Abstract of thesis entitled

'QUANTITATIVE EVALUATION OF COLOUR EMOTIONS'

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ABSTRACT

During the colour perception process, an associated feeling or emotion is induced in our brains, and this kind of emotion is termed 'colour emotion'. The aims of this study were to investigate the colour emotions of human beings, evaluate the influence of the physical specifications of colour on colour emotions and quantify the colour emotions with the standard colour specifications, CIE L^*, C^* and h^0. Twelve opponent-word pairs were used to express certain emotions semantically. Due to the psychological nature, subjects of different cultural and traditional backgrounds are considered as influential factors of colour emotions, and, therefore, only the Hong Kong Chinese were invited to be the subjects in the visual assessments and mathematical models were derived for quantifying their colour emotions. With the establishment of these models, the designers can select colours for their products according to the evoked emotions and the communication between the designers or colour users and the colourists can be much improved by using numerical values. From the analysis, it was found that the influence of hue of colour on the colour emotion pairs used in this study was not so significant in general, with a comparatively large effect found only for the 'warm-cool' colour emotion, whereas the influence of chroma was found to be the

dominant parameter affecting 'warm-cool', 'vivid-sombre', 'gaudy-plain', 'striking-subdued', and 'dynamic-passive' colour emotions. Lightness of colour was found to be the dominant parameter affecting 'deep-pale', 'heavy-light', 'soft-hard', and 'strong-weak' colour emotions, whereas 'light-dark', 'transparent-turbid', and 'distinct-vague' colour emotions were found to be influenced by both lightness and chroma of colour.

Colour emotion is influenced by many factors, and typical examples of these factors are the gender, educational, national, cultural and traditional differences of the viewers. In this study, the influences of gender and cultural effects on colour emotions were analysed. In general, good correlations of colour emotions in male and female Hong Kong Chinese subjects were found. The best correlation was found in the 'deep-pale' colour emotion that very similar observations were obtained in the their perception. In the cross-cultural comparison of colour emotion, the visual assessment results of the Japanese, Thai and United Kingdom subjects obtained in their own regions correspondingly were compared with those of the Hong Kong Chinese subjects. The closest perception was found to be in the 'transparent-turbid' colour emotion. Better correlations were found in the colour emotions of the Asians, whereas weaker correlation of colour emotion was found with the British.

The effect of assessment method on colour emotions was studied in this work. The 2-point method, which was used for the derivation of mathematical models and comparison of the effects of the influential factors, was done by the selection of either one opponent word in each pair, without any neutral point. For example, +1 point was assigned to the 'warm' selection while −1 point was assigned to the 'cool' selection, and the subject should select either one without 0 point. Since the 7-point method allows the subjects to give a neutral assessment, i.e., 0 point, and there are more subdivided grades for the subjects to select, this assessment method was also carried out in this study for the comparison of the results obtained from the 2-point method. Similar influences of the colorimetric attributes on the colour emotions were observed in the 7-point method as in the case of the 2-point method. It is recommended to carry out 7-point assessment method for further analysis because more selections were provided in this method so that better indication of colour emotions of subjects could be obtained.

In this study, colour planners were derived for representing the quantitative correlation of colour emotions and standard colour specifications. The extent of change in each colour emotion pair caused by changing the lightness or chroma of a colour was clearly presented in the colour planners. Fashion, graphic, interior, web site or other designers can select suitable colours for inducing target colour emotions in the customers' or product-users' minds by means of these colour planners. In addition, a visualization of colours in the colour planner was achieved by establishing a computerized colour emotion display system which provides a means for the designers or colour users to select colours from the monitor. The designers or colour users can select the target colours from the displayed colour gamut, and the system will automatically show the standard colour specifications and colour emotions of the selected colours. This is the most convenient way to show the correlation of colour emotions and standard colour specifications.

Since one of the objectives of this study was to derive tools for designers to select suitable colours for their products, it was considered worthwhile to investigate the similarities and differences of colour emotions between designers and general public. Hence, designers were also invited to carry out the visual assessments. Their results showed that they had generally similar colour emotions to the ordinary subjects and some colours of large differences in colour emotions between them were pointed out in this study.

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1. Cheng, K. M., Xin, J. H. and Chong, T. F. (1999). *Method for Quantifying Colour Emotions.* 2nd International Textile and Apparel Conference CITC '99, Brazil, 21-23 July, 1999.

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6. Cheng, K. M., Xin, J. H. and Taylor, G. (2001). *Comparison of Colour Emotions between Designers and General Customers.* The 6th Asian Textile Conference, Hong Kong, 22-24 August, 2001.

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8. Cheng, K. M., Xin, J. H. and Talyor, G. *A Study on Quantifying Colour Emotions* has been submitted to Journal of Experimental Psychology-General.

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10. Cheng, K. M., Xin, J. H. and Taylor, G. *Colour Display System for Colour Selection* to be submitted to Colour Research and Applications.

11. Cheng, K. M., Xin, J. H. and Taylor, G. *A Study on the Colour Emotions of Male and Female* to be submitted to Perception.

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INTRODUCTION

Colour is essential to our daily lives. It is defined as "sensation produced in the eye by rays of decomposed light" and "effect produced by a ray of light of a particular wavelength, or by a mixture of these" from the dictionary (Hornby, 1989 and Sinclair, 1995). In the domain of physics, colour means a certain kind of light stimulus which has an effect on the human eyes. In the domain of psychology, colour has a deep impact on the mind of the viewer. In other words, human eyes sense a colour as a stimulus in the form of light, and human brains further process the colour with the result that feelings and emotions are evoked (Billmeyer and Saltzman, 1981). The process of perceiving colour comprises of three components: a source of light, an object to be illuminated, and the eye and brain to perceive the colour. An associated feeling or emotion towards the perceived colour is induced in our brains simultaneously. This feeling or emotion is termed 'colour emotion'. This new term was used recently by researchers in this field (Nakamura et al., 1992, Xin et al., 1998 and Sato et al., 2000).

Humphrey (1976) suggested that colour directly affects the parts of the nervous system which induce emotional arousal. Many researchers in the field of colour emotion have indicated that every colour has its own meaning, and different colours or colour combinations convey different meanings to people (Kobayashi, 1981). Sharpe (1980) and Hsiao (1995) pointed out that when a person is viewing a colour, his/her mental perception includes memories, e.g. soft-hard, warm-cool, gaudy and plain etc., and these are incorporated in the emotional response. Since many psychologists have suggested that different colours will induce different feelings in human beings, systematic study is necessary to investigate the meanings of colours, i.e., the colour emotion of human beings.

In this research, it was considered worthwhile to analyse the use of colour for product and interior design in order to convey suitable meanings and induce target impressions in the customers' or subjects' minds by appropriate selection of colour. Conventionally, the selection of the colours for the products to be designed is based on the judgement of the designers. Their selection may be according to their own preference but may not match the tastes of the target customer group. Hence, a colour planner illustrating the relationship between colours and the associated induced emotions of the general subjects would be useful for their colour selection process.

Colour plays an important role in industrial production as it influences the aesthetic appearance and functionality of the end products. The colourists use quantitative systems to identify colours, such as CIE (International Committee on Illumination) LAB system, Munsell colour order system, etc.. Colours in these systems are all specified in terms of numerical values so that they will be precisely communicated between the colorists. However, since the designers and other users of colour may not be familiar with these quantitative colour systems, it is difficult to ask them to select colours by means of numerical values or communicate using colour numbers. The traditional communication of designers and colour users with colourists is by means of verbal description, and it is both abstract and confusing. This subjective communication method results in unnecessary misunderstandings. As a result of the above, a quantitative system relating colour emotion and standard colour specification was considered to be necessary while a visualization of colours showing the relationship between colour and colour emotion, coupled with a standard colour specification, would be helpful for the designers or other users of colour to select suitable colours and communicate with the colourists.

Colour emotion is influenced by many factors due to its psychological nature. Typical examples of these factors are the gender, educational, geographical, national, cultural and traditional differences of the viewers (Hsiao, 1995 and Crozier, 1996). Therefore, it was considered worthwhile to evaluate the extent of influence of such factors on the colour emotions of human beings. This study involved quantitative research on the associated feelings or emotions on colour perception, therefore only the similarities or differences in the colour perception of subjects with different backgrounds are provided, but the reasons underlying these findings or causes of such phenomena are excluded in this research.

1.1 Objectives

The aims of this study were to investigate the colour emotions of human beings and evaluate their relationships with the physical specification of colour. To achieve the aims, the objectives of this research were listed as follows:

- to conduct experiments to scale various colour emotions;
- to derive mathematical models for quantifying the colour emotions with the colour specifications;
- to categorize the colour emotions into different groups according to the dominant parameter(s);

- to compare the colour emotion results obtained from male and female subjects;
- to compare the colour emotion results obtained from different regions, including Japan, Thailand, United Kingdom and Hong Kong;
- to evaluate the influence of experimental effect on colour emotions --- the differences in the results obtained from a 2-point method and those from a 7-point method;
- to derive colour planners of colour emotions which represent the quantitative correlation of colour emotions and standard colour specifications;
- to introduce a colour emotion display system so that the designers can select colours for their products according to the colour emotions of the general public using this computer program; and
- to anaylse the colour emotions of designers so that the similarities or differences in colour emotions between them and the general subjects are obtained.

1.2 Scope of this Research

As colour emotion is influenced by the cultural and geographical background as well as age of subjects, the visual assessment of this research was carried out by Hong Kong Chinese subjects aged around 20. In Chapter 5 of this dissertation, which is a study of 'Cross-cultural and Cross-geographical Comparisons of Colour Emotions', the visual assessment results of the Japanese, Thai and British subjects were provided by the Kyoto Institute of Technology in Japan, Chulalongkorn University in Thailand and Leeds University in the United Kingdom respectively.

In the visual assessments of this research, twelve word pairs were used to express some of the colour emotions. They were 'warm-cool', 'light-dark', 'deep-pale', 'heavy-light', 'vivid-sombre', 'gaudy-plain', 'striking-subdued', 'dynamic-passive', 'distinct-vague', 'transparent-turbid', 'soft-hard' and 'strong-weak'. The Japanese research group has done an experiment in the selection of the descriptive words for colour emotion (Nakamura et al., 1994). Over a hundred of descriptive words were collected by them, and those frequently selected by the subjects for expressing the human feelings or emotions for colours were listed out. The twelve word pairs in this study were those frequently selected descriptive words which could form an 'opponent' word pair. They were selected because they represent the basic impression of colours to human beings and they involve lower level of emotion in the human brains, that means they avoid reference to individual colour preferences; hence the obtained results were considered to be independent to the taste of the individual subject.

The mathematical models and colour planners for correlating the colour emotions and colorimetric attributes quantitatively were expressed in terms of CIE L^*, C^* and h^0 system. This system was selected because it is a popular colour system used by the colorists and researchers.

1.3 Significance of this Research

The quantitative relationship between colours and the emotions induced by colour perception was considered to be quite valuable due to the following facts:

1. Selecting colours to give a desired colour impression for design purposes can be more objective using the colour planners, than by subjective method. The colour emotions obtained by extensive studies are more reliable to use in the colour design process because of their psychological nature.

2. The use of numerical values to give required colour emotion can speed up the design process for colour and can facilitate accurate communication between different parties such as designers and colourists.

3. The mapping of the colour emotion which is a psychological term to a physical term of standard colorimetric system such as CIE system will benefit further researches in understanding human colour perception.

4. The comparisons of colour emotions obtained from subjects of different genders and regions can provide some information and understandings of the similarities and differences in their perceptions, which can be used for further analyses of colour psychology.

1.4 Content of this Dissertation

Chapter 2 is the literature review on the physical and psychological aspects of colours. It gives an introduction to the nature of colour, perception of colour and the evolution of colour specifications. Moreover, for the psychological aspect of colour, the meanings of colour to human beings and the influence of cultural and gender effects on colour emotions are revised. In addition, the quantitative evaluation of colour psychology, which has been done by other colour researchers, are discussed in this chapter.

Chapter 3 presents the investigation on the colour emotions of the Hong Kong Chinese subjects and the quantitative relationships of colour emotions and standard colorimetric attributes. Mathematical models illustrating these quantitative relationships have been derived and the twelve colour emotions pairs have been categorized according to the dominant parameter(s) influencing them.

In Chapter 4, the influence of gender effect on colour emotions has been studied and the colour emotions of male and female subjects are compared. No significant difference is found between the selections of the male and female subjects in most of the colour emotion pairs.

Chapter 5 illustrates the cross-cultural and cross-geographical comparisons of colour emotions of the Japanese, Thai, British and Hong Kong Chinese subjects. They are compared through the correlation coefficients between them as preliminary analyses, graphical presentations of raw results of colour emotions obtained from them, mathematical models derived for each of them and cross-cultural colour planners. The colour emotions of the Asians are found to be close to each other, while larger deviations are found in the comparisons with the British.

Chapter 6 indicates the experimental effects by using the 7-point method instead of the 2-point method in the questionnaire of the visual assessment. When comparing the results obtained from these two methods, the dominant parameter influencing the selection of colour emotion is found to be the same in these methods.

In Chapter 7, the applications of colour emotions are discussed. Colour planners of colour emotions for representing the quantitative correlation of colour emotions and standard colour specifications are introduced. In addition, a colour emotion display system through the computer monitor is derived so that the designers can select colours for their products according to the colour emotions of the general public using this computer program.

Chapter 8 provides an elementary analysis of colour emotion of designers, and the similarities and differences of colour emotions between designers and the general public are discussed.

Finally, Chapter 9 provides an overall conclusion and the major findings obtained in this research. The remaining problems and the recommendations of further research work are discussed.

LITERATURE REVIEW

2.1 Colour

2.1.1 What Is Colour?

Colour is an essential component in our daily lives. It can enrich our visual perception (Quiller, 1989 and Bomford and Roy, 2000). Scientifically, colour may mean a certain kind of light stimulus which has an effect on the human eyes, or alternatively the result of such an effect has an impact in the mind of the viewer (Lynch, 1995). There are three elements involved in the colour perception process: a source of light, an object to be illuminated, and the eye and brain to perceive the colour. In other words, recognizing a colour involves both physical actions, i.e. a stimulus in the form of light, and psychological results, i.e. this stimulus received by the eye and interpreted by the brain, which introduces feeling and emotion (Boynton, 1992, Burnham, 1963, Davis, 2000 and Hardin and Maffi, 1997).

2.1.2 How Can We Perceive Colour?

Mahnke (1996) claims that perceiving colour, thereby experiencing colour, is both an objective and a subjective process, and colour, which is created by light, is a form of energy influencing mind and emotion. Colour affects cortical activation (brain waves), function of the autonomic nervous system (which regulates the body's internal environment), as well as hormonal activity; and that colour arouses definite emotional and aesthetic associations. He suggests that colour perception always carries visual, associative, synaesthetic, symbolic, emotional, and physiological effects with it, and to perceive colour means to 'experience'---that is to become conscious or aware. In 1990, Mahnke introduced a 'colour experience' pyramid which assumes six basic interrelated factors influencing this experience. The 'colour experience' pyramid is illustrated in Figure 2.1. The base of the pyramid is the biological reactions of the human beings to the colour stimulus; then the second level is the associations that is not controlled or caused by the intellect or conscious rational thought; the third level represents the conscious symbolism or associative power of colour, that means the associations, impressions, and symbolism made on a conscious level or it may be 'learnt' responses; the forth level comes to the colour associations, symbolism, impressions, and mannerisms that are characteristic of specific cultures and groups, they play a role in how colour is experienced and used; the fifth level points out the trends, fashions and styles having influence on the colour experience; and the sixth level is our personal relationship to colour which expresses our like, indifference, or dislike of certain hues, in other words, it reveals the own colour preference of each individual. In conclusion, the sum of these elements: light and object with colour(s), contribute to an overall impression to the viewer, and this impression generates a reaction that carries some types of emotional content (Mahnke, 1996).

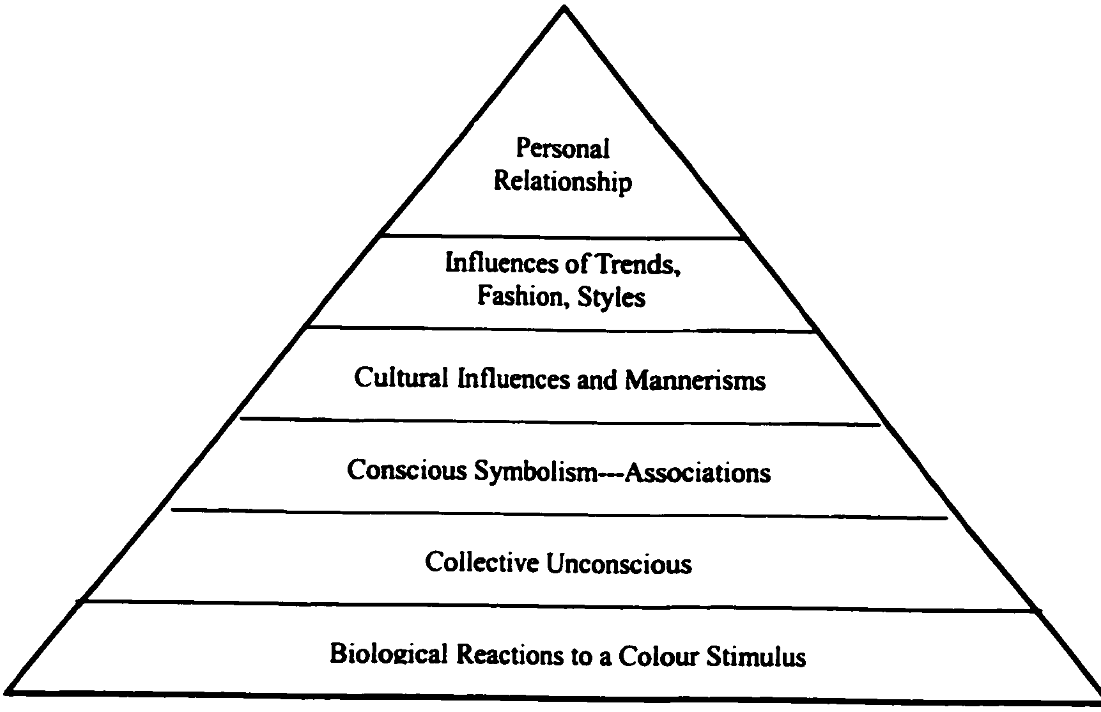

Figure 2.1 The 'Colour Experience' Pyramid by Frank H. Mahnke

2.2 Colour Theory

2.2.1 Colour Dimensions

There are three variables commonly used to describe a colour subjectively. They are hue, lightness and chroma. Hue is the attribute concerning whether an object is red, orange, yellow, green, blue or violet. Lightness is the attribute of visual sensation corresponding to the luminous intensity of the object. For reflecting objects, lightness ranges from black to white. Saturation is the attribute of visual sensation regarding the proportion of pure chromatic colour; in other words, it is used to signify the relative white content of a stimulus perceived as having a particular hue. This means if a colour has a lower saturation, it appears nearer to a neutral colour; while a colour of higher saturation is represented as a higher chromatic colour (Chong, 1988, Bridgeman, 1987, Kuehni, 1993, Trucco, 1998 and Sloane, 1989).

2.2.2 Colour Order System

As claimed by Hård and Sivik (1981), a common colour language for describing the colour perceptions, which the visual environment actually consists of, is essential for colour communication. The language should offer a means of describing colours using readily comprehensible terms. Hence, some systematic arrangements and descriptions of colour have been developed for facilitating and unifying the communications between the colourists and/or colour users (Zelanski and Fisher, 1999). Some popular colour order systems are discussed below.

2.2.2.1 Munsell Colour System

Munsell colour system was introduced by Albert H. Munsell with the thought that colour should be supplied with an appropriate system, which is based on the hue, value, and chroma of our sensations, but should not be attempted to describe by the infinite and varying colours of natural objects (Nickerson, 1976). Perhaps Munsell colour system is the best known among all the colour order systems. The colours in this system are arranged based on the steps of equal visual perception, and they are described in terms of three coordinates, Munsell Hue, Munsell Value, and Munsell Chroma. Hue is the quality of colour described by the words red, yellow, green, blue, purple and so forth; value is the quality by which a colour can be classified as equivalent in lightness and it is correlated with the reflectance of a sample; chroma is the quality that describes the degree of difference between a colour (which is itself not a white, grey, or black) and a grey of the same value or lightness, and it has about the same meaning as saturation (Billmeyer and Saltzman, 1981, Kaiser and Boynton, 1996, Wyler, 1992 and Kuehni, 1997).

The colour samples in the Munsell colour system are positioned in a spherical space by the three Munsell coordinates: hue, value an chroma, and it is illustrated in Figure 2.2. Munsell divided the colour circle into ten segments according to the hue. Each colour sample carries a Munsell Notation denoting its position; this notation has three symbols representing the Munsell Hue, Value, and Chroma in such order. Munsell Hue is expressed by a number and letter combination such as 5R or 10PB in which the letters are taken from the ten major hue names (**R**ed, **Y**ellow, **G**reen, **B**lue and **P**urple, and the five intermediate hue names, e.g. **P**urple-**B**lue), and the numbers run from the divisions 1 to 10. Munsell Value and Munsell Chroma are written after the hue denotation and are separated by a diagonal line. An example of a typical complete Munsell designation is 5R3/8, where 5R is the Munsell Hue, 3 is the Munsell Value and 8 is the Munsell Chroma.

