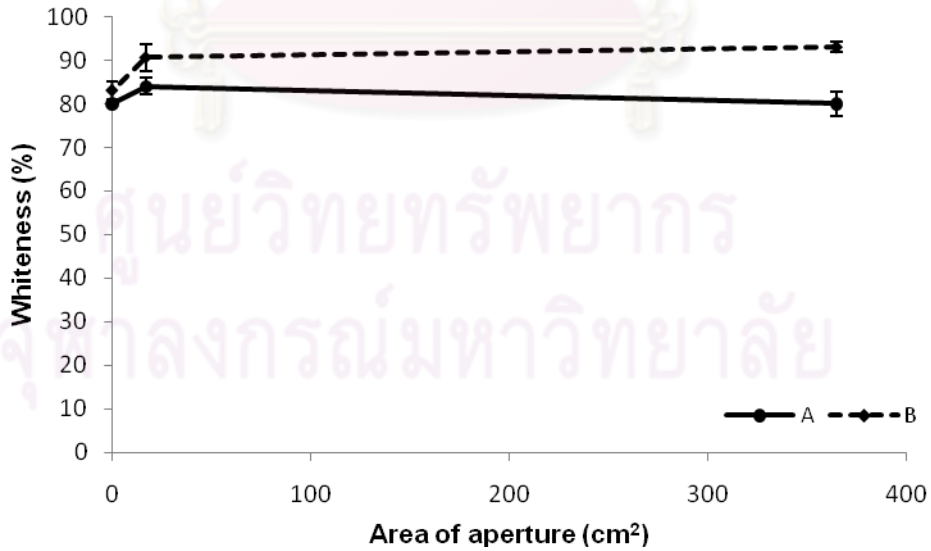

Fig.4-17a The result of apparent lightness at various size of aperture in the picture set 2 of subject PP.

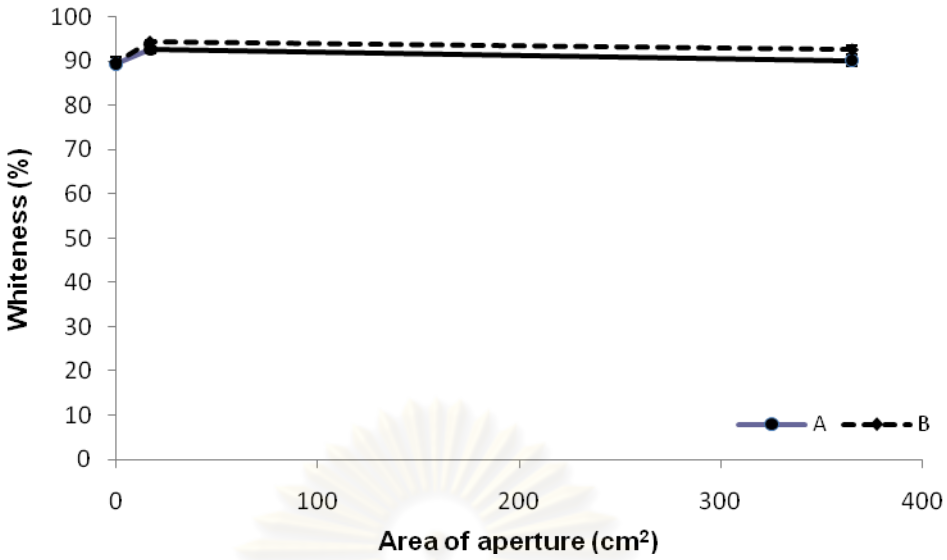

Fig.4-17b The result of apparent lightness at various size of aperture in the picture set 2 of subject JP.