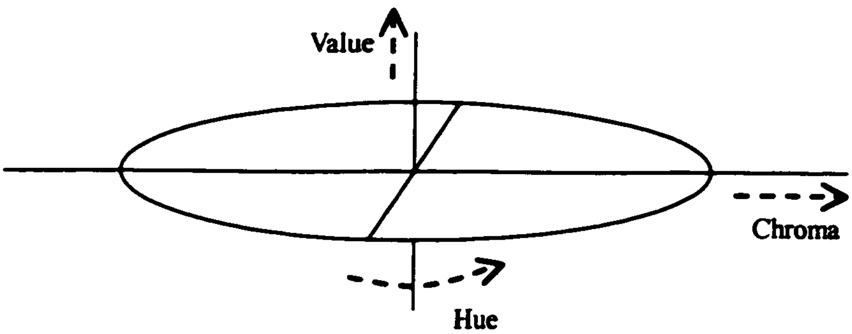

Figure 2.2 Relationship of Munsell Hue, Munsell Value and Munsell Chroma

2.2.2.2 Natural Colour System (NCS)

The Natural Colour System (NCS), which was developed in Sweden, attempts to provide a common, easily understood language with which people can communicate their perceptions of colour (Kaiser and Boynton, 1996). It is a three-dimensional colour space, with two coordinates representing the amounts of the opponent-colour pairs, elementary red or green and elementary blue or yellow, and with the third dimension representing the amounts of elementary black and white (Backhaus, 1998). Its scaling is based on the concept that all colour sensations can be judged as the sum of six basic perceptions: red, green, yellow, blue, black, and white, with only four for a given colour. For example, an orange colour may consist of 35 yellow, 35 red, 20 white, and 10 black, where the numbers indicate the degree of similarity to the fundamental sensations of that name and the sum of these numbers is always 100 (Kuehni, 1983). A key idea in this system is that anyone with normal colour vision can, with little training, learn to make the ratings, which constitute a practical, useful language for describing colours under any conditions (Kaiser and Boynton, 1996).

The NCS System contains over 2000 colour specifications, and 1412 of these have been realized in the form of painted paper samples. The limitations of this system are that the colour brown cannot easily be described with the elementary scales provided and it does not possess a metric for deriving colour differences (Backhaus, 1998, Kaiser and Boynton, 1996, and Kuehni, 1983).

2.2.3 The CIE System

The CIE System (International Commission on Illumination) is usually used in connection with instruments for colour measurement. This system starts with the premise that proper combination of a source of light, an object and an observer results in colour stimulus. In 1931, the CIE introduced the element of standardization of source and observer, and also, the methodology for deriving numbers that provide a measure of a colour seen under a standard source of illumination by a standard observer. The CIELAB colour space was recommended for general use by CIE in 1976, and was also recommended by the Colour Measurement Committee of the Society of Dyers and Colourists (Rigg, 1987). The lightness of the colour sample is represented by L^* on a scale running from zero for black to 100 for white. Chroma of a colour is denoted by C^* which is measured on a scale such that a colorimetric neutral grey has a C^* value of 0 whereas a fluorescent orange may have a C^* value as large as 150. Hue of a colour is interpreted as hue angle in term of h^0 and it is measured in degrees from

0^0 to 360^0. The four psychological primaries, for example a red colour which is neither yellowish nor bluish, have the following approximate hue angles: red 27^0, yellow 95^0, green 162^0 and blue 260^0 (Billmeyer and Saltzman, 1981, Rigg, 1987 and Zollinger, 1999). Since all numerical values are used in the CIE System for the representation of colours, it is the most well-known and commonly used colour communication method for the colourists for reproducing colours.

2.3 Colour Psychology

As mentioned by Mahnke (1996), the psychological effect of colour, or colour psychology, is a huge and complex field. Colour psychology in this study refers to the applied or practical psychological effects which include associations, impressions and characters of colours that are predetermined to create a visual ambience for the human beings (Rhodes and Thame, 1988). Sharpe (1980) and Hsiao (1995) have pointed out that different colours will induce different feelings and emotions to people. When a person is viewing a colour, his/her mental perception includes memories, e.g. soft and hard, warm and cool, gaudy and plain etc., and these are the colour emotions of people. Although individual reacts differently towards colours, many researchers point out that average reactions among groups of people can be justification enough to reach tolerable conclusions.

For example, if the majority of people accept red as a brave colour, although some are disagreed, this will suffice to conclude that red can be considered as a brave colour. Some regular patterns of the relation between the general psychological effects and major hues were listed as below (Birren, 1978, Crozier, 1996, Dove, 1992, Evans, 1974, Feisner, 2001, Hilbert, 1987, Joshi, 1984, Mahnke, 1987, Mella, 1990 and Wright, 1995):

- Red is regarded as adventurous, aggressive, sociable, powerful, protective, brave, arousing, passion, sexy and exciting.
- Orange is considered to be jovial, lively, motivated and energetic. A bright orange appears exciting while a light orange is cheering.
- Yellow is the happiest among all colours. It is thought to be cheerful, high-spirited, jovial, funny, affectionate and impulsive.
- Green represents perfect balance and it is at the center of the spectrum. It tends to be stable, peaceful, calm, quiet, natural and restful. As green is a mixture of yellow and blue, when it slips toward yellow, it becomes more stimulating and lighter; when it slips toward blue, it becomes colder, more fastidious, and sensitive.
- Blue is a noble colour representing dignity, conservatism, poise, and reserve. It

is regarded as intellectual, relaxing, comfortable, encouraging, cautious, pleasant, soothing, calm and restful.

- Purple or violet is a blend of red and blue; violet is a lighter shade of purple and a pure spectral hue. Purple is considered as regal, dignified, elegant, mysticism, sensitive and magic.
- Black is an achromatic colour representing powerful, mighty, protective and ominous. However, in fashion field, black usually expresses status, elegance, richness and diginity.
- White is another achromatic colour and it is regarded as spiritual, hope, holiness, purity, clean and innocence.
- Grey is associated with conservative, quiet, calm, tired, passive and without life. Since it is the bipolar between light and dark, and also white and black, it is neutral that there is no clarity in any direction in this grey zone.

As the above is a basic overview, the impressions, associations and effects of these colours may be deviated and changed when the hue, lightness and saturation of these colours are changed to some extent.

2.3.1 Influence of Cultural Difference

The colour emotions involve the psychology of people and these may be different due to the differences in their nationalities, cultures as well as traditional customs (Gage, 1993 and 1999). Sharpe (1980) claims that different cultures have different attitudes toward various colours. For example, black is commonly associated with mourning in the Western society whereas the Chinese people use white for mourning. Interestingly, both cultures use white to signify purity and righteousness. Crozier (1996) points out white stands for repose and understanding in classic Indian philosophy, while red paint was used and the bride should dress in yellow at the wedding ceremony in India in the past (Birren, 1978). Red and yellow are also the marriage hues of Egypt, Russia, and the Balkans. In China red colour is associated with wedding because all the decorations and dressing of the bride are in red. However, white colour is connected with wedding for the Japanese. In the Western society, white colour is the dominant colour in the wedding ceremony as they regard white as purity; but the bride is suggested to wear something in blue colour for the happiness and luck in the future (Birren, 1978). In short, people in different societies have their own believes and thoughts on the colour meanings due to the differences in traditional backgrounds of them.

In addition, people living in different regions generally have different impressions and feelings when they are perceiving the same colour. This is due to the geographical difference, which involves the differences in climate, urbanization, and features etc. of their living environments.

2.3.2 Influence of Gender Difference

Hsiao (1995) claims that when the same colour is viewed by people who live in the same society, deviations in the colour emotion occur according to different gender, age, education level, experience, and individual character. Many studies have indicated that there are differences in response to colour between genders (Khouw, 2001). But these findings are ambiguous and mainly focused on colour preference. Eysenck (1941) has done a review of colour studies which points out the relationship between gender and colour. Yellow was found to have a higher affective value for the males than females, and males preferred blue to red whereas females preferred red to blue. In both the studies of Eysenck (1941) and Birren (1978), orange was preferred by males to yellow while females preferred yellow to orange. Guilford and Smith (1959) found that males showed larger tolerant toward achromatic colours, i.e. white, black and grey, than females, and hence, they proposed that females might have higher consciousness on colours and their colour tastes might be more flexible and diverse. In addition, some researches found that females preferred tints to shades, and more females preferred cool colours than males whereas more males preferred bright colours and stronger chromatic colours than females did (McInnis and Shearer, 1964). The above examples illustrate that the colour preferences or tastes of males and females are somewhat different, but the differences in emotions or impressions of males and females during colour perception are still unclear since the research in this area is very limited.

2.4 Quantitative Evaluation of Colour Psychology

2.4.1 Colour Image Scale by Nippon Colour and Design Research Institute (NCD)

Although different people have different impressions about certain colours, there are still consistencies in the mental feelings induced from colours as suggested by Nippon Colour and Design Research Institute (NCD) (Kobayashi, 1981). NCD conducted many studies on colour emotions and as a result, a "Colour Image Scale" was developed. The colour image scale is equivalent to the colour emotional scale applied in this study. The original idea for developing the scale was to investigate the common meanings between colours and words.

The development of the colour image scale involved the use of a systematic method relating colours (chromatic plus some achromatic) with image word (an adjective) database semantically. To select colours for investigation, a Hue and Tone System was introduced by NCD based on the ISCC-NBS naming method and the Munsell System (Kobayashi, 1981). The system includes 40 hues and a maximum of 12 tones for each hue. The best representatives of the tone colour (characteristic point) in each hue section were selected and the tone divisions were defined.

NCD suggested that colour emotions should be put into words and classified systematically. Many adjectival words were selected from the Japanese language and they were categorised into five adjective factors. These were evaluative, sensitive, emotional, dynamic, and scale factors respectively. For each factor, there were twenty to twenty-five adjectival words. To each adjectival word, an opposite meaning word was paired with it to form an adjectival pair (Kobayashi, 1981 and 1990).

Three psychological axes, warm-cool, soft-hard, and clear-greyish were derived from analysis of the colours and colour combinations semantically. These three axes constitute the semantic space or the Colour Image Scale (Kobayashi, 1981) which is shown in Figure 2.3.

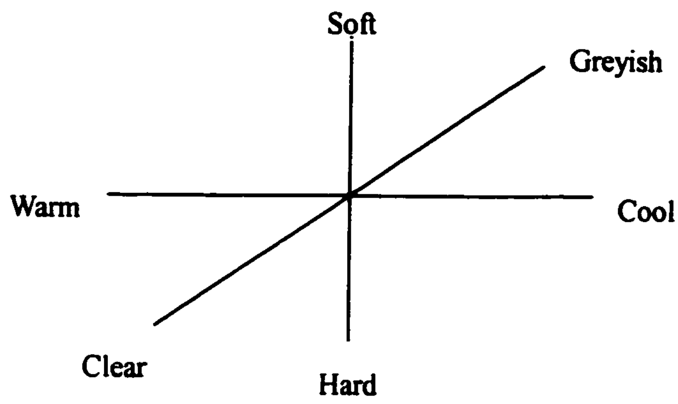

Figure 2.3 The colour image scale in three dimensions by NCD

Image measurement was conducted by two ways: 1) choosing a word which has a meaning appropriate to describe a colour, e.g. using a word "modern" to describe a colour of green hue and of bright tone, and 2) making a colour combination with an appropriate image for a word, e.g. using a colour combination of R/Dp (red hue, deep tone), Y/S (yellow hue, strong tone) and P/Dp (purple hue, deep tone) to describe extravagance.

Colours in the colour image scale are grouped according to their perceived images. The semantic space of colours and the word space are combined on the same scale; hence one can simply give a meaning to a certain colour by applying the word occupying the same position (Kobayashi, 1981 and 1990).

The introduction of the colour image scale provided a new method of colour planning for industrial design. Moreover, it would be very useful for the colour image scale (Kobayashi, 1990) to be applied to different areas such as fashion, interior design, product design, and visual media (Kobayashi, 1998). However, the lack of quantitative relationship between the colours and their corresponding colour image scales makes it difficult to reproduce a colour with a desired colour emotion.

2.4.2 Colour Image Scale by Nakamura et al.

Researches have been carried out in order to discover the quantitative relationships between colours defined by colour specification systems and their colour emotions. A colour image scale was derived by Nakamura et al. (1992) using Munsell colour system in an attempt to express colour emotions quantitatively. The colour image scale is divided into several colour image regions, such as clean, happy, warm and rich regions. Each colour was plotted on the scale according to its Munsell hue, value and chroma as well as colour depth. By superimposing the colours in the scale and their corresponding colour image regions, it was expected that their qualitative relationships could be determined effectively. This colour image scale composed of colour depth (D_L^*) and Hue Image Chroma (HIC). The HIC was divided into two extremes, warm and cool. The calculations of these components of the scale are shown below.

$$D_L^* = (10 - V) + \frac{2C(m + \Delta H_{5P}) \times 10^{-3}}{\log 2}$$

where D_L^* is colour depth, V is the Munsell value, C is the Munsell chroma, m set to 5, and ΔH_{5P} is the Munsell hue step from 5P ($0 \le \Delta H_{5P} \le 50$).

For the warm extreme,

$$HIC = C \bullet M_W$$

where C is the Munsell chroma, and M_W is the degree of warm index which is equal to $0.5[1+\cos(3.6^0 \times \Delta H_{5YR})]$ in which ΔH_{5YR} is the Munsell hue step from 5YR (($0 \le \Delta H_{5YR} \le 50$)

For the cool extreme,

$$HIC = C \bullet M_C$$

where C is the Munsell chroma and M_C is the degree of cool index which is calculated by $M_C = 0.5[1+\cos(3.6^0 \times \Delta H_{5B})]$ in which ΔH_{5B} is the Munsell hue step from 5B ($0 \leq \Delta H_{5B} \leq 50$).

In this colour image scale, unlike the one developed by the NCD, colours were defined quantitatively according to Munsell hue, value and chroma. However, the colours had no quantitative relation with the emotions induced by them. The corresponding emotions occupied different regions in the scale and had different sizes. For example, the emotions of clear, cool and cold occupied a relatively large area in the cool region of the scale whereas the emotion of passionate occupied a small area in the warm region of the scale. An example is shown in Figure 2.4.

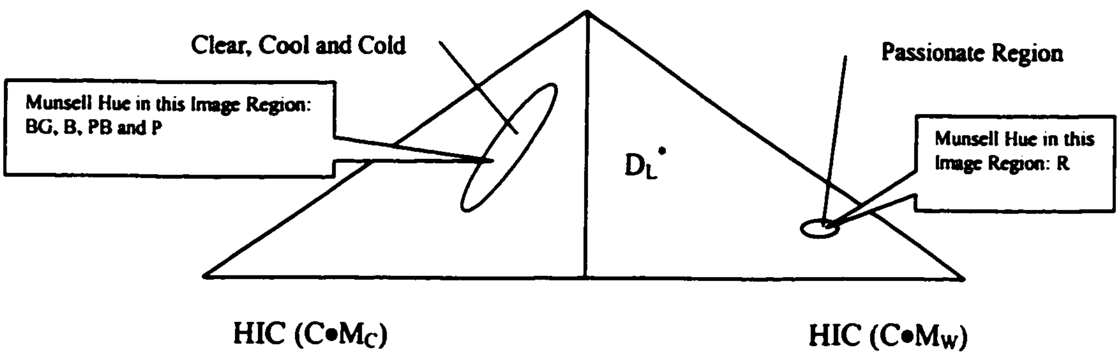

Figure 2.4 Superimposing colours and image regions in the colour image scale

2.4.3 Colour Image Scale Using Fuzzy Set Technique

In a study of colour planning in product design (Hsiao, 1995), the colour image of a product was quantified by using the membership function (or grade of membership) of a fuzzy set. The Hue and Tone System and the colour image scale of NCD were employed to transform colours into image and image into colours. In this study, four tones and ten hues were selected. The selected tones are vivid, pale, dark and light whereas the selected hues were 5R, 5YR, 5Y, 5GY, 5G, 5BG, 5B, 5PB, 5P and 5RP. Ten adjectival words such as elegant, delicate, fresh, etc. were used to described the image of a product which was an ice shaver.

In order to construct a semantic space to correlate colours and adjectival words, the composite operation for fuzzy sets was used. The method simulating the colour emotions was referred to colour projection in Hsiao's paper, in which the equivalent feelings between colours and words were established. A computer program was set up to calculate and analyse various colours described by image words and a table was constructed. That enables designers to select target colour by simply selecting a desired image word according to the characteristic and impression of a product. Consequently, the efficiency of the decision process for selecting the right colour was improved.

2.4.4 Linguistic-Based Image Scale For Evaluating Colour Harmony

In a study of colour harmony for interior design, a linguistic-based image scale was used (Shen et al., 1996). The image scale was one-dimensional with the feelings of "exciting" and "calm" at the two ends of the scale. The CIELUV and CIELAB colour spaces were selected, in which the colours were transformed. The correlations of the colours to "exciting" and "calm" feelings were found using the fuzzy set theory. To design the image scale, the principle of colour-similarity-coherence was used. As claimed by Shen et al. (1996), the colour-similarity-coherence was the inheritance of colour similarity from the tristimulus domain to linguistic domain, i.e., if two colours are similar in our vision, the corresponding colour linguistic values will be similar in the desired image scale. Based on this image scale, the harmony of colours could be assessed by the similarity of their corresponding feelings, and the mental colour impression of interior images analysed according to the grade of colour harmony.

2.4.5 Colour Emotional Scales

Nakamura and Sato et al. (Nakamura et al., 1996 and 1997; Sato et al., 1997a and 1997b) investigated 12 pairs of colour emotional words which they considered to be fundamental (Nakamura et al., 1994) in an attempt to quantify these words using the colorimetric specification of the colours. Visual experiments were conducted using 218 polyester fabric samples selected from SCOTDIC PLUS 2000 system, which is a fabric version of Munsell colour system. Of those 218 samples, 212 were chromatic colours and 6 were achromatic colours. The observers who participated in the visual experiments were native Japanese aged around 20 years old. In the experiments, one word was assigned to a colour from a pair of words, e.g., either "cool" or "warm" is assigned to a colour by the observers. The results of the experiments were analysed and empirical formulae were obtained to correlate the colorimetric values of colours to their corresponding emotions. These formulae are discussed in the following sections.

2.4.5.1 Warm-cool index

Nakamura et al. (1996) attempted to quantify warm-cool feelings of colours using their colorimetric values. The results reveal that the warm-cool feeling is influenced by hue and brightness (the definition of brightness Br is given below) rather than by hue and chroma. The following empirical formulae were developed to represent the warm-cool indices based on the Munsell system (WC) and CIELAB system (WC_{CIELAB}):

$$WC = a \bullet Br - 80$$

where Br stands for the brightness and it is calculated by $Br = 10C / (2.509D_L^*)$ in which C is the Munsell chroma and D_L^* is the colour depth (the formula was defined and is discussed in the previous section on the subject of Colour Image Scale by Nakamura et al.); a is a coefficient and it is calculated by $a = 20\{\cos(\pi \times \Delta H_{5YR} / 50)+1\}$ in which ΔH_{5YR} is the Munsell hue step from 5YR $(0 \leq \Delta H_{5YR} \leq 50)$

$$WC_{CIELAB} = 3.5[\cos(h\text{-}50) + 1]B - 80$$

where h^0 is the CIELAB hue-angle, and B is the Dyer's brightness which is calculated by:

$B = 50C^*(1-\Delta h_{290}/360)/D$ in which C* is the CIELAB chroma, Δh_{290} is the CIELAB hue-angle difference from h=290, $0 \leq h_{290} \leq 180$, and D is the colour depth calculated by:

$D = (100-L^*) + (0.1+\Delta h_{290}/360)(1-\Delta h_{290}/360)C^*$ where L* is the CIELAB lightness.

The WC or WC_{CIELAB} ranges from 100 to -100. When it is equal to 100, this means all observers assess the colour sample as "warm". When it is equal to -100, all observers assess the colour sample as "cool". If WC is outside of the boundary of −100 to 100, it is assumed to be equal to −100 or 100.

2.4.5.2 Light-dark, deep-pale, and heavy-light indices

The light-dark, deep-pale, and heavy-light emotions of colour were analysed quantitatively by Sato et al. (1997a). The experimental results show that the feelings of light-dark, deep-pale, and heavy-light of colour were mainly influenced by lightness and colour depth. The empirical formulae derived are given below. LD, DP and HL stand for the light-dark, deep-pale and heavy-light indices based on the Munsell system, whereas LD_{CIELAB}, DP_{CIELAB} and HL_{CIELAB} are the indices based on the CIELAB colour system.

For the Light-Dark Indices,

$$LD = 40V + \{20 - 5\cos(\Delta H_{10YR}\pi / 5)\}C - 300$$

where V is the Munsell value, C is the Munsell chroma, and ΔH_{10YR} is the Munsell hue step from 10YR ($0 \leq \Delta H_{10YR} \leq 50$)

$$LD_{CIELAB} = 4L^* + [4 - \cos(h\text{-}68)]C^* - 300$$

where L* is the CIELAB lightness, h^0 is the CIELAB hue-angle, and C* is the CIELAB chroma.

For the Deep-Pale indices,

$$DP = 35D_L^* - 190$$

where D_L^* is the colour depth which has been defined in the section of "Colour Image Scale by Nakamura et al.".

$$DP_{CIELAB} = 3.5D\text{-}190$$

where D is the colour depth described in the previous section of "Warm-Cool Index".

For the Heavy-Light indices,

$$HL = -35V + 190$$

where V is the Munsell value.

$$HL_{CIELAB} = -3.5L^* + 190$$

where L^* is the CIELAB lightness.

Similar to the Warm-Cool indices, when the value is 100, it represents all observers assess the colour sample as "light", "deep", or "heavy". When the value is -100, it represents all observers assess the colour sample as "dark", "pale", or "light". The values of these indices should all be in the range of -100 to 100. Otherwise truncation will be used as for the Warm-Cool index.

2.4.5.3 Other colour emotional indices

The other colour emotional indices are vivid-sombre, gaudy-plain, striking-subdued, dynamic-passive, distinct-vague, transparent-turbid, soft-hard, and strong-weak. Sato et al. (1997b) found that these feelings were mainly influenced by Munsell chroma and Munsell value. The following empirical formula suggested by Sato et al. is a generalised form representing the above mentioned eight pairs of colour feelings based on the Munsell system.

$$CI = [\{kv(V-V_0)\}^2 + \{kc(C-C_0)\}^2]^{1/2} - ks$$

where CI is the Colour Image Feeling value, V is the Munsell value, C is the Munsell chroma, kv is the constant attributable to the effect of Munsell value to the colour emotion, kc is the constant attributable to the effect of Munsell chroma to the colour emotion, ks is the constant for the scaling of the colour emotion, and V_0 and C_0 are the Munsell value and chroma whose effect to the colour emotion is minimal.

Individual formulae were derived based on the experimental assessments of each pair of emotional words by the observers. These are listed as the following using both Munsell and CIELAB colour system:

For Vivid-Sombre,

$$VS = [\{25(V\text{-}5)\}^2 + (20C)^2]^{1/2} - 130$$

$$VS_{CIELAB} = [\{2.5(L^*\text{-}50)\}^2 + \{5.4(1\text{-}\Delta h_{290}/360)^2\}^{1/2} - 130$$

For Gaudy-Plain,

$$GP = [\{20(V\text{-}5)\}^2 + (20C)^2]^{1/2} - 140$$

$$GP_{CIELAB} = [\{2(L^*\text{-}50)\}^2 + \{5.2(1\text{-}\Delta h_{290}/350)\}^2]^{1/2} - 140$$

For Striking-Subdued,

$$SS = [\{20(V\text{-}5)\}^2 + (20C)^2]^{1/2} - 125$$

$$SS_{CIELAB} = [\{2(L^*\text{-}50)\}^2 + \{5.4(1\text{-}\Delta h_{290}/360)C^*\}^2]^{1/2} - 125$$

For Dynamic-Passive

$$DYP = [\{6(V\text{-}5)\}^2 + (16C)^2]^{1/2} - 110$$

$$DYP_{CIELAB} = [\{0.6(L^*\text{-}50)\}^2 + \{4.6(1\text{-}\Delta h_{290}/360)C^*\}^2]^{1/2} - 115$$

For Distinct-Vague

$$DV = [\{40(V\text{-}6.5)\}^2 + (20C)^2]^{1/2} - 140$$

$$DV_{CIELAB} = [\{4(L^*\text{-}65)\}^2 + \{5.4(1\text{-}\Delta h_{290}/360)C^*\}^2]^{1/2} - 140$$

For Transparent-Turbid

$$TT = [\{50(V\text{-}4)\}^2 + (20C)^2]^{1/2} - 170$$

$$TT_{CIELAB} = [\{5(L^*\text{-}40)\}]^2 + [5.8\{1+0.35\cos(\Delta h_{220})\}(1\text{-}\Delta h_{290}/360)C^*]^2]^{1/2} - 180$$

For Soft-Hard

$$SH = [(32V)^2 + (10C)^2]^{1/2} - 180$$

$$SH_{CIELAB} = [(3.2L^*)^2 + \{2.4(1\text{-}\Delta h_{290}/360)C^*\}^2]^{1/2} - 180$$

For Strong-Weak

$$SW = [\{40(V\text{-}8)\}^2 + (16C)^2]^{1/2} - 150$$

$$SW_{CIELAB} = [\{4(L^*\text{-}80)\}^2 + \{4.6(1\text{-}\Delta h_{290}/360)C^*\}^2]^{1/2} - 150$$

where Δh_x is the CIELAB hue-angle difference from h=x, $0 \le \Delta h_x \le 180$.

Similarly, when the value of the index is 100, the colour feeling is "vivid", "gaudy", "striking", "dynamic", "distinct", "transparent", "soft" or "strong". When the value of the index is -100, the colour feeling is "sombre", "plain", "subdued", "passive", "vague", "turbid", "hard" or "weak". The same truncation applies when the value of these indices is outside the range of −100 to 100.

2.4.6 Summary

Various research groups have correlated colours with their corresponding emotions and they are summarised in Table 2.1 below:

Table 2.1

Investigating colour psychology by different studies

Method	General Description	Quantitative Relationship Between Colour and Emotion
Colour Image Scale by NCD	Develop a 3-D image scale with the axes: warm-cool, soft-hard and clear-greyish.	No. Colours are plotted on the scale according to their corresponding emotions.
Colour Image Scale by Nakamura et al.	Introduce a 2-D image scale that is composed of colour depth and warm-cool feeling.	No. But the colours are defined quantitatively by Munsell hue, value and chroma.
Colour Image Scale using Fuzzy Set Technique by Hsiao	Derive a system for the designers to select colour by simply selecting a desired image word and inputting it to the system	Yes. The relationship is expressed in term of a computer program.
Linguistic-Based Image Scale by Shen et al.	Construct a 1-D image scale with the feelings of "exciting" and "calm" only.	Yes. But the main purpose of this scale is to assess the colour harmony, not to correlate colours with emotions.
Colour Emotional Scales by Nakamura and Sato et al.	Derive mathematical models, in terms of Munsell colour notations and CIELAB colour specifications, for different colour emotional words.	Yes. To each pair of emotional word, empirical formulae are deduced to represent the relationship.

The perception of colour image has the complicity of being affected by factors such as nationality, and cultures. Further investigations that involve different nationalities and cultures were being carried out in this research in order to analyse the similarities and differences in colour emotions of people in different countries.

QUANTITATIVE REPRESENTATION OF COLOUR EMOTIONS

3.1 Objectives

- To investigate the correlation of colour emotions for colour standard specifications.
- To derive mathematical models for quantifying the colour emotions with the colour specifications.
- To categorize the colour emotions into different groups according to the dominant parameter(s).

3.2 Methodology

3.2.1 Visual Assessment

3.2.1.1 Subjects

All subjects in the visual assessments were native Hong Kong Chinese aged around twenty. 70 subjects, half of whom were male and half female, participated in the visual assessments. The required number of subjects for giving a meaningful and representative investigation in this study was determined carefully using the average of the maximum error of estimate (Hopkins et. al., 1996), which is shown in Appendix A. From this statistical analysis, the reliability of subjects was evaluated and it was found that more than 35 subjects would give sufficiently representative results. Each subject was asked to take the Isihara Colour Blindness Test before doing the visual assessment in order to ensure they possess normal colour vision.

3.2.1.2 Colour samples

218 colour samples with a size of 1.0 cm x 1.5 cm were used. They were selected from the SCOTDIC PLUS 2000 system which is a colour specifier containing 2450 shades dyed with disperse dyes on polyester. It is a textile version of the Munsell colour order system (Ho, 1996).

The notation of each colour sample has two components, Munsell hue and tone region of a Colour Score diagram. For example, the notation of 5R1 indicates that the Munsell hue of this colour sample is 5R and the tone region in the Colour Score Diagram is 1. In the Colour Score Diagram, there were theoretically 19 tone regions for each Munsell hue. Colorimetric values of a central point in each tone region were determined. Colour chips from the SCOTDIC system with colorimetric values similar to the central points were selected. For some small number of tone regions, dyed textile samples were not available due to the non-existence of dyestuffs. All the notations of colour samples in this study are provided in Appendix B.

The spectral reflectance of each sample was measured using the Macbeth Colour Eye 2180 spectrophotometer with the small aperture. The reflectance data was then converted into CIE L^*, a^* and b^* colorimetric values for studying the distribution of colours in the CIELAB colour space and facilitating the establishment of quantitative correlation of colours and emotions. The CIE colorimetric values for all colour samples and the distribution of them in the CIE colour space are shown in Appendix C.

3.2.1.3 Experimental conditions

A Verivide artificial daylight D_{65} with colour temperature 6500K was used for visual assessment conforming to the British Standard Specification for Artificial Daylight for the Assessment of Colour (BS 950: Part I: 1967). The colour of background for the visual assessment was neutral grey according to the ASTM Standard for Visual Evaluation of Colour Differences of Opaque Materials (ASTM: D 1729-89). When viewing the colours, a neutral grey mask was used to cover the surround of each colour sample in order to ensure that the assessment was not influenced by the colour of surround. An example illustrating the assessment of colour sample 5R1 by covering the grey mask is shown in Figure 3.1. The colour samples were illuminated along their normal, i.e., directly facing the light, and viewed at approximately 45^0 to the normal.

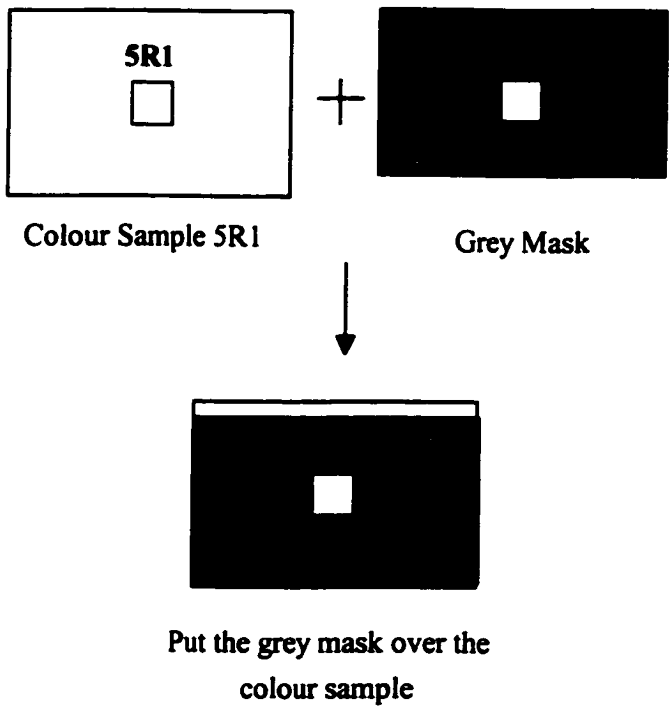

Figure 3.1 Assessing a colour sample by covering its surrounding background with a grey mask

3.2.1.4 Questionnaire

Each subject was asked to fill in the questionnaire during the visual assessment. In the questionnaire, there were twelve pairs of opponent words for describing the human emotions. They were 'warm-cool', 'light-dark', 'deep-pale', 'heavy-light', 'vivid-sombre', 'gaudy-plain', 'striking-subdued', 'dynamic-passive', 'distinct-vague', 'transparent-turbid', 'soft-hard' and 'strong-weak'. These word pairs were written in Chinese language since all subjects were native Hong Kong Chinese using Chinese as the mother language. An example of the questionnaire containing the twelve pairs of colour words is shown in Appendix D.

After viewing a colour sample, each subject was requested to select a more appropriate word to describe the colour from each word pair. The colour samples were given to the subjects randomly. The reason for this was to reduce the comparison effect of one colour sample to another.

3.2.1.5 ANOVA test

The significance of the results obtained from the visual assessment was investigated by ANOVA (Analysis of Variance) (Hopkins et. al., 1996, Harris, 1998, Clarke, 1980, Kiess, 1989 and Siegel and Morgan, 1996). This was used as the preliminary analysis of the variations in the assessments of the colour samples with respect to each pair of colour emotion words. *F*-test was used in this test, and the details of the calculation of this statistical method and the ANOVA table indicating the results are shown in Appendix E. In this analysis, the variations in colour emotions between colour samples were found to be sufficiently significant. As a result, it was valuable for further investigation on the quantitative relationship between the colour emotions and the colorimetric values and derivation of mathematical models. SPSS was used as a tool for the calculation of the ANOVA test (Hedderson and Fisher, 1993, Kinner, 1994 and Tsoi and Choi, 1993).

3.2.2 Method for Quantifying Colour Emotions

3.2.2.1 Two-point method

After obtaining the results of the visual assessments, the two-point method was used to quantify the colour emotion of each colour. In assessing a colour by each word pair, +1 point was given to the selection of 'warm', 'light', 'deep', 'heavy', 'vivid', 'gaudy', 'striking', 'dynamic', 'distinct', 'transparent', 'soft' or 'strong'; while –1 point was given to the selection of 'cool', 'dark', 'pale', 'light', 'sombre', 'plain', 'subdued', 'passive', 'vague', 'turbid', 'hard' or 'weak'. The 'warm-cool', 'light-dark', 'deep-pale', 'heavy-light', 'vivid-sombre', 'gaudy-plain', 'striking-subdued', 'dynamic-passive', 'distinct-vague', 'transparent-turbid', 'soft-hard' and 'strong-weak' colour emotions were expressed in terms of percentages as *WC*, *LD*, *DP*, *HL*, *VS*, *GP*, *SS*, *DyPa*, *DV*, *TT*, *SH* and *SW* respectively. The above are illustrated in Table 3.1.

Table 3.1

<u>The corresponding point for the selection of word within a colour emotion pair</u>

Colour emotion pair: In Chinese	Colour emotion pair: In English	Colour emotion percentage	Point given to the selection of this colour emotion word: +1	Point given to the selection of this colour emotion word: -1
暖-冷	Warm-Cool	*WC*	Warm	Cool
光-暗	Light-Dark	*LD*	Light	Dark
深-淺	Deep-Pale	*DP*	Deep	Pale
重-輕	Heavy-Light	*HL*	Heavy	Light
鮮明-暗淡	Vivid-Sombre	*VS*	Vivid	Sombre
俗艷-樸素	Gaudy-Plain	*GP*	Gaudy	Plain
奪目-柔和	Striking-Subdued	*SS*	Striking	Subdued
動-靜	Dynamic-Passive	*DyPa*	Dynamic	Passive
清晰-模糊	Distinct-Vague	*DV*	Distinct	Vague
通透-混濁	Transparent-Turbid	*TT*	Transparent	Turbid
柔軟-堅硬	Soft-Hard	*SH*	Soft	Hard
強-弱	Strong-Weak	*SW*	Strong	Weak

For example, when the warm-cool colour emotion of colour sample 5R1 was assessed by the subjects, the calculation of the warm-cool percentage (*WC*) of 5R1 became:

$$WC = \frac{x \times (+1) + y \times (-1)}{x + y} \times 100\% \qquad (3.1)$$

where x and y are the number of subjects selecting warm and cool colour emotions for colour sample 5R1 respectively; and

$x+y$ is the total number of subjects, i.e., 70 for this study.

If all subjects selected 'warm' to describe the colour, WC was equal to 100%. If all subjects selected 'cool' to describe the colour, WC was equal to −100%. All the other colour emotion percentages were calculated by this method.

3.2.2.2 Graphical representation of colour emotion against colorimetric attribute

The relationships of the colour emotions and each of the colorimetric attributes were plotted on graphs and analysed. In cases that a linear proportion plotting or a specific trend was obtained, the colour emotion pair had a direct or significant correlation with the colour attribute. On the other hand, if the points in the graphs were scattered, the colour emotion pair and that colorimetric attribute had no significant relationship.

The plottings of colour emotions against lightness and chroma were further divided into four regions according to hue so that a clearer and deeper analysis of the influence of such colorimetric attribute to colour emotion could be obtained. The four regions were red (hue angles between 315^0 and 45^0), yellow (hue angles between 45^0 and 135^0), green (hue angles between 135^0 and 225^0) and blue (hue angles between 225^0 to 315^0) regions.

3.2.2.3 Correlation between colour emotion and colorimetric attribute

In addition to the graphical representation of the correlation between the colour emotion and colorimetric attribute, the correlation coefficient, *r*, between each colour emotion pair and each colorimetric attribute was calculated as the quantitative evaluation of the dominant parameter(s) influencing the selection of colour emotion. The calculation of *r* is shown below (Freund and Simon, 1995 and Sincich, 1993):

$$r = \frac{n(\sum_{i=1}^{n} x_i y_i) - (\sum_{i=1}^{n} x_i)(\sum_{i=1}^{n} y_i)}{\sqrt{\left[n\left((\sum_{i=1}^{n} x_i^2)\right) - (\sum_{i=1}^{n} x_i)^2\right]\left[n\left((\sum_{i=1}^{n} y_i^2)\right) - (\sum_{i=1}^{n} y_i)^2\right]}} \quad (3.2)$$

The correlation coefficient, *r*, measures the strength and direction of a relationship between two variables and it ranges from −1 to +1. If *r* is near or equal to +1, there is a strong and positive linear relationship between the variables.

If r is near or equal to -1, there is a strong and negative linear relationship between the variables. If there is no linear relationship or only a very weak relationship between the variables, the value of r is close to 0.

3.2.2.4 Derivation of Mathematical Models

The results obtained from the visual assessments indicated by the two-point calculation were used to find out the quantitative relationships between colour emotions and colorimetric attributes. Mathematical multiple regression technique was used as a tool to derive models for representing the relationships. The CIE colorimetric attributes, L^*, C^* and h^0, were the independent variables whereas each colour emotion percentage was the dependent variable in the mathematical model. Optimization by C++ programming was used for the derivation of the mathematical models (Adams et.al., 1998 and Hahn, 1994).

3.3 Results and Discussion

3.3.1 Correlation of Colour Emotion and Colorimetric Attribute

3.3.1.1 Graphical representation

The graphs of each colour emotion pair against each colorimetric attribute were plotted and are shown in the following figures. For the further analysis of a meaningful correlation, the subdivision of the data according to hue was necessary, and these figures which have significant correlation are included in this section. Others are shown in Appendix F. In addition, the visual assessment results of each colour emotion pair are shown in Appendix H for reference.