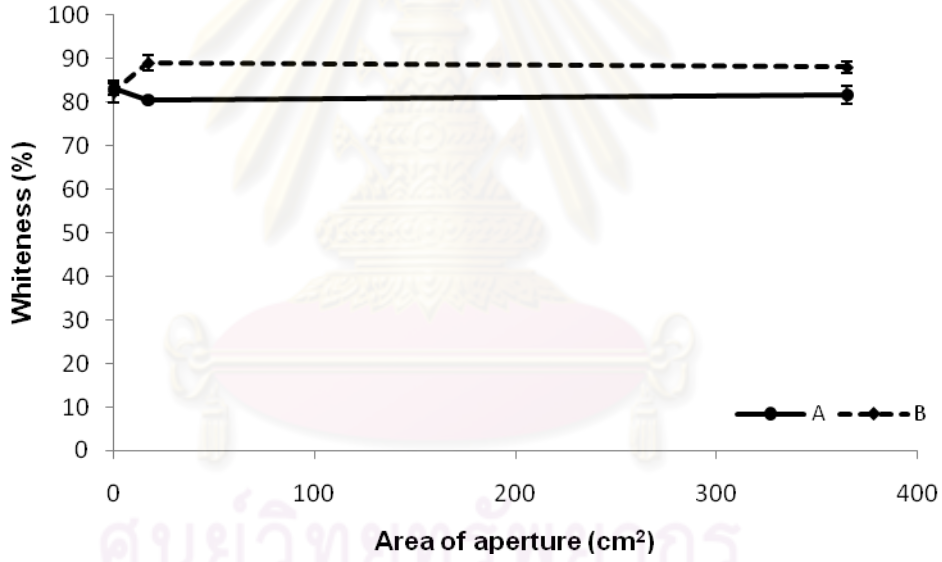

Fig.4-17c The result of apparent lightness at various size of aperture in the picture set 2 of subject PR.

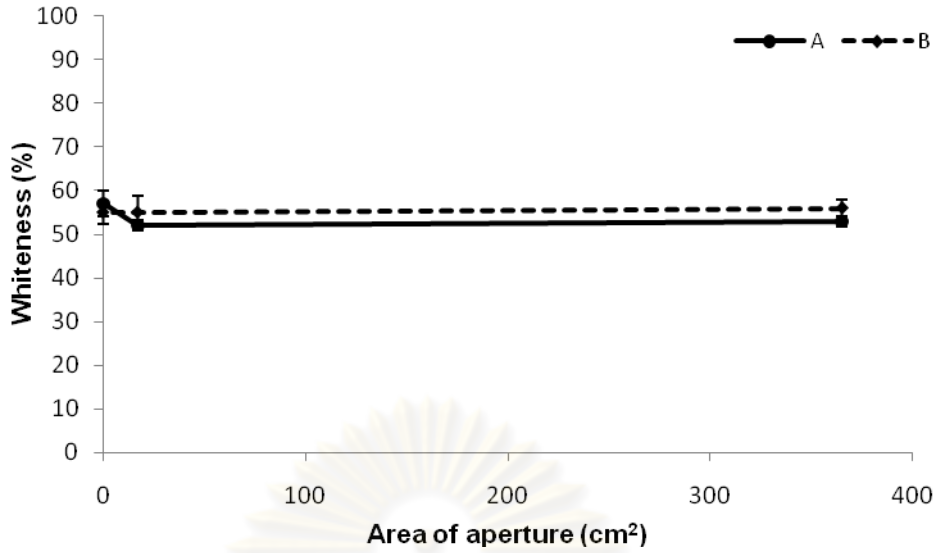

Fig.4-17d The result of apparent lightness at various size of aperture in the picture set 2 of subject SS.

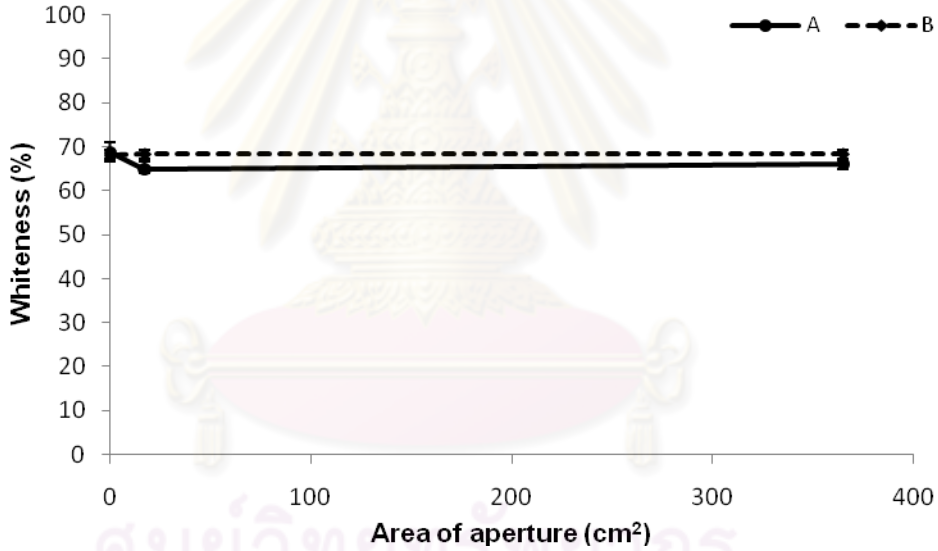

Fig.4-17e The result of apparent lightness at various size of aperture in the picture set 2 of subject CJ.