Warm-Cool Colour Emotion

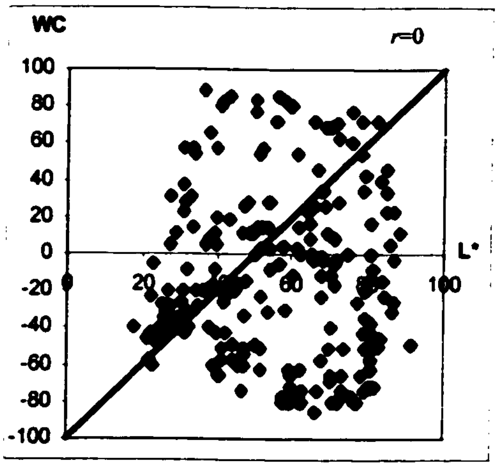

Figure 3.2 Correlation of 'warm-cool' colour emotion, WC, with lightness, L^*

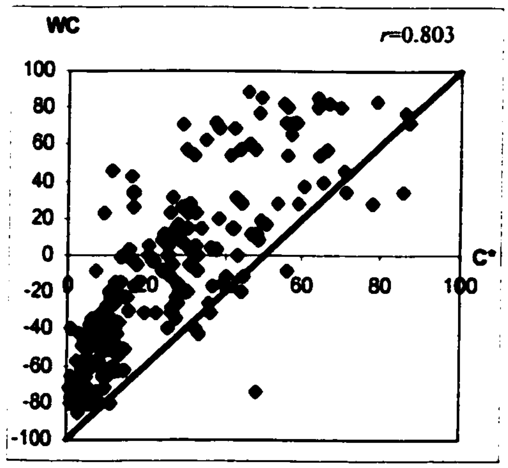

Figure 3.3 Correlation of 'warm-cool' colour emotion, WC, with chroma, C^*

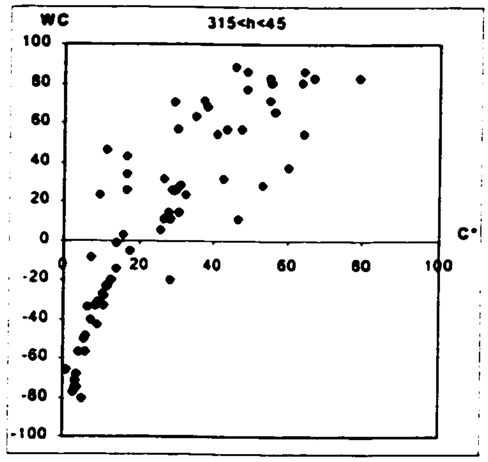

Figure 3.3a Subdivided graph of WC against C^* of red colours

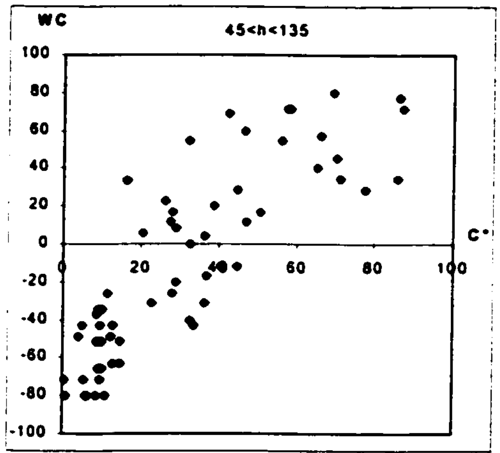

Figure 3.3b Subdivided graph of WC against C^* of yellow colours

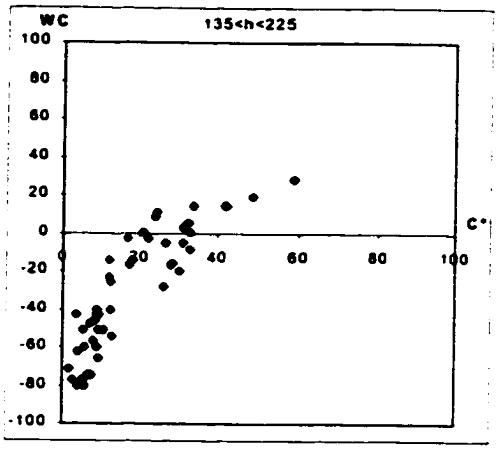

Figure 3.3c Subdivided graph of *WC* against C^* of green colours

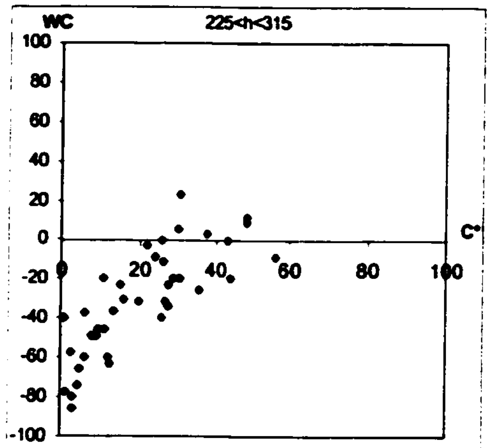

Figure 3.3d Subdivided graph of *WC* against C^* of blue colours

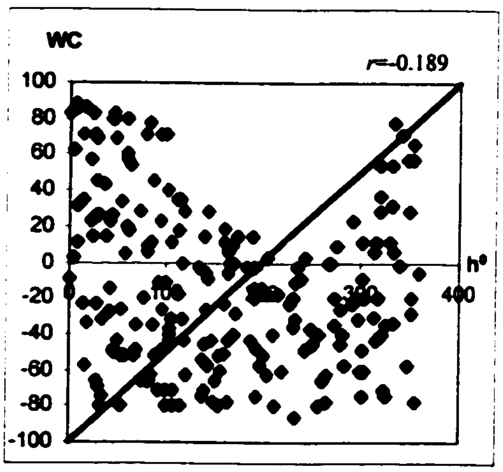

Figure 3.4 Correlation of 'warm-cool' colour emotion, *WC*, with hue, h^0

From Figure 3.2, 'warm-cool' colour emotion was found to have no correlation with the lightness of colour because the plots scatter in the whole graph. However, the 'warm-cool' colour emotion was found to have significant correlation with chroma and hue of colour, which are shown in Figures 3.3 and 3.4 respectively. As the chroma of colour increased, a tendency to 'warmer' feeling was evoked in the subjects. In order to gain a more thorough understanding of the influence of chroma to 'warm-cool' colour emotion, the plottings were further subdivided into four regions according to hue (Figures 3.3a – 3.3d). In the red and yellow regions, a low chroma colour gave a 'cool' impression to the subjects, whereas increasing the chroma tended to increase the 'warm' impression of them (Figures 3.3a and 3.3b). In the green and blue regions, increasing the chroma of colour also gave a 'warmer' impression to the subjects but most of the greenish and bluish colours tended to give 'cool' images to them as the 'warm-cool' percentages were less than 30% in Figures 3.3c and Figure 3.3d. These observations gave the same findings as the plots of 'warm-cool' colour emotion against hue (Figure 3.4), in which almost no 'warm' emotion was obtained when the hue angle of colour was between 200^0 to 250^0; however, in the case of the colours with hue angle between 0^0 to about 130^0 and 320^0 to 360^0, they gave 'warm' as well as 'cool' impressions to the subjects. If the scattered plots distribute in a form of 'sine' curve in the graph of colour emotion against hue angle, this represents a relationship is detected because different hues reults in different colour emotions.

Light-Dark Colour Emotion

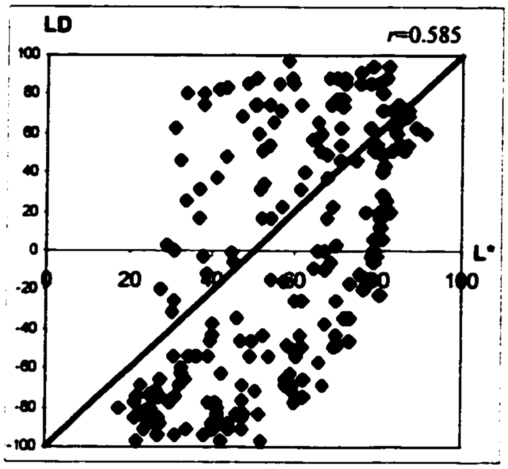

Figure 3.5 Correlation of 'light-dark' colour emotion, *LD*, with lightness, L^*

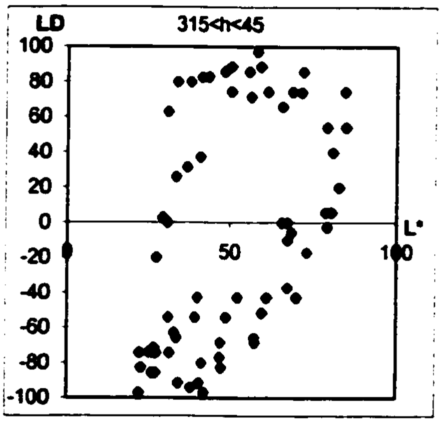

Figure 3.5a Subdivided graph of *LD* against L^* of red colours

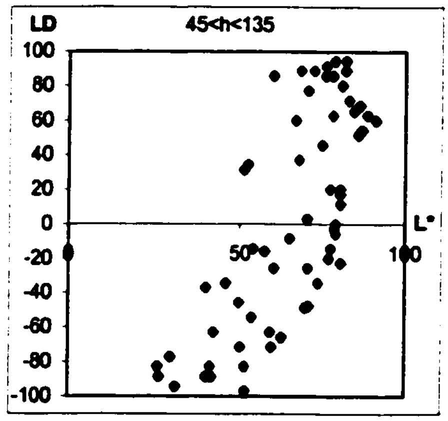

Figure 3.5b Subdivided graph of *LD* against L^* of yellow colours

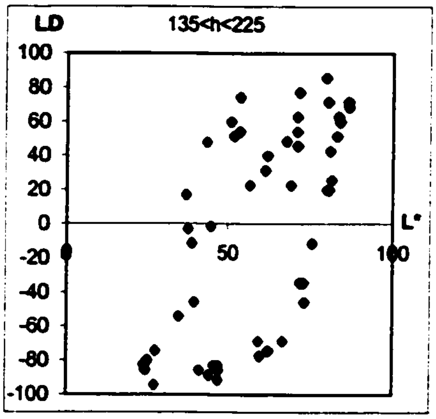

Figure 3.5c Subdivided graph of *LD* against L^* of green colours

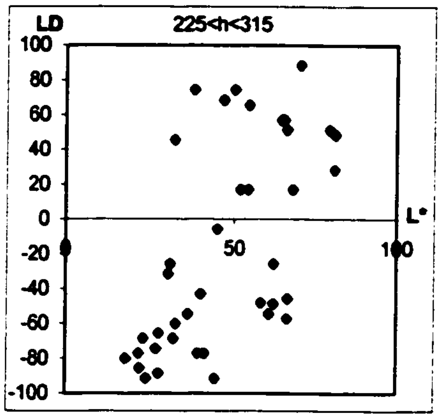

Figure 3.5d Subdivided graph of *LD* against L^* of blue colours

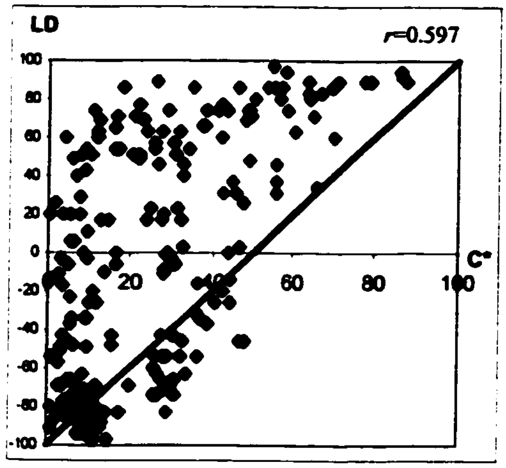

Figure 3.6 Correlation of 'light-dark' colour emotion, *LD*, with Chroma, C^*

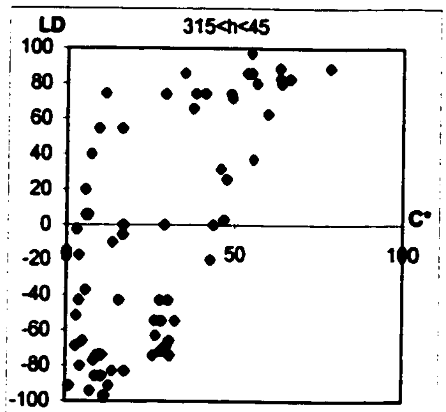

Figure 3.6a Subdivided graph of *LD* against C^* of red colours

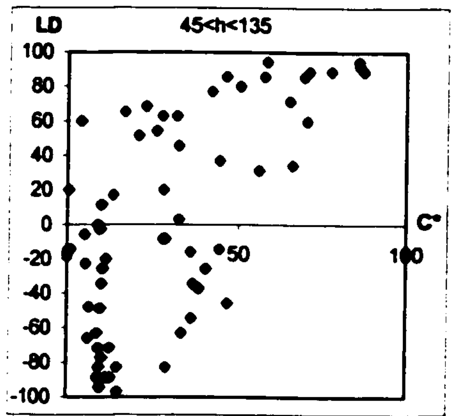

Figure 3.6b Subdivided graph of *LD* against C^* of yellow colours

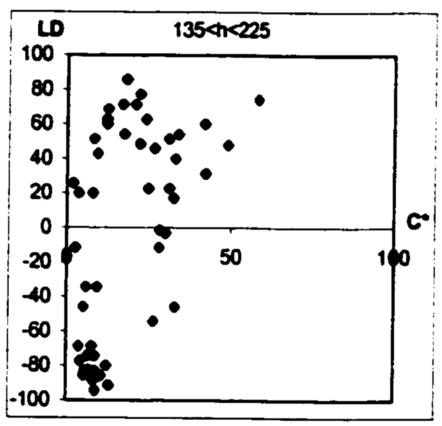

Figure 3.6c Subdivided graph of *LD* against C^* of green colours

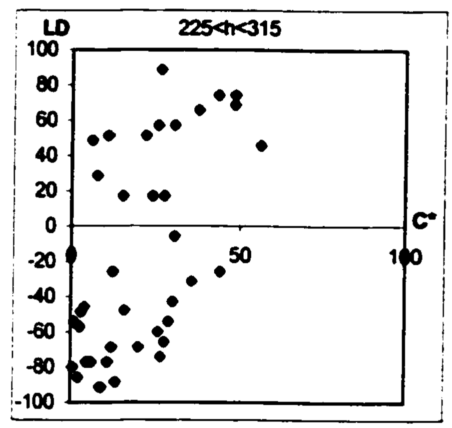

Figure 3.6d Subdivided graph of *LD* against C^* of blue colours

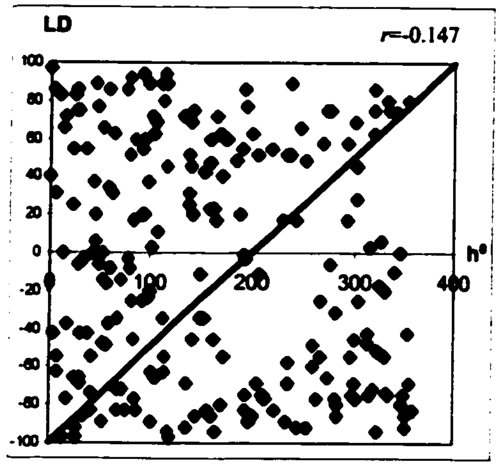

Figure 3.7 Correlation of 'light-dark' colour emotion, *LD*, with hue, h^0

Figures 3.5 and 3.6 illustrate that as the lightness and chroma of colour increased, they generally tended to induce a sense of 'light' to the subjects. Although they were not in linear proportion, some trends were still observed. For further analysis of their correlations, the graphs of of the four hue quadrants were plotted as shown in Figures 3.5a to 3.6d. Among the plottings of 'light-dark' colour emotion against lightness, it was found that there were more obvious correlations in the yellow and green regions (Figures 3.5b and 3.5c), whereas the points were more scattered in the red and blue regions (Figures 3.5a and 3.5d). Figures 3.6a to 3.6d shows that as the chroma increased, the colour emotion generally tended to be 'light', except in the green region where the points were more scattered and the correlation was less obvious (Figure 3.6c). When 'light-dark' colour emotion with hue was evaluated, no significant correlation was found between them (Figure 3.7).

Deep-Pale Colour Emotion

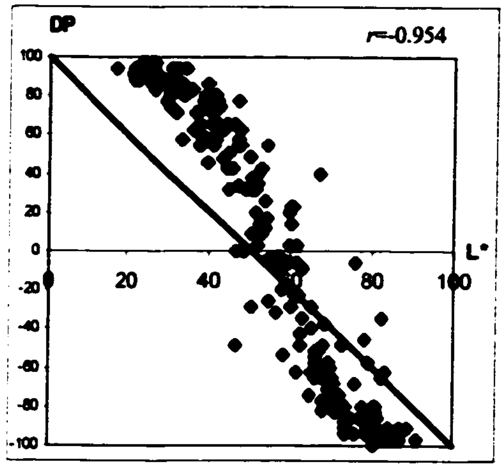

Figure 3.8 Correlation of 'deep-pale' colour emotion, DP, with lightness, L^*

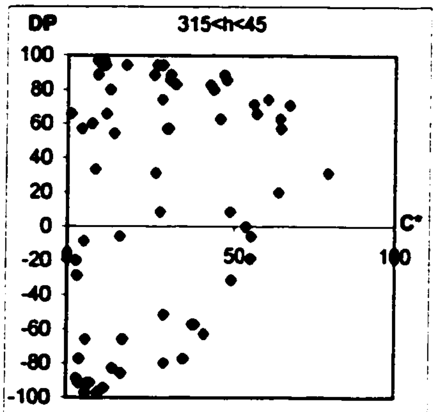

Figure 3.9a Subdivided graph of DP against C^* of red colours

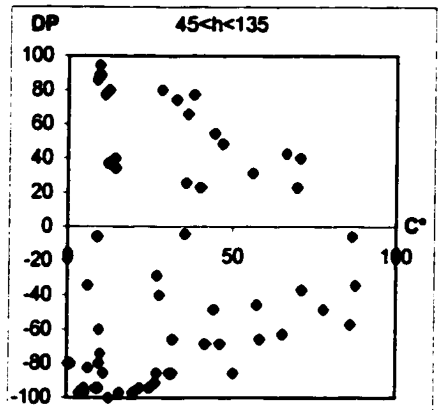

Figure 3.9b Subdivided graph of DP against C^* of yellow colours

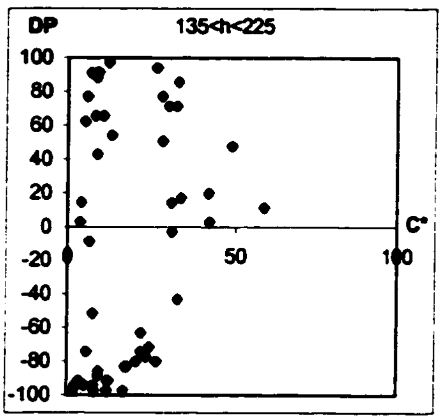

Figure 3.9c Subdivided graph of DP against C^* of green colours

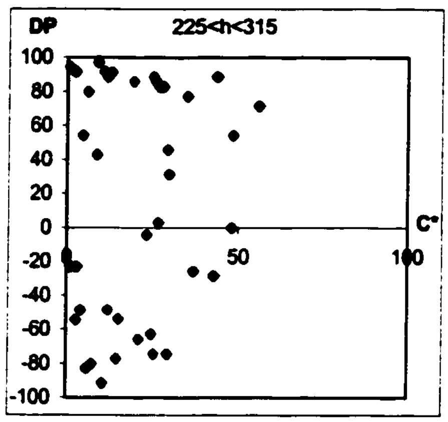

Figure 3.9d Subdivided graph of DP against C^* of blue colours

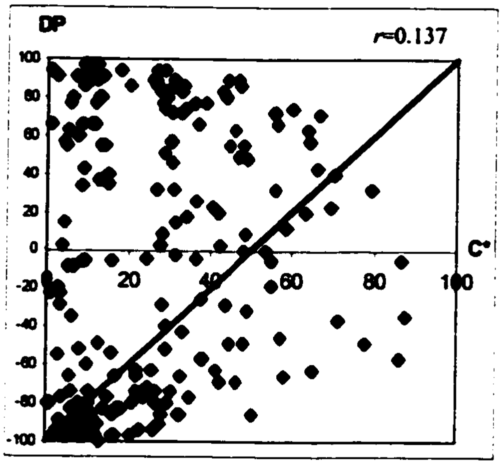

Figure 3.9 Correlation of 'deep-pale' colour emotion, DP, with chroma, C^*

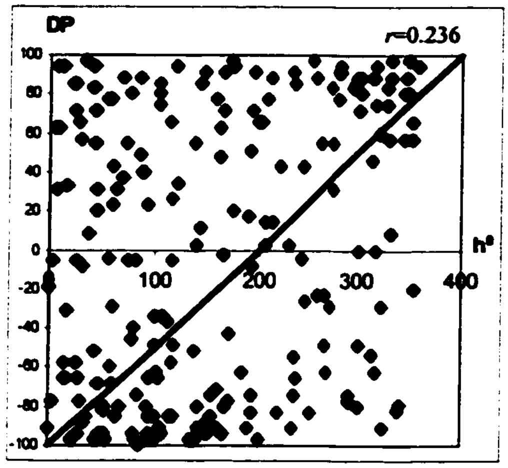

Figure 3.10 Correlation of 'deep-pale' colour emotion, DP, with hue, h^0

When comparing the influence of the three colorimetric attributes on 'deep-pale' colour emotion (Figures 3.8 to 3.10), a significant and good correlation was found with lightness (Figure 3.8) whereas no obvious correlation was found with hue (Figure 3.10). As the lightness of colour increased, a 'pale' emotion was induced in the subjects' minds. Figure 3.9 shows that a large variety of 'deep' to 'pale' feelings were induced for colours with low chroma, but a more 'neutral' feeling, i.e., neither 'deep' nor 'pale', was given to the subjects as the chroma of colour increased. For further analysis of the correlation of 'deep-pale' colour emotion with chroma, the graphs were plotted in the four hue quadrants and are shown in Figures 3.9a to Figure 3.9d. As the chroma increased, 'neutral' feelings were generally induced in red, yellow and green regions with slightly 'deep' feelings in the red region (Figure 3.9a) and slightly 'pale' feelings in the yellow region (Figure 3.9b) for the high chromatic colours. However, no tendency of inducing a 'neutral' feeling was found in the blue region despite the increase in the chroma of colour (Figure 3.9d).

Heavy-Light Colour Emotion

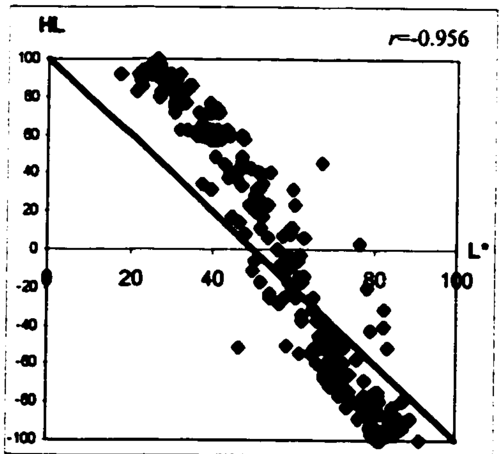

Figure 3.11 Correlation of 'heavy-light' colour emotion, *HL*, with lightness, L^*

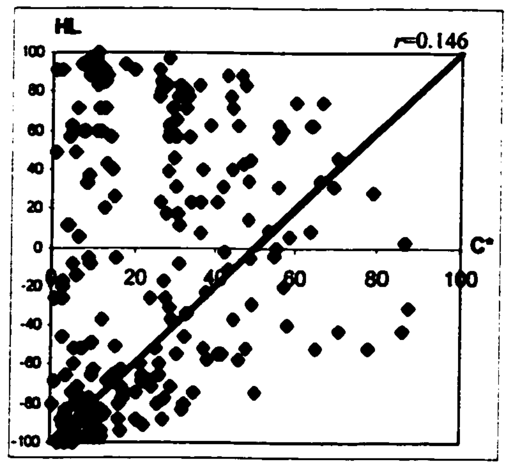

Figure 3.12 Correlation of 'heavy-light' colour emotion, *HL*, with chroma, C^*

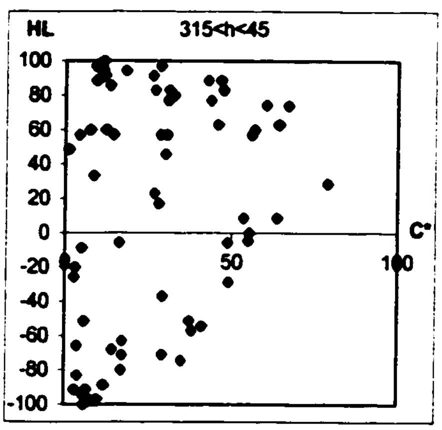

Figure 3.12a Subdivided graph of *HL* against C^* of red colours

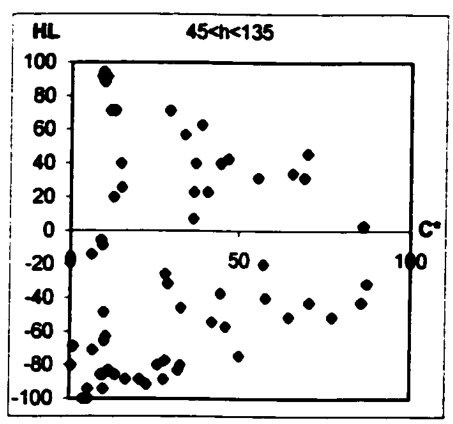

Figure 3.12b Subdivided graph of *HL* against C^* of yellow colours

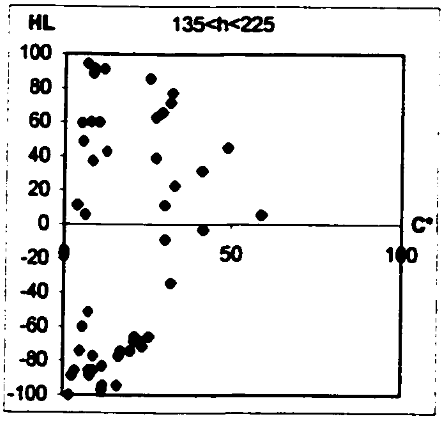

Figure 3.12c Subdivided graph of *HL* against C^* of green colours

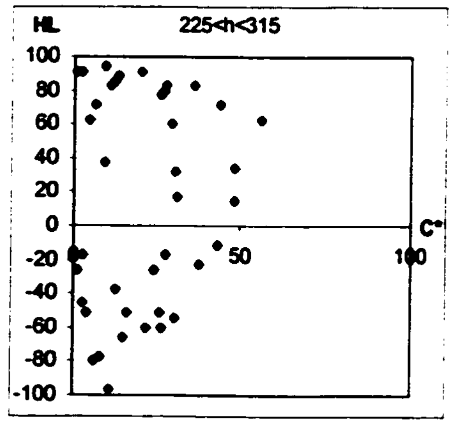

Figure 3.12d Subdivided graph of *HL* against C^* of blue colours

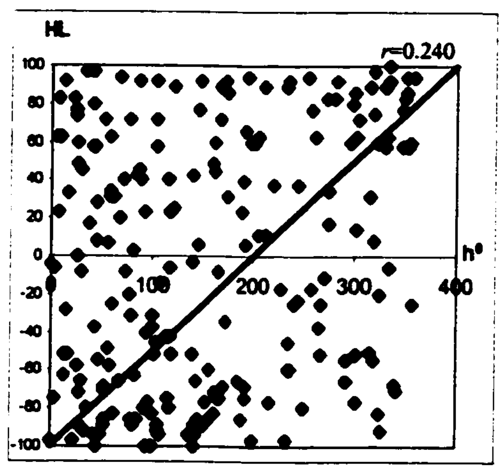

Figure 3.13 Correlation of 'heavy-light' colour emotion, *HL*, with hue, h^0

Similar trends to those observed in the case of 'deep-pale' colour emotion were found in the 'heavy-light' pair. Figure 3.11 indicates that a high correlation between 'heavy-light' colour emotion and lightness was found, in which 'heavy' emotions were induced for colours with low lightness whereas 'light' emotions were induced for those with high lightness. The trend of approaching 'neutral' feelings for high chromatic colours was also found in the 'heavy-light' pair as shown in Figure 3.12. From the four subdivided graphs (Figures 3.12a - 3.12d), similar observations to those of the 'deep-pale' pair were found, i.e., for high chromatic colours, there was less tendency to 'neutral' feelings in the blue region (Figure 3.12d) whereas 'neutral' with slightly 'heavy' feelings in red region (Figure 3.12a) and 'neutral' with slightly 'light' feelings in yellow region (Figure 3.12b) were observd. When the correlation of 'heavy-light' colour emotion pair with hue in Figure 3.13 was evaluated, no significant correlation between them was observed.

Vivid-Sombre Colour Emotion

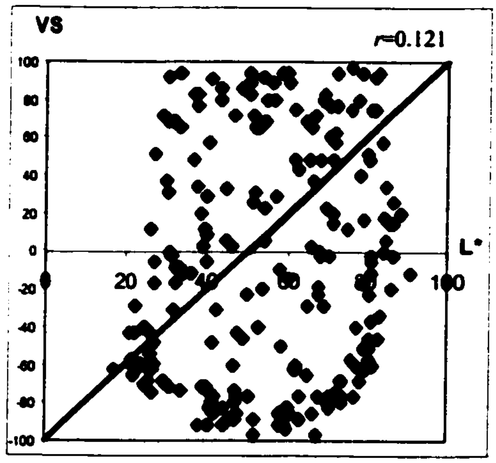

Figure 3.14 Correlation of 'vivid-sombre' colour emotion, VS, with lightness, L^*

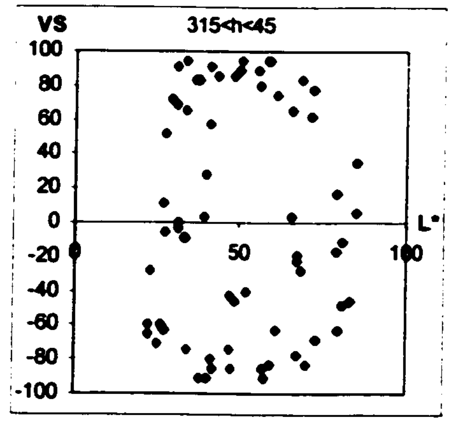

Figure 3.14a Subdivided graph of *VS* against L^* of red colours

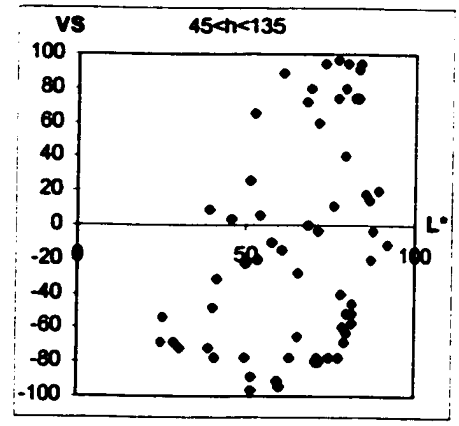

Figure 3.14b Subdivided graph of *VS* against L^* of yellow colours

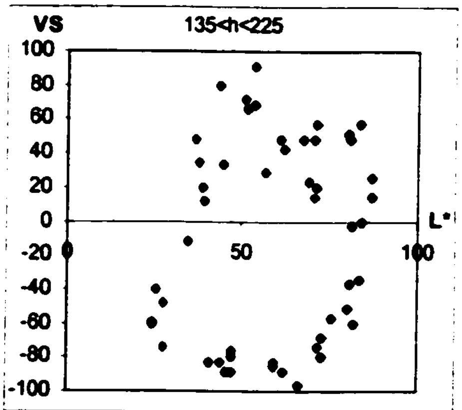

Figure 3.14c Subdivided graph of *VS* against L^* of green colours

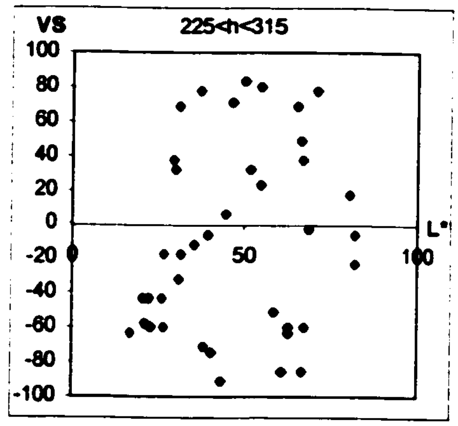

Figure 3.14d Subdivided graph of *VS* against L^* of blue colours

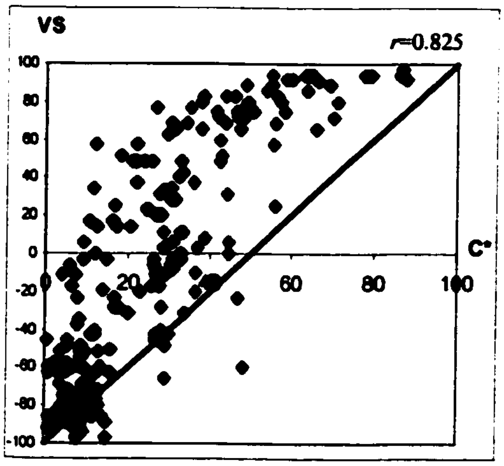

Figure 3.15 Correlation of 'vivid-sombre' colour emotion, *VS*, with chroma, C^*

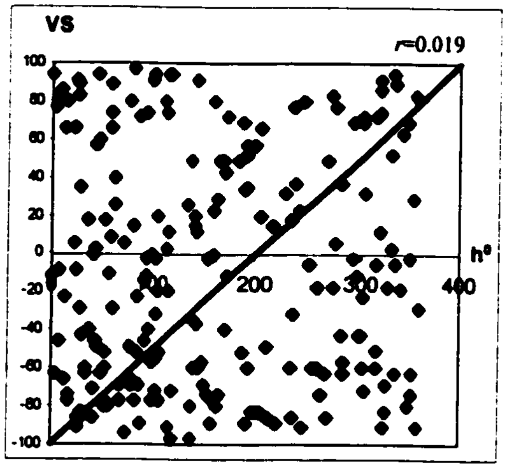

Figure 3.16 Correlation of 'vivid-sombre' colour emotion, *VS*, with hue, h^0

Of the three colorimetric attributes, chroma was found to have the largest impact to the selection of 'vivid-sombre' colour emotion (Figure 3.15), in which as the chroma increased, a 'vivid' feeling tended to be perceived by the subjects. However, no signification correlation to 'vivid-sombre' colour emotion was found with either lightness or hue (Figure 3.14 and Figure 3.16). However, from the further analysis of the four subdivided graphs of the correlation of 'vivid-sombre' colour emotion and lightness, it was found that when the lightness of colour was at a low value, i.e., about 20 to 30, a 'sombre' feeling was induced in the yellow, green and blue regions (Figures 3.14b, 3.14c and 3.14d). However, in the red region, a variety of 'vivid' and 'sombre' emotions were given to the subjects for those colours with low lightness (Figure 3.14a). This indicates that red colours evoked 'vivid' emotions even though they had low lightness values.

Gaudy-Plain Colour Emotion

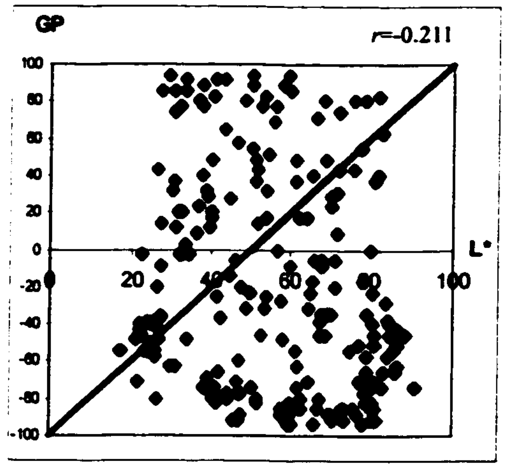

Figure 3.17 Correlation of 'gaudy-plain' colour emotion, *GP*, with lightness, L^*

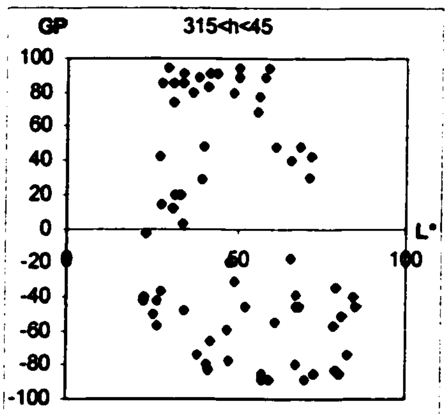

Figure 3.17a Subdivided graph of *GP* against L^* of red colours

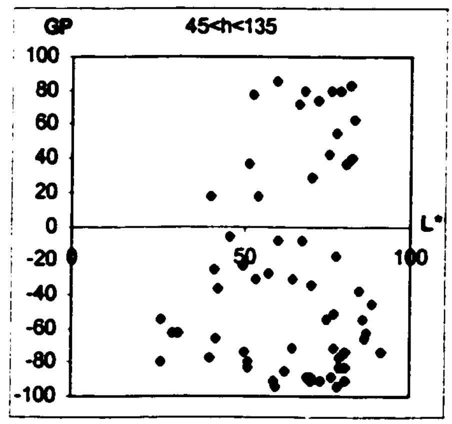

Figure 3.17b Subdivided graph of *GP* against L^* of yellow colours

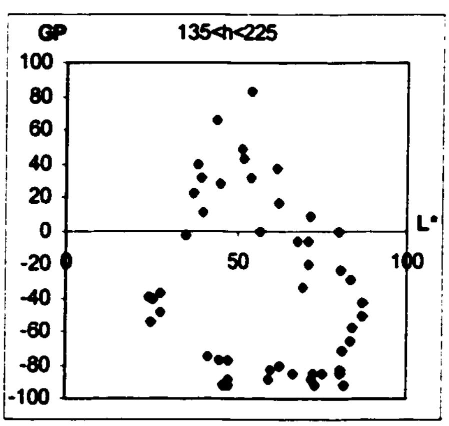

Figure 3.17c Subdivided graph of *GP* against L^* of green colours

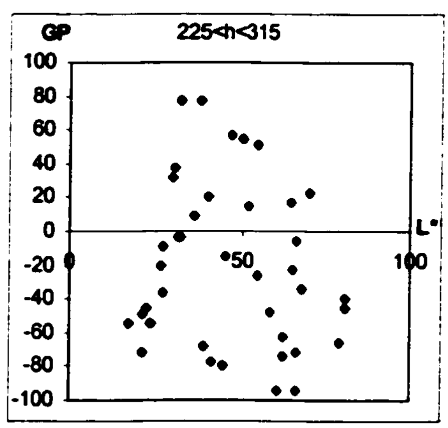

Figure 3.17d Subdivided graph of *GP* against L^* of blue colours

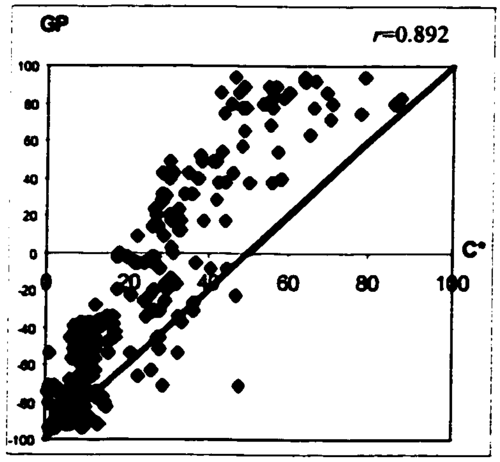

Figure 3.18 Correlation of 'gaudy-plain' colour emotion, *GP*, with chroma, C^*

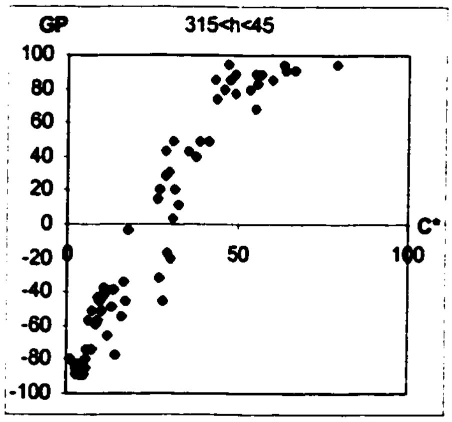

Figure 3.18a Subdivided graph of *GP* against C^* of red colours

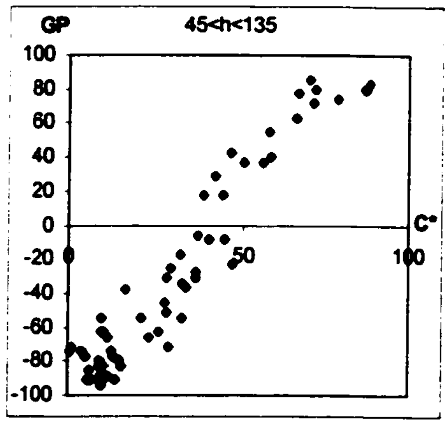

Figure 3.18b Subdivided graph of *GP* against C^* of yellow colours

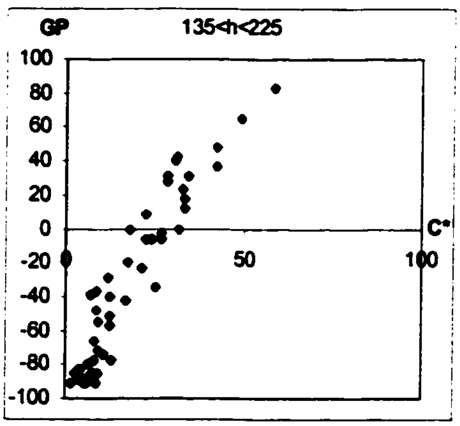

Figure 3.18c Subdivided graph of *GP* against C^* of green colours

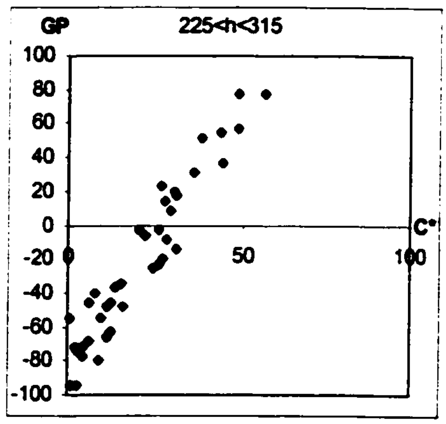

Figure 3.18d Subdivided graph of *GP* against C^* of blue colours

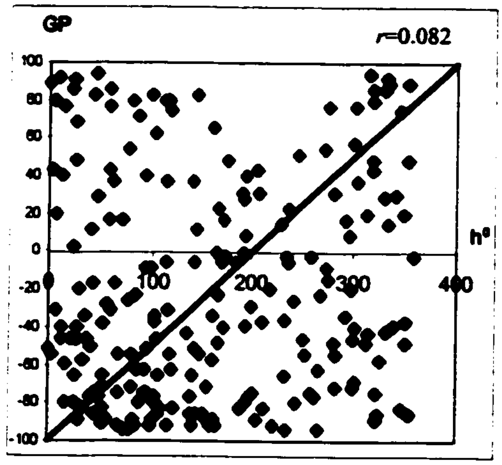

Figure 3.19 Correlation of 'gaudy-plain' colour emotion, *GP*, with hue, h^o

The plottings of 'gaudy-plain' colour emotion against the three colorimetric attributes were found to be similar to those for 'vivid-sombre'. No significant correlation was observed between 'gaudy-plain' and lightness, since the points were scattered randomly in Figure 3.17. However, when evaluating the four subdivided graphs, it was found that 'plain' feelings were usually induced in the subjects' minds for those colours with low lightness values in the yellow, green and blue regions (Figures 3.17b, 3.17c and 3.17d). As in the case of the 'vivid-sombre' pair, in the red region of the 'gaudy-plain' against lightness graph, a variety of 'gaudy' and 'plain' emotions were induced even they had low lightness values (Figure 3.17a).

A very good correlation was obtained between 'gaudy-plain' pair and chroma, which is shown in Figure 3.18. From the four subdivided graphs of 'gaudy-plain' against chroma, linear correlations were found in these graphs (Figures 3.18a - 3.18d). It was observed that in the red region, when the values of chroma were larger than 45, more than 80% subjects assessed these red colours as 'gaudy' (Figure 3.18a), whereas in the yellow region, the values of chroma should be larger than 70 for 80% subjects assessing these yellow colours to be 'gaudy' (Figure 3.18b). This indicates that red colours in this study gave 'gaudy' impressions to the subjects at lower chroma values than the colours of other hues.

Although chroma was found to have the largest impact on the 'gaudy-plain' colour emotion, a slight influence was observed by the hue (Figure 3.19). When the hue angles were between 190^0 to 250^0, less than 50% subjects assessed these greenish blue colours as 'gaudy' whereas for the other hues, a large variety of 'gaudy' and 'plain' emotions were observed.