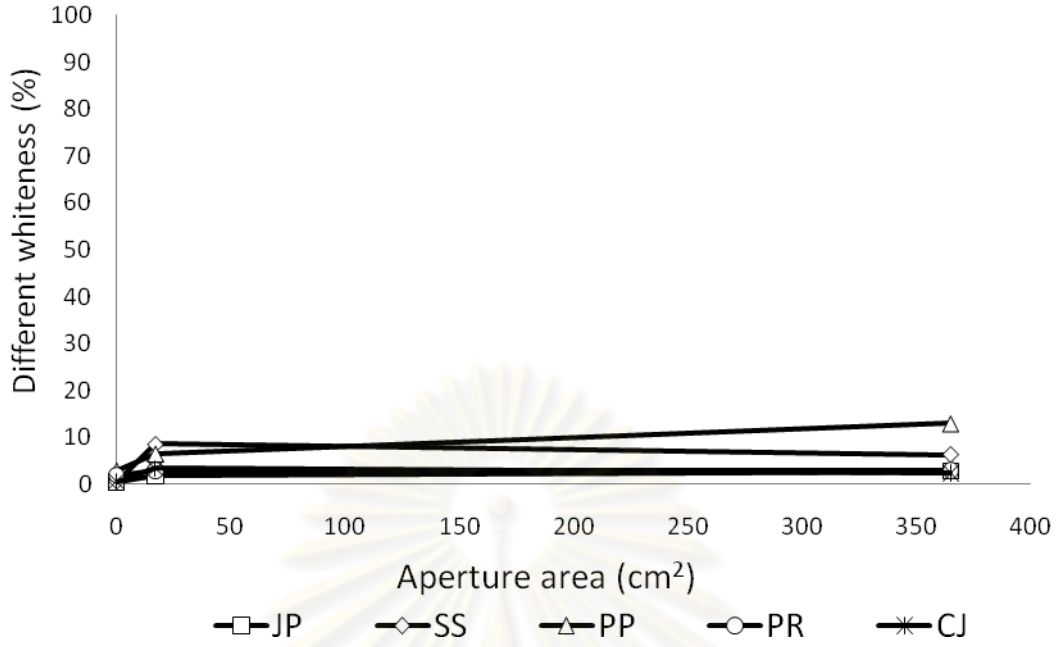

Fig.4-18 Difference of apparent lightness between test patch pattern A and B at various size of aperture in the picture set 2.

In picture Set 3, illumination of the subject room and the test room was the same, the results of five subjects were almost the same as shown in Fig.4-19 (a-e). The perceived lightness of both test patches was no difference when the subjects saw the test with the various size of aperture

The difference of the apparent lightness between Patterns A and B at various sizes of aperture is shown in Fig.4-20. That showed the lines were almost parallel along X-axis and they were near to 0.

This result can be explained with the same concept as the result of Condition 3 in experiment Part 1, even if it observes with the picture. In this case, the size of RVSI of the subject room and the test room was the same. Thus apparent lightness of the test patches were the same no matter what Pattern A, that was judge base on illumination of the subject room, or B, that was judge base on illumination of the subject room.

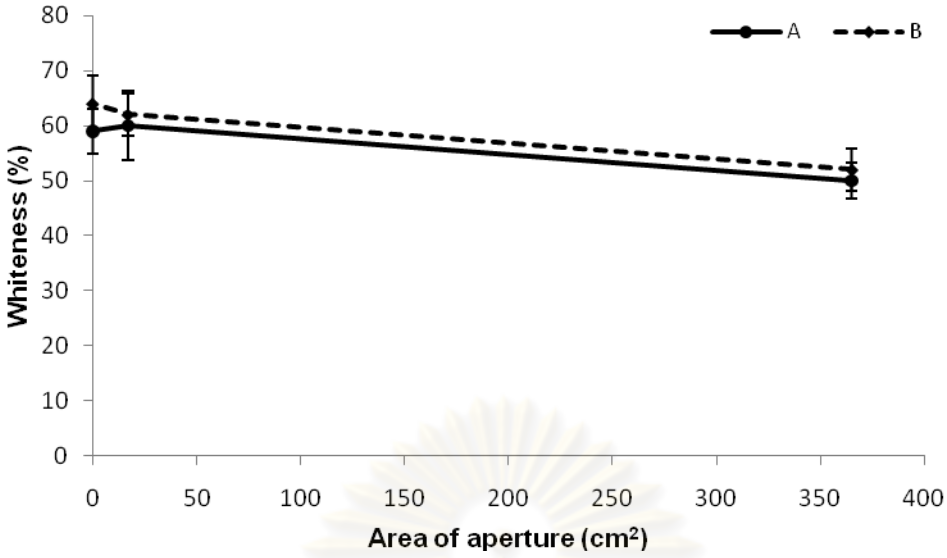

Fig.4-19a The result of apparent lightness at various size of aperture in the picture set 3 of subject PP.