Striking-Subdued Colour Emotion

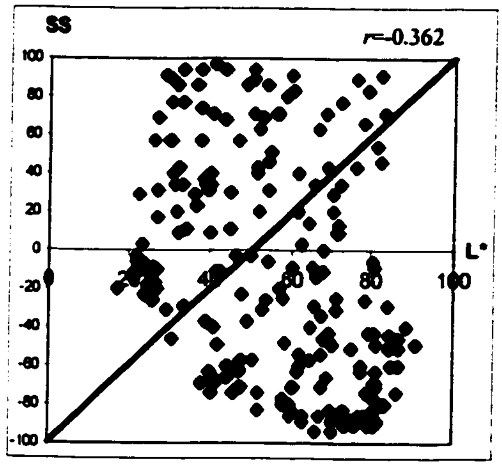

Figure 3.20 Correlation of 'striking-subdued' colour emotion, *SS*, with lightness, L^*

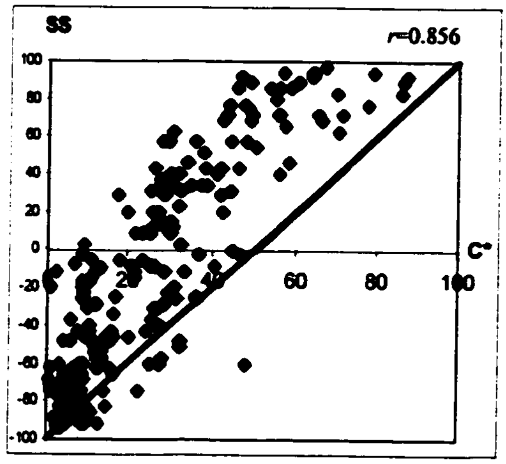

Figure 3.21 Correlation of 'striking-subdued' colour emotion, *SS*, with chroma, C^*

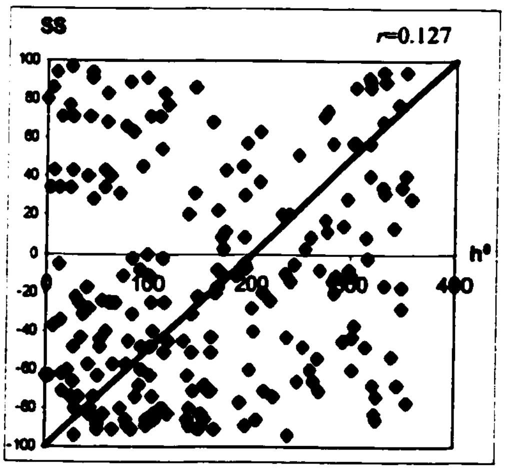

Figure 3.22 Correlation of 'striking-subdued' colour emotion, *SS*, with hue, h^0

As in the cases of the 'vivid-sombre' and 'gaudy-plain' colour emotions, 'striking-subdued' pair also shows high correlation with chroma (Figure 3.21), less significant correlation with hue (Figure 3.22) and no significant correlation with lightness (Figure 3.20). As the chroma of colour increased, a 'striking' feeling was induced. Less 'striking' feeling was found when hue angles are between 180^0 to 250^0.

Dynamic-Passive Colour Emotion

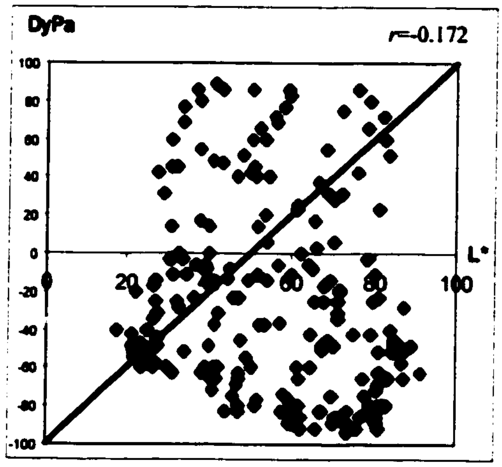

Figure 3.23 Correlation of 'dynamic-passive' colour emotion, *DyPa*, with lightness, L^*

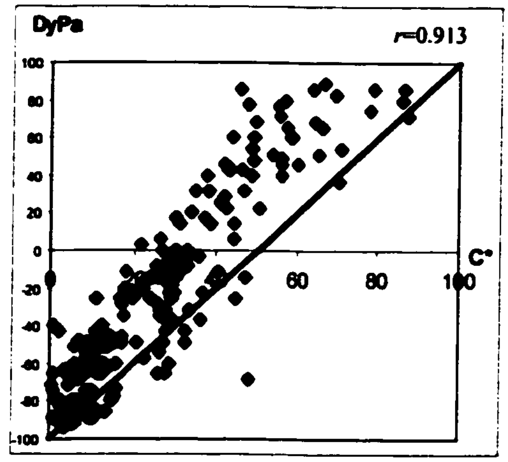

Figure 3.24 Correlation of 'dynamic-passive' colour emotion, *DyPa*, with chroma, C^*

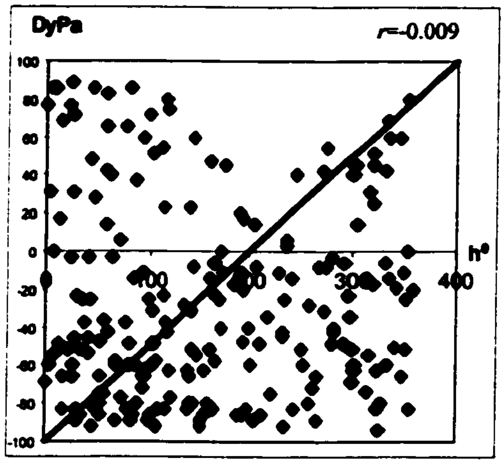

Figure 3.25 Correlation of 'dynamic-passive' colour emotion, *DyPa*, with hue, h^0

The influences of lightness and chroma on 'dynamic-passive' colour emotion were found to be similar to those on 'vivid-sombre', 'gaudy-plain' and 'striking-subdued' pairs (Figures 3.23 and 3.24). Figure 3.24 shows a high correlation between 'dynamic-passive' colour emotion and chroma, a 'dynamic' emotion was induced when perceiving a high chromatic colour, whereas Figure 3.23 shows almost no correlation between 'dynamic-passive' and lightness because the points were scattered randomly in the graph. However, a more significant correlation between 'dynamic-passive' and hue was observed than in the cases of the 'vivid-sombre', 'gaudy-plain' and 'striking-subdued' pairs. In Figure 3.25, it is evident that less than 50% subjects assessed those colours with hue angles between 160^0 to 320^0 as 'dynamic'. This suggests that green and blue colours gave less 'dynamic' feelings than red and yellow colours.

<u>Distinct-Vague Colour Emotion</u>

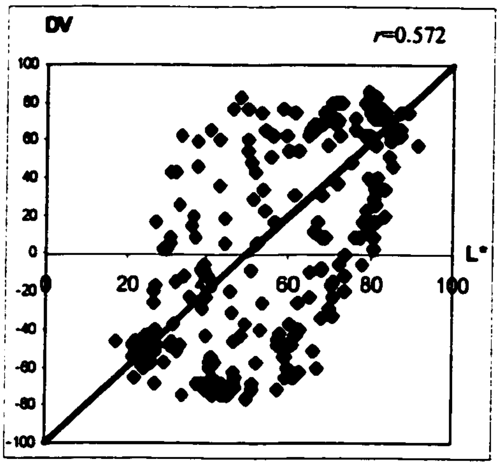

Figure 3.26 Correlation of 'distinct-vague' colour emotion, *DV*, with lightness, L^*

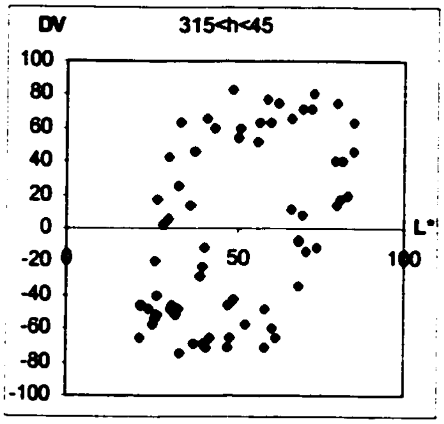

Figure 3.26a Subdivided graph of DV against L^* of red colours

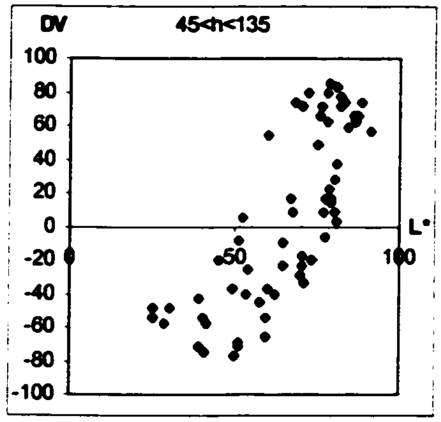

Figure 3.26b Subdivided graph of DV against L^* of yellow colours

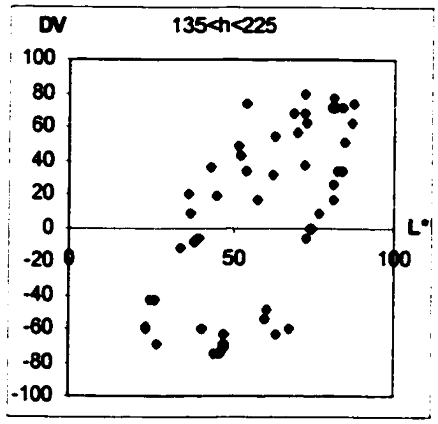

Figure 3.26c Subdivided graph of DV against L^* of green colours

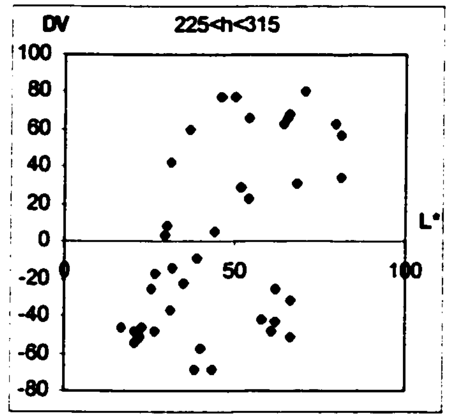

Figure 3.26d Subdivided graph of DV against L^* of blue colours

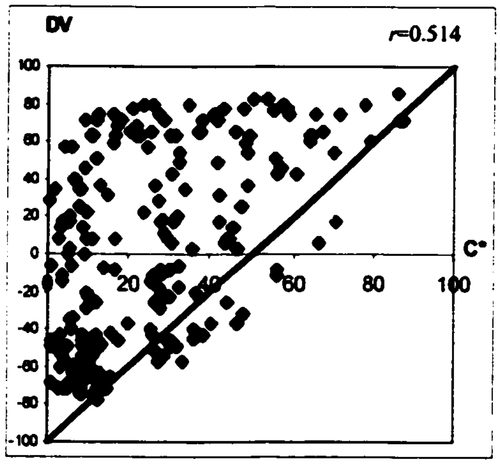

Figure 3.27 Correlation of 'distinct-vague' colour emotion, DV, with chroma, C^*

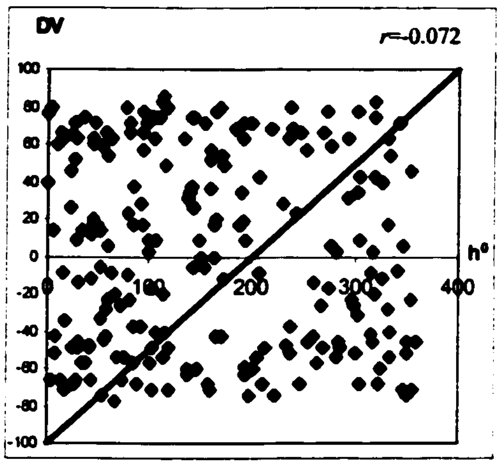

Figure 3.28 Correlation of 'distinct-vague' colour emotion, DV, with hue, h^0

Figure 3.26 illustrates a less obvious trend between 'distinct-vague' and lightness, in which a 'vague' impression was given for colours at low lightness whereas a 'distinct' impression was given for colours at high lightness. When evaluating the four subdivided graphs, more significant correlations with lightness were found in the yellow and green regions (Figures 3.26b and 3.26c) whereas more scattered plots were obtained in the red and blue regions (Figures 3.26a and 3.26d). This result shows that the 'distinct-vague' emotion was much more dependent on the lightness of yellow and green colours than on that of red and blue colours. A 'distinct' emotion was always induced when perceiving colours of high chroma but a variety of 'distinct' and 'vague' emotions were induced when the chroma of colours were low (Figure 3.27). The graph of 'distinct-vague' emotion against hue demonstrates that no obvious correlation was found between them since the plots scattered a lot (Figure 3.28).

Transparent-Turbid Colour Emotion

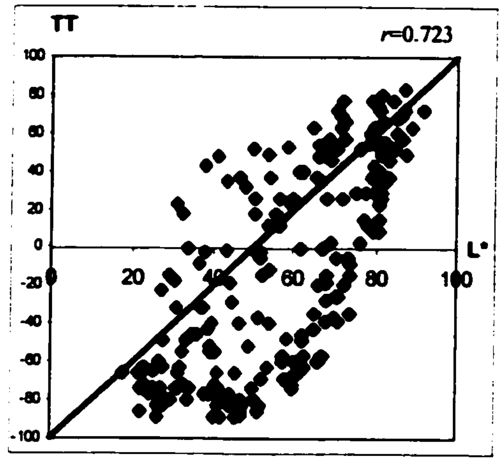

Figure 3.29 Correlation of 'transparent-turbid' colour emotion, *TT*, with lightness, L^*

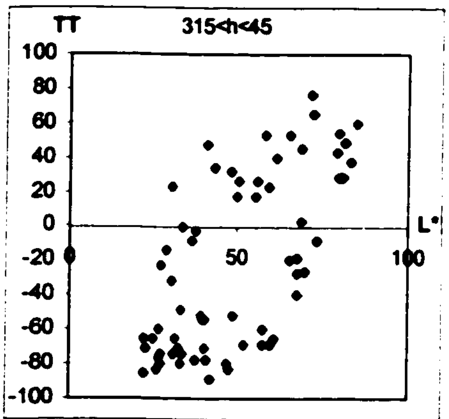

Figure 3.29a Subdivided graph of *TT* against L^* of red colours

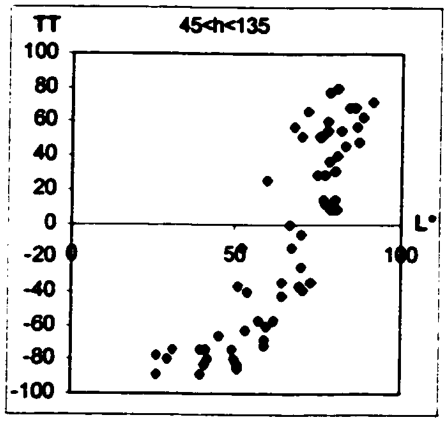

Figure 3.29b Subdivided graph of *TT* against L^* of yellow colours

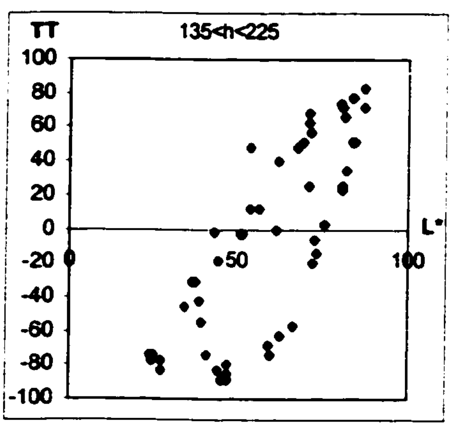

Figure 3.29c Subdivided graph of *TT* against L^* of green colours

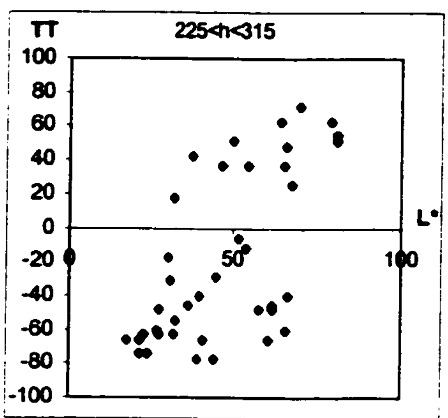

Figure 3.29d Subdivided graph of *TT* against L^* of blue colours

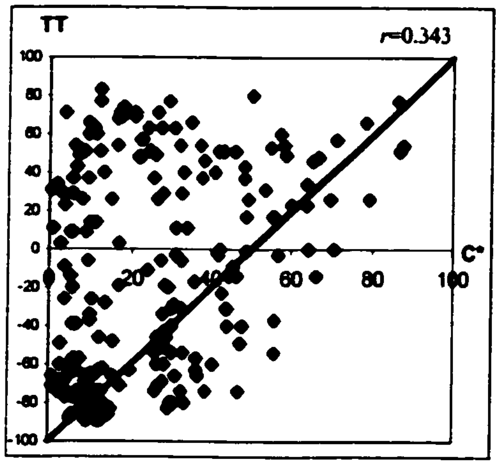

Figure 3.30 Correlation of 'transparent-turbid' colour emotion, *TT*, with chroma, C^*

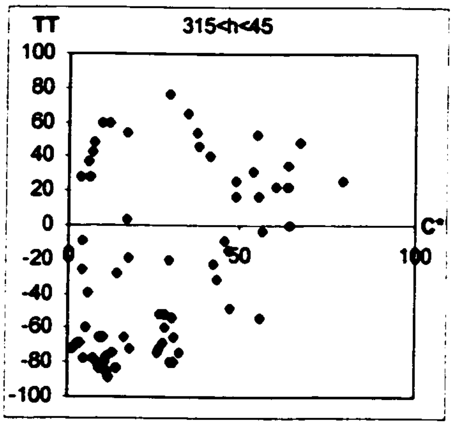

Figure 3.30a Subdivided graph of *TT* against C^* of red colours

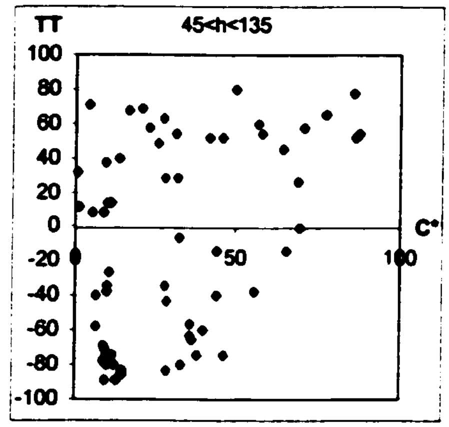

Figure 3.30b Subdivided graph of *TT* against C^* of yellow colours

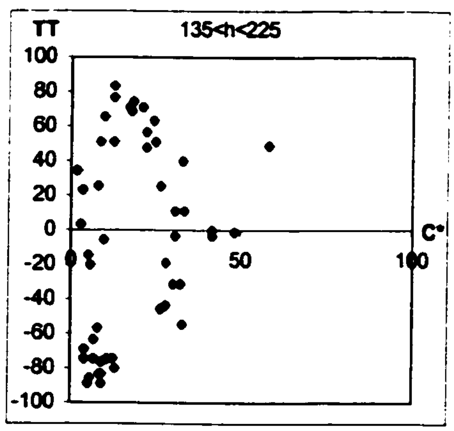

Figure 3.30c Subdivided graph of *TT* against C^* of green colours

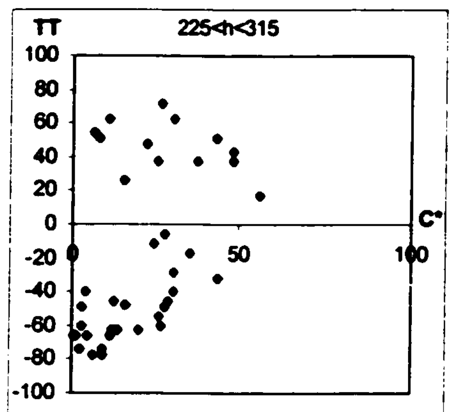

Figure 3.30d Subdivided graph of *TT* against C^* of blue colours

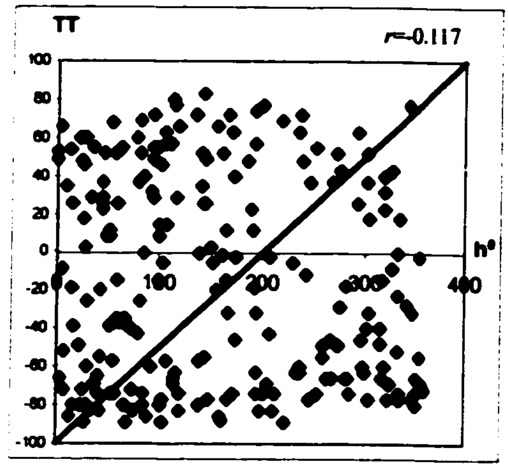

Figure 3.31 Correlation of 'transparent-turbid' colour emotion, TT, with hue, h^0

The 'transparent-turbid' colour emotion was found to have similar correlations to lightness, chroma and hue as those of the 'distinct-vague' colour emotion pair. However, a more obvious correlation with lightness was found in the 'transparent-turbid' colour emotion pair which is shown in Figure 3.29. When the four subdivided graphs were observed, a very good correlation was found between 'transparent-turbid' colour emotion and lightness of yellow colours (Figure 3.29b) and a significant correlation was obtained for the lightness of green colours (Figure 3.29c). However, as in the case of the 'distinct-vague' colour emotion pair, the correlations of 'transparent-turbid' emotion and lightness of red and blue colours, which are shown in Figures 3.29a and 3.29d respectively, were not as obvious as in the cases of yellow and green colours.