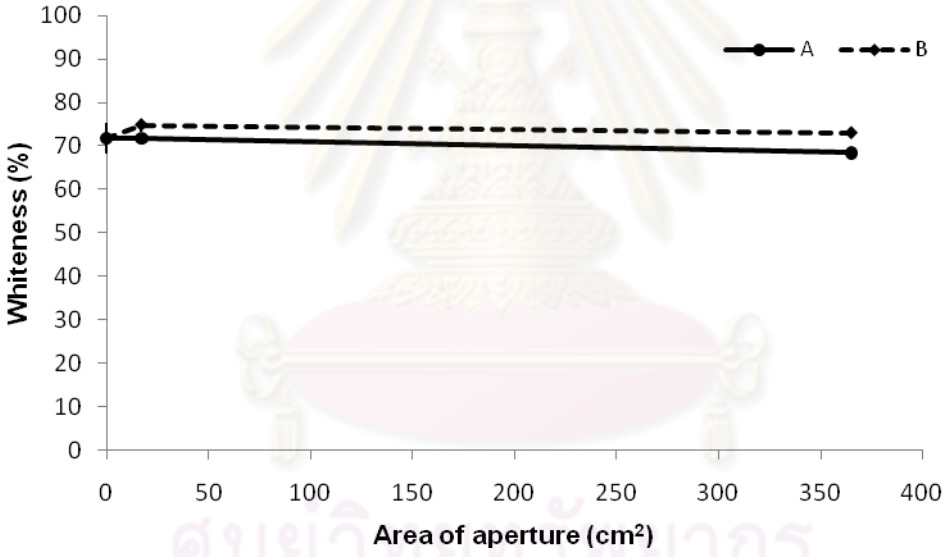

Fig.4-19b The result of apparent lightness at various size of aperture in the picture set 3 of subject JP.

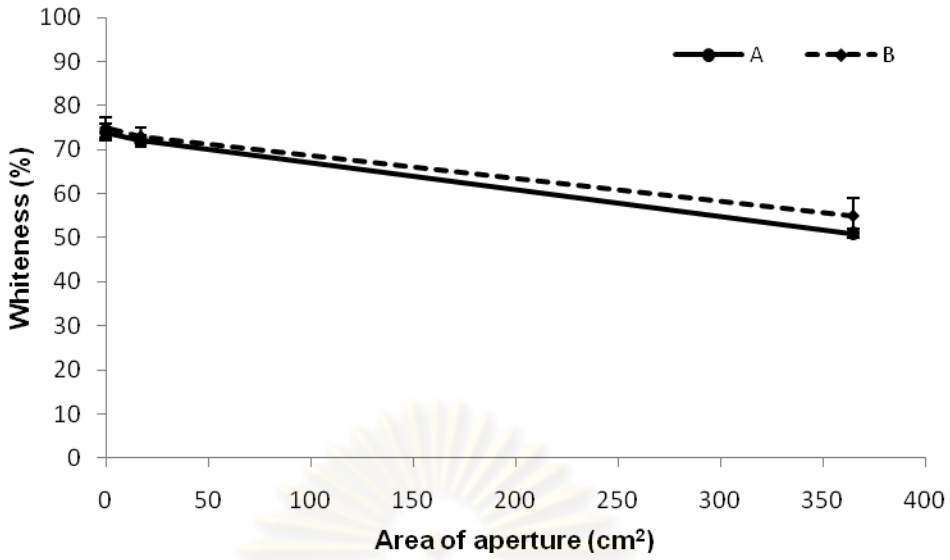

Fig.4-19c The result of apparent lightness at various size of aperture in the picture set 3 of subject PR.

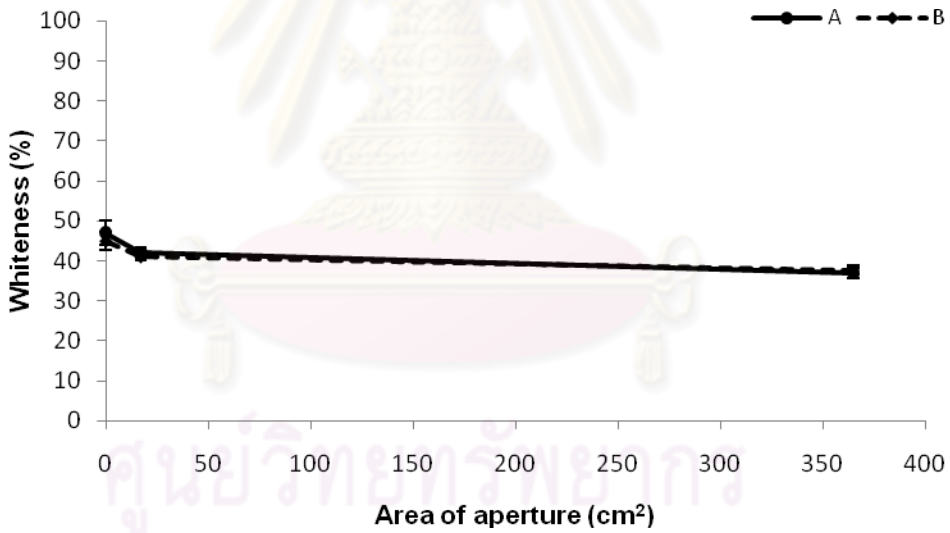

Fig.4-19d The result of apparent lightness at various size of aperture in the picture set 3 of subject SS.

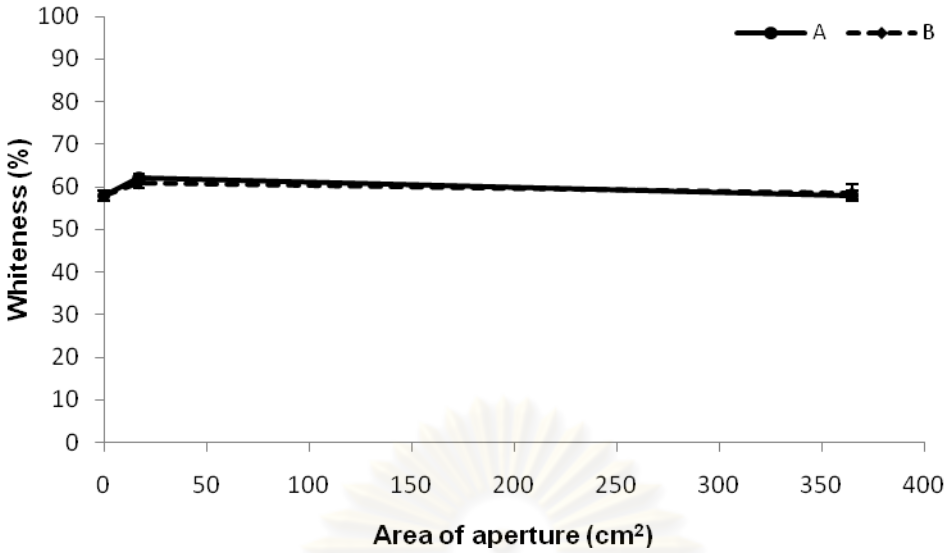

Fig.4-19e The result of apparent lightness at various size of aperture in the picture set 3 of subject CJ.