Figure 3.30 indicates the 'transparent-turbid' emotion approaching to 'transparent' as the chroma of colour increased. This is best illustrated in the subdivided graph showing the correlation with chroma of yellow colours (Figure 3.30b). Other subdivided graphs for red, green and blue colours, which are shown in Figures 3.30a., 3.30c and 3.30d respectively, the points were more scattered and weaker correlation was observed between chroma and 'transparent-turbid' emotion.

No significant correlation was found between the 'transparent-turbid' colour emotion and hue of colour, as shown in Figure 3.31.

Soft-Hard Colour Emotion

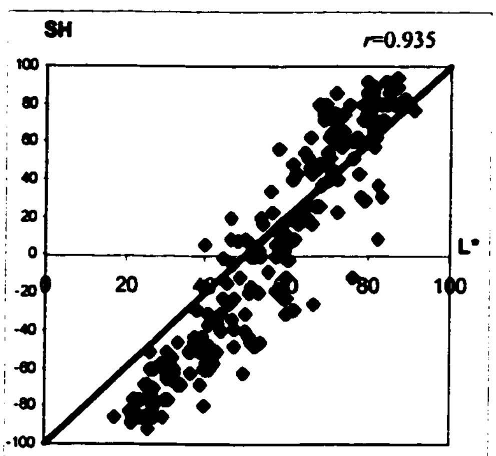

Figure 3.32 Correlation of 'soft-hard' colour emotion, SH, with lightness, L^*

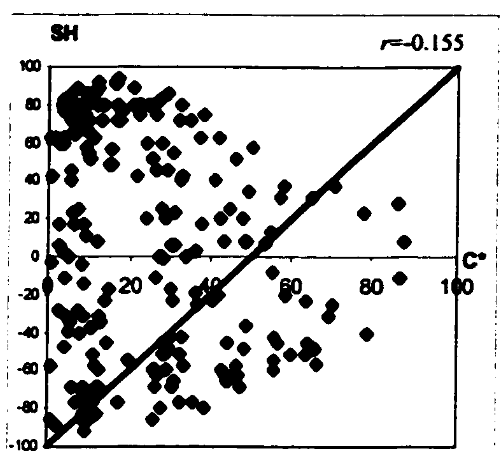

Figure 3.33 Correlation of 'soft-hard' colour emotion, SH, with chroma, C^*

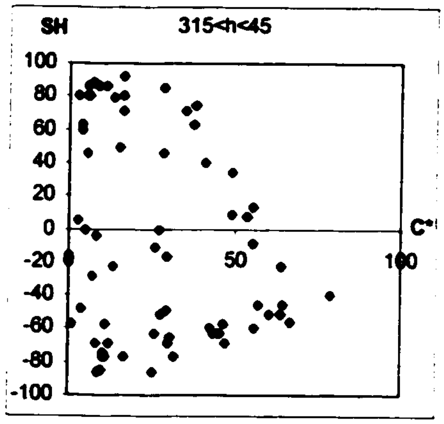

Figure 3.33a Subdivided graph of SH against C^* of red colours

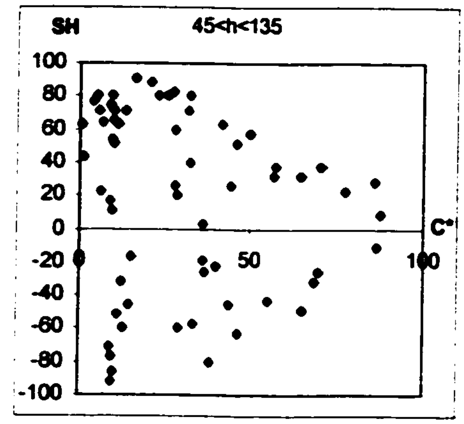

Figure 3.33b Subdivided graph of SH against C^* of yellow colours

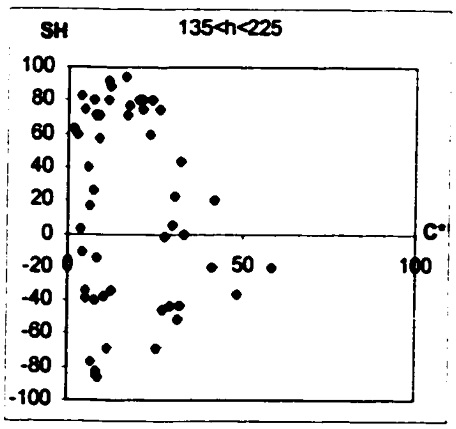

Figure 3.33c Subdivided graph of SH against C^* of green colours

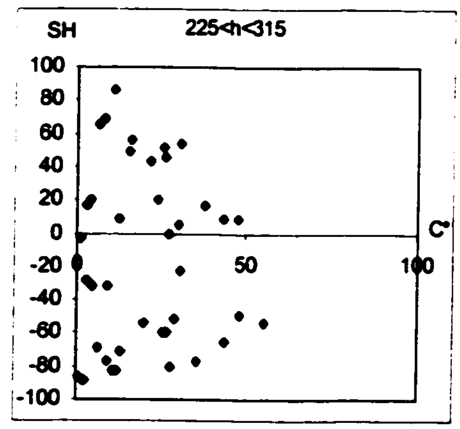

Figure 3.33d Subdivided graph of SH against C^* of blue colours

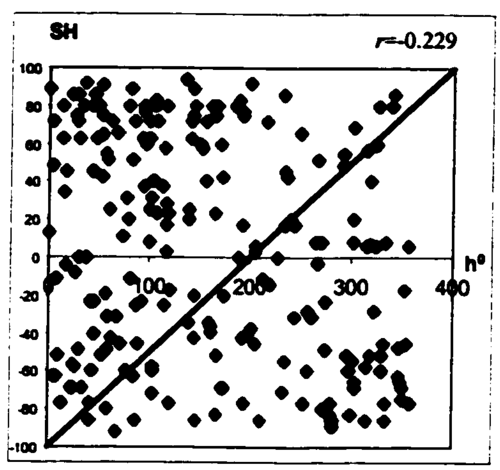

Figure 3.34 Correlation of 'soft-hard' colour emotion, SH, with hue, h^0

A direct linear proportion was found between the 'soft-hard' colour emotion and lightness. Figure 3.32 demonstrates a very good correlation of which 'hard' emotion was induced as the colour had a low lightness value and a 'softer' impression was given as the lightness increased. When the influence of chroma on 'soft-hard' colour emotion was evaluated, it was found that a variety of 'soft' and 'hard' emotions were induced for colours at low chroma, and 'soft-hard' emotion was approaching to 'neutral' as chroma increased to a high value (Figure 3.33). Among the four subdivided graphs shown in Figures 3.33a to 3.33d, this type of trend was found to be most significant in the yellow region (Figure 3.33b), but gradually changed to 'harder' impression was found for the high chromatic colours in the red region (Figure 3.33a). The hue influence on the 'soft-hard' colour emotion was found to be insignificant in the case of the graphical representation shown in Figure 3.34.

Strong-Weak Colour Emotion

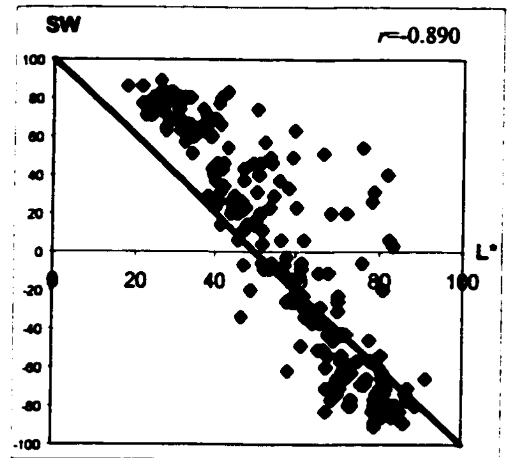

Figure 3.35 Correlation of 'strong-weak' colour emotion, SW, with lightness, L^*

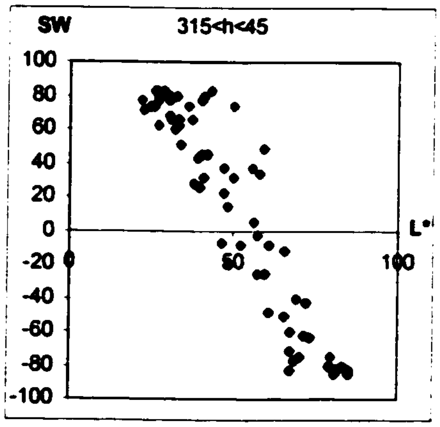

Figure 3.35a Subdivided graph of SW against L^* of red colours

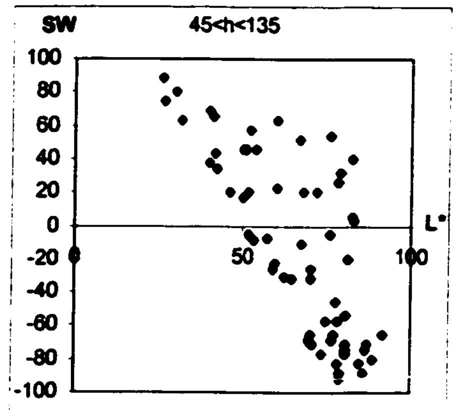

Figure 3.35b Subdivided graph of SW against L^* of yellow colours

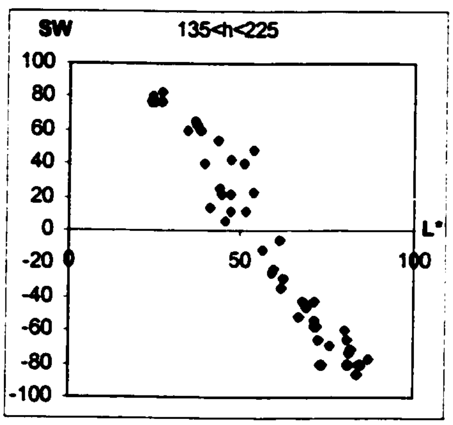

Figure 3.35c Subdivided graph of SW against L^* of green colours

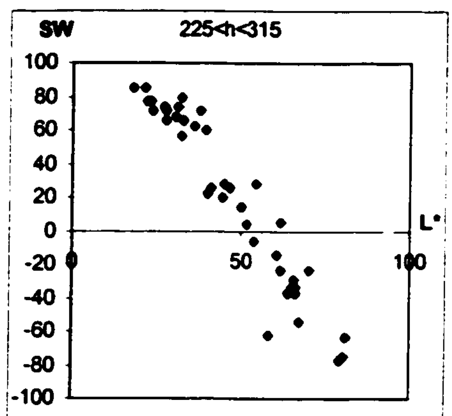

Figure 3.35d Subdivided graph of SW against L^* of blue colours

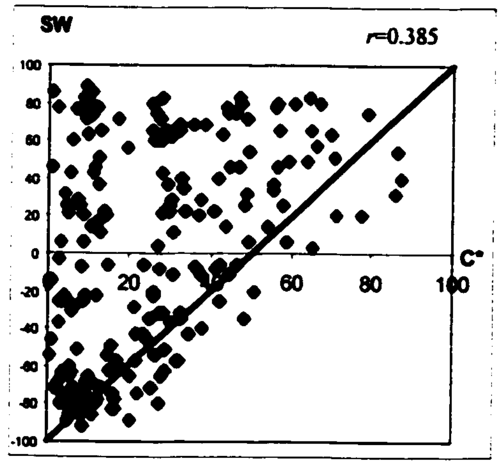

Figure 3.36 Correlation of 'strong-weak' colour emotion, *SW*, with chroma, C^*

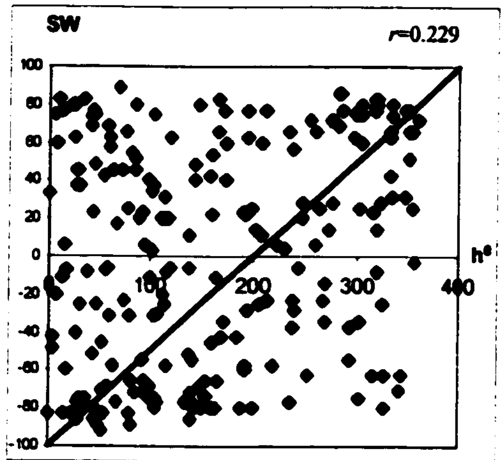

Figure 3.37 Correlation of 'strong-weak' colour emotion, *SW*, with hue, h^0

The 'strong-weak' colour emotion was found to have a significant and linear correlation with the lightness of colour (Figure 3.35), of which a 'weak' emotion was perceived by the subjects for a colour with high lightness. However, when analysing the four subdivided graphs which are shown in Figures 3.35a to 3.35d, some 'strong' impression for the high lightness colours were identified in the yellow region, instead of 'weak' impression as expected (Figure 3.35b). This is because these 'strong' yellow colours were of high chroma. As shown in Figure 3.36, 'strong' feelings were generally perceived by the subjects for the high chromatic colours, whereas a variety of 'strong' and 'weak' emotions are obtained for low chromatic colours. When evalating the influence of hue on 'strong-weak' colour emotion, no significant correlation was observed (Figure 3.37).

3.3.1.2 Correlation Coefficient

The correlation coefficient, *r*, of each colour emotion pair and each colorimetric attribute was calculated and plotted as shown in Table 3.2.

Table 3.2

The correlation coefficient, *r*, of colour emotion and colorimetric attribute

Colour Emotion Pair	Correlation Coefficient, *r*		
	L^*	C^*	h^o
Warm-Cool	0	0.803	-0.189
Light-Dark	0.585	0.597	-0.147
Deep-Pale	-0.954	0.137	0.236
Heavy-Light	-0.956	0.146	0.240
Vivid-Sombre	0.121	0.825	0.019
Gaudy-Plain	-0.211	0.892	0.082
Striking-Subdued	-0.362	0.856	0.127
Dynamic-Passive	-0.172	0.913	-0.009
Distinct-Vague	0.572	0.514	-0.072
Transparent-Turbid	0.723	0.343	-0.117
Soft-Hard	0.935	-0.155	-0.229
Strong-Weak	-0.890	0.385	0.229

From Table 3.2, it may be seen that 'warm-cool' colour emotion was found to be mostly influenced by chroma, C^*, slightly correlated to hue, h^0, and not correlated to lightness, L^*. The influence of L^* and C^* on 'light-dark' colour emotion were found to be similar while only minimal correlation was found with h^0. 'Deep-pale' and 'light-dark' colour emotions had similar correlations to the colorimetric attributes, in that high correlations were found with L^*, whereas only small influences of C^* and h^0 were obtained. The 'vivid-sombre', 'gaudy-plain', 'striking-subdued' and 'dynamic-passive' colour emotions were mainly influenced by C^*, had no significant correlations with L^* and h^0, except for 'striking-subdued' pair, of which a comparatively large influence of L^* on was obtained. 'Distinct-vague' colour emotion was found to be influenced by both L^* and C^* to similar extents, but no significant correlation was found with h^0. 'Transparent-turbid' colour emotion was also found to be influenced by both L^* and C^*, with L^* being the larger one. As in the case of the 'distinct-vague' pair, hue was also found to have no correlation with the 'transparent-turbid' emotion. 'Soft-hard' and 'strong-weak' colour emotions were found to be largely affected by L^* and slightly affected by h^0. But there was a comparatively larger influence of C^* on the 'strong-weak' pair.

3.3.2 Mathematical Models

From the above graphical representations and correlation coefficients illustrating the relationship between colour emotions and colorimetric attributes, it can be concluded that hue was found to have an influence on 'warm-cool', 'deep-pale', ' heavy-light', 'gaudy-plain', 'striking-subdued', 'dynamic-passive', 'soft-hard' and 'strong-weak' colour emotions but not on 'light-dark', 'vivid-sombre', 'distinct-vague' and 'transparent-turbid' colour emotions. Since h^0 ranges from 0^0 to 360^0 and the perception of hue at 0^0 is equivalent to that of at 360^0, two models were derived for those colour emotion pairs which were significantly influenced by hue. One model is for $0^0 \leq h < 180^0$ and the other is for $180^0 \leq h < 360^0$, so that the contribution of hue to those colour emotion pairs could be better quantified. For those pairs that have no significant correlation with hue, only one model was derived for each pair. The mathematical models were derived by optimization, which is called Method I in this study. The models are shown below:

For Warm-Cool colour emotion index,

$$WC_{0^0 \leq h < 180^0} = 0.154L^* + 39.378C^{*(0.372)} - 0.303h - 113.855 \qquad (3.3a)$$

$$WC_{180^0 \leq h < 360^0} = 0.355L^* + 23.476C^{*(0.429)} - 0.159(360^0 - h) - 105.710 \qquad (3.3b)$$

For Light-Dark colour emotion index,

$$LD = 2.111L^{*} + 2.021C^{*} + 0.082h - 187.082 \quad (3.4)$$

For Deep-Pale colour emotion index,

$$DP_{0^0 \leq h < 180^0} = -3.590L^{*} + 0.451C^{*} + 0.040h + 189.467 \quad (3.5a)$$

$$DP_{180^0 \leq h < 360^0} = -3.674L^{*} - 0.216C^{*} + 0.098(360^0 - h) + 189.127 \quad (3.5b)$$

For Heavy-Light colour emotion index,

$$HL_{0^0 \leq h < 180^0} = -3.340L^{*} + 0.476C^{*} + 0.037h + 175.467 \quad (3.6a)$$

$$HL_{180^0 \leq h < 360^0} = -3.477L^{*} - 0.264C^{*} + 0.072(360^0 - h) + 182.866 \quad (3.6b)$$

For Vivid-Sombre colour emotion index,

$$VS = 0.774L^{*} + 17.036C^{*(0.591)} + 0.097h - 172.145 \quad (3.7)$$

For Gaudy-Plain colour emotion index,

$$GP_{0^0 \leq h < 180^0} = -0.332L^{*} + 4.574C^{*(0.867)} - 0.081h - 73.973 \quad (3.8a)$$

$$GP_{180^0 \leq h < 360^0} = -0.114L^{*} + 13.195C^{*(0.664)} - 0.005(360^0 - h) - 103.481 \quad (3.8b)$$

For Striking-Subdued colour emotion index,

$$SS_{0^0 \le h < 180^0} = -0.750L^* + 2.847C^{*(0.961)} - 0.052h - 35.564 \quad (3.9a)$$

$$SS_{180^0 \le h < 360^0} = -0.748L^* + 10.597C^{*(0.684)} + 0.060(360^0 - h) - 54.801 \quad (3.9b)$$

For Dynamic-Passive colour emotion index,

$$DyPa_{0^0 \le h < 180^0} = -0.296L^* + 3.162C^{*(0.931)} - 0.073h - 68.835 \quad (3.10a)$$

$$DyPa_{180^0 \le h < 360^0} = -0.120L^* + 4.385C^{*(0.864)} + 0.032(360^0 - h) - 84.791 \quad (3.10b)$$

For Distinct-Vague colour emotion index,

$$DV = 1.762L^* + 1.468C^* + 0.101h - 148.556 \quad (3.11)$$

For Transparent-Turbid colour emotion index,

$$TT = 2.227L^* + 1.097C^* + 0.100h - 181.715 \quad (3.12)$$

For Soft-Hard colour emotion index,

$$SH_{0^0 \le h < 180^0} = 2.900L^* - 0.510C^* - 0.051h - 146.700 \quad (3.13a)$$

$$SH_{180^0 \le h < 360^0} = 2.953L^* + 0.424C^* - 0.020(360^0 - h) - 159.795 \quad (3.13b)$$

For Strong-Weak colour emotion index,

$$SW_{0^0 \le h < 180^0} = -2.625L^* + 1.185C^* + 0.053h + 116.320 \quad (3.14a)$$

$$SW_{180^0 \le h < 360^0} = -2.758L^* + 0.353C^* + 0.050(360^0 - h) + 135.877 \quad (3.14b)$$

where *WC, LD, DP, HL, VS, GP, SS, DyPa, DV, TT, SH* and *SW* are the 'warm-cool', 'light-dark', 'deep-pale', 'heavy-light', 'vivid-sombre', 'gaudy-plain', 'striking-subdued', 'dynamic-passive', 'distinct-vague', 'transparent-turbid', 'soft-hard' and 'strong-weak' colour emotion indices respectively;

L^* is the CIELAB lightness; C^* is the CIELAB chroma; *and* h^0 is the CIELAB hue-angle;

the models with $0^0<h\leq 180^0$ were derived from the visual assessment results obtained from the hue-angles between 0^0 to 180^0 and those with $180^0<h\leq 360^0$ were derived from the visual assessment results obtained from the hue-angles between 180^0 to 360^0.