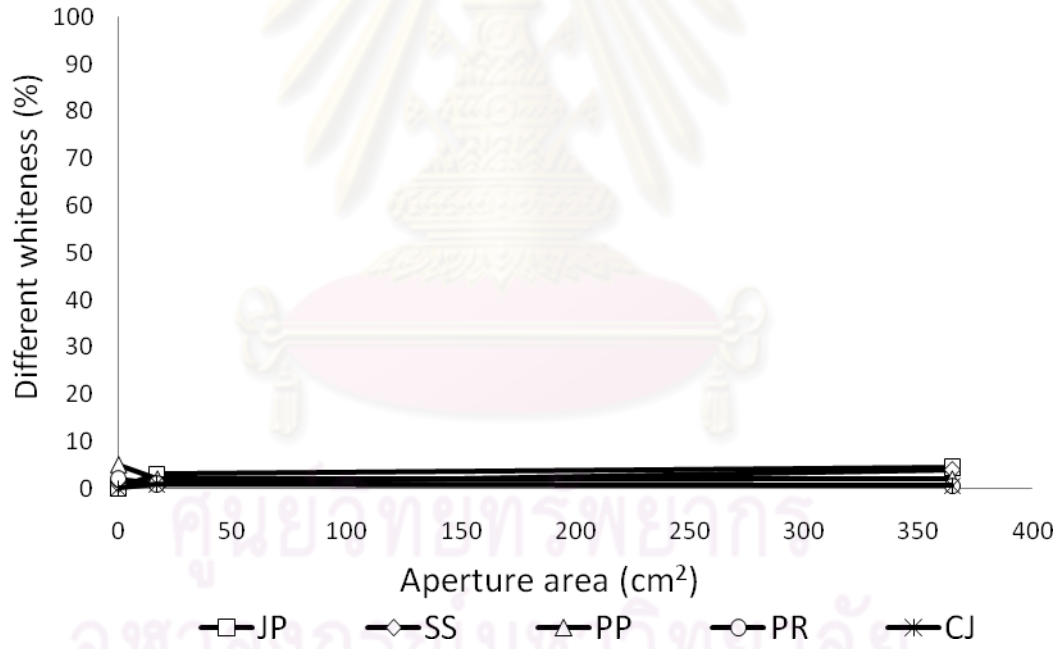

Fig.4-20 Difference of apparent lightness between test patch pattern A and B at various size of aperture in the picture set 3.

CHAPTER 5
CONCLUSIONS

In this research, the main experiment can be deviled into two parts. First is to find the relation of apparent lightness to the size of aperture in the real space by using two separated room that had different illumination and the two stimulus patterns that were designed for perceiving in the different space; Pattern A appeared in the subject room, Pattern B appeared in the test room. The aperture area of the windows which is at divided wall was controlled by 4 masks; W1, W2, W3 and W4. When the subject observed with W1, he/ she could not see the test room around the stimulus pattern but with W2, W3 and W4, they were bigger aperture area. So the subject could see the test room around the stimulus pattern. Three conditions were used in this experiment; i.e. Condition 1, the illumination of the subject room was darker than the test room, Condition 2, the illumination of the subject room was brighter than the test room, Condition 3, the illumination of the subject room and the test room was the same. Second part is to find the relation of apparent lightness to the size of aperture in the 3D picture. The eighteen pictures, that were used, were the experimental room pictures that attach two stimulus patterns; Patterns A and B, with three masks; W1, W2 and W4. And the pictures had three set; Set 1, the illumination of the subject room was darker than the test room, Set 2, the illumination of the subject room was brighter than the test room, Set 3, the illumination of the subject room and the test room was the same. The subject observed the pictures with a viewing box which was the apparatus that limit the subject's field of view so that only picture could be seen in order to make subject perceive 3D picture.

The result show that when the aperture is small as W1 the subject can see only the stimulus pattern on the window and the test patches of both patterns are seen as the object places in the subject room. The lightness of both pattern are determined in relation to size of the subject room RVSI. So their apparent lightness is not different. When the subject looks at the stimulus pattern though W2 he/she can see some part of the test room around the stimulus pattern. Then the apparent lightness of test patch of Patterns A and B are different when the illumination of the subject room and the test

room is different. The results of W3 and W4 are about the same. This shows that the subject could recognize the illumination of the test room, the new RVSI for test room is constructed and the apparent lightness of the Pattern B test patch, which is designed for appearing in test room, is judged based on the new RVSI. We see that the difference of apparent lightness of A and B increases when the subject see with W2 and becomes stable when the subject see with W3 and W4 no matter what Condition 1 or 2. In case of the 3D picture when the subject sees with the viewing box to perceive 3D, the results are the same as those of the real room. It can be explained with the same concept as the real room. But the amount of the effect in the picture is less.

In conclusion, the subject perceives lightness according to RVSI of the space where object appeared. Although the area surround test patch is very small as W2, the RVSI of the test room can be perceived. **And the size of aperture has no effect on perceived lightness. Only a small gap that allows the observers to see another space, it is enough information to perceive lightness of that space.** This is true not only in the real scene but also in the 2D picture that can perceive as 3D.

5.1 Suggestion

This experiment, only five subjects were employed the result show the tendency of the fact. The precision of the data might not enough to apply to real situation. More subjects are required and statistic should be considered to obtain more precision values.

To stimulate this experiment in the monitor, more situations and more factors could be employed easily. In this case the high resolution is required. In fact in the beginning of this experiment the monitor had been used but the limitation of the resolution real scene could not be perceived.

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