These colour emotion indices range from -100 to +100. When equal to +100, indicating that a 'warm', 'light', 'deep', 'heavy', 'vivid', 'gaudy', 'striking', 'dynamic', 'distinct', 'transparent', 'soft' or 'strong' colour emotion is perceived by the subjects. When equal to −100, this means a 'cool', 'dark', 'pale', 'light', 'sombre', 'plain', 'subdued', 'passive', 'vague', 'turbid', 'hard' or 'weak' colour emotion is perceived by them. If the calculated index is outside the boundaries of −100 to +100, it can be assumed to be equal to −100 or +100 respectively.

From the derived mathematical models, it was found that both the lightness and chroma parameters influenced all the colour emotions studied to different extents. In other words, these two attributes contribute to the emotion of the subjects during colour perception. However, the influence of hue was found to be less important in comparison to lightness and chroma. Hue had the largest effect on the 'warm-cool' colour emotion. Therefore, it may be concluded that no matter what the hue of a colour is, most colour emotions studied in this work are only altered by changing in lightness and chroma.

3.3.2.1 Reliability of the mathematical models

The reliability of each derived mathematical model was analysed by calculating the correlation coefficient, *r*, between the data of colour emotion obtained from the visual assessment and calculated from the derived model. They were shown in Table 3.3. The graphical representations showing these correlations were plotted and illustrated in Appendix G.

Table 3.3

Correlation coefficient of colour emotion obtained from visual assessment and that calculated from the derived model

Colour Emotion Pair	Correlation Coefficient, *r*
Warm-Cool	0.862
Light-Dark	0.913
Deep-Pale	0.974
Heavy-Light	0.975
Vivid-Sombre	0.881
Gaudy-Plain	0.943
Striking-Subdued	0.939
Dynamic-Passive	0.938
Distinct-Vague	0.851
Transparent-Turbid	0.868
Soft-Hard	0.958
Strong-Weak	0.965

From the above table, it may be seen that the correlations of all colour emotions obtained from visual assessment and calculated from the derived models were good, since all of the correlation coefficients were larger 0.8. Among these, eight colour emotion pairs, i.e. 'light-dark', 'deep-pale', 'heavy-light', 'gaudy-plain', 'striking-subdued', 'dynamic-passive', 'soft-hard' and 'strong-weak' colour emotions, were found to have very good correlations as the correlation coefficients were larger than 0.9. Hence, it can be concluded that the mathematical models derived in this study were reliable.

3.3.2.2 Mathematical models derived by other method (Method II)

In quantifying colour emotion, other mathematical approaches were also suggested by the Japanese research group, which is called Method II in this study. The models were illustrated here for reference and comparison with those derived by optimization, Method I, in this study.

For Warm-Cool colour emotion index,

$$WC = [3 + 1.9\{\cos(\Delta h_{55})\}]\,(1 - \Delta h_{290}/360)C^{*} - 70$$

For Light-Dark colour emotion index,

$$LD = [\{4.1L^{*}\}^{2} + \{8\,(1 - \Delta h_{290}/360)C^{*}\}^{2}]^{1/2} - 305$$

For Deep-Pale colour emotion index,

$$DP = [\{4.3(L^{*}-100)\}^{2} + \{1.7\,(1 + 0.8\cos(\Delta h_{90}))(1 - \Delta h_{290}/360)C^{*}\}^{2}]^{1/2} - 195$$

For Heavy-Light colour emotion index,

$$HL = -[\{3.8(L^{*}-20)\}^{2} + \{0.9\,(1 - \Delta h_{290}/360)C^{*}\}^{2}]^{1/2} + 145$$

For Vivid-Sombre colour emotion index,

$$VS = [\{3.1(L^*-85)^2 + \{7.5\,(1-\Delta h_{290}/360)C^*\}^2\}^{1/2} - 165$$

For Gaudy-Plain colour emotion index,

$$GP = [\{0.6(L^*-50)\}^2 + \{4.7\,(1-\Delta h_{290}/360)C^*\}^2]^{1/2} - 105$$

For Striking-Subdued colour emotion index,

$$SS = [\{0.1(L^*-40)\}^2 + \{4.7\,(1-\Delta h_{290}/360)C^*\}^2]^{1/2} - 95$$

For Dynamic-Passive colour emotion index,

$$HL = -[\{3.8(L^*-20)\}^2 + \{0.9\,(1-\Delta h_{290}/360)C^*\}^2]^{1/2} + 145$$

For Distinct-Vague colour emotion index,

$$DV = [\{4.8(L^*-100)\}^2 + \{5.0\,(1-\Delta h_{290}/360)C^*\}^2]^{1/2} - 155$$

For Transparent-Turbid colour emotion index,

$$TT = [\{4.8\,(L^* - 35)\}^2 + [4.7\,\{1 + 0.3\cos(\Delta h_{290})\} \times \{1 + 0.35\cos(\Delta h_{220})\}$$

$$(1 - \Delta h_{290}/360)C^*]^2]^{1/2} - 180$$

For Soft-Hard colour emotion index,

$SH = [(3.2L^*)^2 + \{(1 - \Delta h_{290}/360)C^*\}^2]^{1/2} - 180$

For Strong-Weak colour emotion index,

$SW = [\{3.1(L^* - 85)\}^2 + \{2.6\,(1 - \Delta h_{290}/360)C^*\}^2]^{1/2} - 105$

where L^* is the CIELAB lightness; C^* is the CIELAB chroma; h^0 is the CIELAB hue-angle; and Δh_x is the hue-angle difference from h=x, $0 \leq \Delta h_x \leq 180$

The correlation coefficient, *r*, between the data of colour emotion obtained from the visual assessment and calculated from Method II for each pair is shown in Table 3.4. In addition, the correlation coefficient between the visual assessment data and the data calculated from Method I was included for comparison.

Table 3.4

Comparison of correlation coefficients of the colour emotion data from visual assessment and those calculated from the models derived by Methods I and II

Colour Emotion Pair	Correlation Coefficient, r	
	Method I	**Method II**
Warm-Cool	0.862	***0.872***
Light-Dark	0.913	***0.923***
Deep-Pale	0.974	***0.978***
Heavy-Light	***0.975***	0.963
Vivid-Sombre	***0.881***	0.862
Gaudy-Plain	0.943	***0.953***
Striking-Subdued	***0.939***	0.920
Dynamic-Passive	0.938	***0.939***
Distinct-Vague	***0.851***	-0.380
Transparent-Turbid	0.868	***0.870***
Soft-Hard	***0.958***	0.936
Strong-Weak	***0.965***	0.962

From Table 3.4, it may be seen that the correlation coefficients of visual assessment data and the data calculated from the Method II models were very close to those from the Method I models in almost all colour emotion pairs, with the exception in the 'distinct-vague' colour emotion pair for which the correlation with the Method II mathematical model was very poor, with r=-0.380. This modelling method was not suitable for the 'distinct-vague' colour emotion of

Hong Kong's subjects. Table 3.4 illustrates that half of the colour emotion pairs showed a better correlation with the models derived by Method II whereas half of them had a higher correlation with the models derived by Method I. Those with higher correlation coefficients are highlighted with **bold** and *italics* in Table 3.4. Since the mathematical models derived by the two methods performed similarly in terms of correlation coefficient and those derived in this study are simpler and readily understood, Method I modelling technique will be used for further analysis of other data in the following chapters.

3.3.3 Categorization of colour emotions

According to the above findings, the dominant parameter(s) of colorimetric attribute influencing the selection of each colour emotion was investigated and they are shown in Table 3.5

Table 3.5

The dominant parameter(s) and its(theirs) effect for each colour emotion pair

Colour Emotion Pair	Dominant Parameter(s), Effect
Warm-Cool	Chroma, Positive (a comparatively large hue influence when comparing among all pairs)
Light-Dark	Chroma & Lightness, Positive for both
Deep-Pale	Lightness, Negative
Heavy-Light	Lightness, Negative
Vivid-Sombre	Chroma, Positive
Gaudy-Plain	Chroma, Positive
Striking-Subdued	Chroma, Positive
Dynamic-Passive	Chroma, Positive
Distinct-Vague	Lightness & Chroma, Positive for both
Transparent-Turbid	Lightness & Chroma, Positive for both
Soft-Hard	Lightness, Positive
Strong-Weak	Lightness, Negative

The correlations of colour emotion pairs were analysed for the purpose of categorization. The correlation coefficients of the twelve colour emotion word pairs were calculated according to the visual assessment results in this study and are shown in Table 3.6.

Table 3.6

The correlation coefficients, *r*, of colour emotion word pairs

r	WC	LD	DP	HL	VS	GP	SS	DyPa	DV	TT	SH	SW
WC	1.0	0.64	0.06	0.07	0.84	0.84	0.79	0.87	0.57	0.41	-0.03	0.25
LD		1.0	-0.57	-0.56	0.84	0.59	0.47	0.62	0.96	0.92	0.56	-0.32
DP			1.0	0.99	-0.09	0.25	0.40	0.23	-0.58	-0.73	-0.97	0.93
HL				1.0	-0.09	0.26	0.41	0.23	-0.58	-0.73	-0.97	0.94
VS					1.0	0.91	0.84	0.90	0.81	0.66	0.11	0.16
GP						1.0	0.97	0.97	0.54	0.34	-0.23	0.48
SS							1.0	0.95	0.43	0.22	-0.39	0.62
DyPa								1.0	0.56	0.36	-0.23	0.48
DV									1.0	0.96	0.58	-0.35
TT										1.0	0.73	-0.53
SH											1.0	-0.95
SW												1.0

The twelve colour emotion pairs shown in Tables 3.5 and 3.6 were categorized into 3 groups according to the parameter of colour which had the largest influence to the selection of colour emotion and the correlation between these colour emotion pairs. The effect of each dominant parameter is shown in Table 3.5, in which a positive effect indicates that as the magnitude of the parameter of a colour increases, the colour emotions will become 'warm', 'light', 'deep', 'heavy', 'vivid', 'gaudy', 'striking', 'dynamic', 'distinct', 'transparent', 'soft' and 'strong'. An opposite representation is applied on the negative effect, i.e., as the magnitude of the parameter increases, the colour emotion will approach to the opposite part of the emotion pair.

From Table 3.6, it may be seen that there was a high correlation between two colour emotion pairs which gave a large magnitude of correlation coefficient, i.e., near 1 or –1. For example, the correlation coefficient between 'Deep-Pale' and 'Heavy-Light' was 0.99, which represents a good correlation between these two colour emotion pairs. In other words, a colour which induces a 'deep' perception to the subjects will also induce a 'heavy' perception. When the correlation coefficient is close to 0, this indicates that there is no correlation between these two colour emotion pairs. For example, the correlation coefficient between 'Vivid-Sombre' and 'Soft-Hard' was 0.11, and this suggests that there is almost no correlation between these two colour emotion pairs. Correlation coefficients with negative signs (-) indicate an adverse effect between the corresponding two colour emotion pairs. For example, the correlation coefficient between 'Heavy-Light' and 'Soft-Hard' was –0.97, this indicates that there was a high correlation between these two pairs, and if a colour gives a 'heavy' feeling to the subjects, a 'hard' feeling will be induced as well; whereas if a colour induces a 'light' emotion, a 'soft' perception will also be given to the subjects when viewing that colour.

Group 1 — The colour emotion selection is mainly affected by the chroma of a colour with a positive effect. The colour emotion pairs in this group are 'warm-cool', 'vivid-sombre', 'gaudy-plain', 'striking-subdued' and 'dynamic-passive'. As the chroma of a colour increases, a 'warm', 'vivid', 'gaudy', 'striking' and 'dynamic' feeling will be perceived by the subjects. However, since hue contributes a certain degree of influence on the 'warm-cool' emotion, green and blue colours induce 'cool' emotion to the subjects' minds whereas 'warm' emotions are generally induced when perceiving red and yellow colours, but increasing the chroma of colour will always gave a 'warmer' feeling to the subjects. The colour emotions in this group are defined as 'Chroma Dependent Colour Emotions'.

Group 2 — The colour emotion selection is mainly affected by the lightness of a colour. The colour emotion pairs in this group are 'deep-pale', 'heavy-light', 'soft-hard' and 'strong-weak'. The effect of lightness was found to be positive in the 'soft-hard' pair. As the lightness of a colour increases, a 'soft' feeling will be perceived by the subjects. However, a negative effect of lightness was found in the 'deep-pale', 'heavy-light' and 'strong-weak' pairs. As the lightness of a colour increases, a 'pale', 'light' and 'weak' feeling will be evoked in the subjects. The colour emotions in this group are defined as 'Lightness Dependent Colour Emotions'.

Group 3 --- The colour emotion selection is mainly affected by both the chroma and lightness of colour. Both parameters have positive effects on 'light-dark', 'distinct-vague' and 'transparent-turbid' colour emotions. As either the chroma or the lightness of a colour increases, the feelings of the subjects will tend to 'light', 'distinct' and 'transparent'. The colour emotions in this group are defined as 'Lightness and Chroma Dependent Colour Emotions'.

3.4 Conclusions

The influence of each colorimetric attribute on each colour emotion pair was analysed in this study. The contribution of hue of colour to colour emotion was found to be less important as the other attributes, and the main influence was found to be in the 'warm-cool' colour emotion pair. Lightness and chroma of colour were found to be the dominant influential attributes in these twelve pairs of colour emotions. In conclusion, human colour emotions are mainly determined by either the lightness or the chroma, or both of them for those colour emotion pairs in this study.

Mathematical models were derived in this study to correlate the colour emotion pairs with the three colorimetric attributes, which are defined by CIE colorimetry. The quantitative correlations between colours and colour emotions are clearly illustrated in the models. With the establishment of these models, the communication between the designers or colour users and the colourists can be much improved. If the designers or colour users wish to know about the colour emotions of the customers after selecting the colours for their products, they can measure the selected colours by means of a spectrophotometer simply to obtain the CIE colorimetric attributes and then insert them into the derived models to obtain the colour emotion indices. Since numerical values are used in such colour emotion models, the designers or colour users can communicate with the colourists by the colorimetric attributes, rather than the subjective description of the colours, so that misunderstandings can be avoided.

Moreover, the colour emotion pairs were categorized into different groups according to the most influential attribute(s) on the selection of colour emotion towards colours, and these groups are the 'Chroma Dependent Colour Emotions' which include 'warm-cool', 'vivid-sombre', 'gaudy-plain', 'striking-subdued' and 'dynamic-passive' colour emotion pairs, 'Lightness Dependent Colour Emotions' which include 'deep-pale', 'heavy-light', 'soft-hard' and 'strong-weak' colour emotion pairs, and 'Lightness and Chroma Dependent Colour Emotions' which include 'light-dark', 'distinct-vague' and 'transparent-turbid' colour emotion pairs.

COMPARISON OF COLOUR EMOTIONS OF DIFFERENT GENDER

4.1 Objectives

- To compare the colour emotion results obtained from male and female.
- To analyse the influence of gender on colour emotions.

4.2 Methodology

4.2.1 Visual Assessment

The subjects, colour samples, experimental conditions and questionnaire in the visual assessment for the comparison of colour emotions between genders were the same as those in Section 3.2.1.

4.2.2 Calculation of Colour Emotion Percentage

The method for calculating the colour emotion percentage was the same as the two-point method for quantifying colour emotions that was shown in Section 3.2.2. However, the colour emotion percentage for each word pair was divided into two groups, which were male and female, so that two percentages of each colour were obtained for each colour emotion pair in this comparison. The following examples show the calculations of the 'warm-cool' percentages, $WC_{male}\%$ and $WC_{female}\%$, after assessing the 'warm-cool' colour emotion of colour sample 5R1 by the male and female subjects respectively.

$$WC_{male}\% = \frac{a \times (+1) + b \times (-1)}{a + b} \times 100\% \qquad (4.1)$$

$$WC_{female}\% = \frac{c \times (+1) + d \times (-1)}{c + d} \times 100\% \qquad (4.2)$$

where a and c are the number of male and female subjects selecting 'warm' colour emotions for colour sample 5R1 respectively;

b and d are the number of male and female subjects selecting 'cool' colour emotions for colour sample 5R1 respectively; and

$a+b$ is the total number of male subjects, whereas $c+d$ is the total number of female subjects, and both of them are equal to 35 in this study.

If all male subjects selected 'warm' to describe the colour, $WC_{male}\%$ was equal to 100%; whereas if all female subjects selected 'warm' to describe the colour, $WC_{female}\%$ was equal to 100%. If all male subjects selected 'cool' to describe the colour, $WC_{male}\%$ was equal to –100%, whereas if all female subjects selected 'cool' to describe the colour, $WC_{female}\%$ is equal to -100%. All the other colour emotion percentages were calculated using this method.

4.2.3 Paired-Samples *t*-Test

The colour emotion results obtained from the male and females subjects for the same colour were paired and the similarity or difference in their colour emotions were compared statistically by paired-sample *t*-test. The calculation of *t*-value for each colour emotion pair is shown below (Hopkins et al., 1996):

$$t = \frac{\overline{X}_1 - \overline{X}_2}{\sqrt{s_{\overline{X}_1}^{\ 2} + s_{\overline{X}_2}^{\ 2} - 2r s_{\overline{X}_1} s_{\overline{X}_2}}} \tag{4.3}$$

in which $s_{\overline{X}_1}^{\ 2} = s_1^{\ 2}/n$ and $s_{\overline{X}_2}^{\ 2} = s_2^{\ 2}/n$;

where $\overline{X}_1$ and $\overline{X}_2$ are the means of the colour emotion results of the male and female subjects respectively;

$s_1^{\ 2}$ and $s_2^{\ 2}$ are the standard deviations for the male and female colour emotion results respectively;

n is the number of pairs; and

r is the correlation between the 2 sets of results.

If the calculated t-value for a colour emotion pair was larger than the critical value of t at the 0.001 level of significance, the colour emotion of the male and female subjects was considered to have a statistically significant difference between them. However, if there are many numbers of pairs, or if two variables correlate highly, even small, trivial differences in means can result in large *t*-ratios, and thus highly significant mean differences. Hence, statistical significance provides the information confidently that there is some difference between the parameters, but the size of the difference should be analysed by some other methods (Dunn, 2001, Hopkins et al., 1996 and Kiess, 1989).

There is a constraint in using the paired-samples *t*-test. Since the denominator in Equation 4.3 involves correlation coefficient, r; if r is small, i.e. two samples are not correlated with each other and thus it is expected that they have significant difference, the denominator in Equation 4.3 becomes large that results in small *t*-ratio which is probably smaller than the critical *t*-value, and, hence, no significant difference between two samples is concluded in the paired-samples *t*-test, that is contradiction to the real case. Therefore, the paired-samples *t*-test is suitable for those having sufficiently high correlation (Heiman, 1992). In this study, if the correlation coefficient, r, of the colour emotion of the male and female subjects was found to be larger than 0.837, i.e. $r^2>0.7$, it was considered that this colour emotion pair is sufficiently correlated for further statistical analysis by the paired-samples t-test. This value was set because the coefficient of determination, r^2, was larger than 0.7, which means 70% of the variation in the dependent variable can be explained by the independent variable and it represents a valuation correlation is found between these two variables.

4.2.4 Definition of terms

In this study, the CIE lightness, $L*$, of the 218 colour samples ranged from 17.4 to 91.3. For convenience, those with $L*$ below 40 were regarded as low lightness colours, with $L*$ in between 40 to 70 were considered as medium lightness colours, while those with $L*$ larger than 70 were the high lightness colours.

The range of CIE chroma, $C*$, of the colour samples was from 0.5 to 87.5. The samples with $C*$ smaller than 20 were considered to be low chromatic colours, while those with $C*$ between 20 and 40 were regarded as colours of medium chroma, and those with $C*$ larger than 40 were the high chromatic colours.

When the hue-angles of the colour samples were smaller than 45^0 or larger than 315^0, they were regarded as 'red' colours. For those colours with hue-angles between 45^0 and 135^0, they were regarded as 'yellow' colours. Those colours with hue-angles between 135^0 and 225^0 were regarded as 'green' colours while those with hue-angles between 225^0 and 315^0 were regarded as 'blue' colours.

When the difference in colour emotion percentages between male and female subjects for a colour was found to be larger than 50%, a practically significant difference was considered to exist in their colour emotion during the perception of this colour. For example, for a specific colour, WC_{male}% was found to be 96% and WC_{female}% was found to be 42% and the difference was 54%; therefore, male and female subjects were regarded as having practically significant difference in their colour emotion when perceiving this colour

4.3 Results and Discussion

Since the twelve colour emotion pairs were categorized into 3 groups according to the dominant parameter(s) in Chapter 3, the following comparisons of colour emotions between male and female subjects are shown under this categorization method.

4.3.1 Correlation Coefficients and Results of Paired-Samples *t*-Test

The correlation coefficients, *r*, and results of paired-samples *t*-test showing the comparison of colour emotions between different gender are illustrated in

Table 4.1. Since the correlation coefficients were all calculated to be larger than 0.837, they were regarded as valuable for further investigation by the pair-samples t-test. If the calculated t-value in the t-test was smaller than the critical t-value, the colour emotion between the male and female subjects was considered to have 'no statistically significant difference' between them.

Table 4.1

Comparison of colour emotions between the male and female subjects by correlation coefficients and paired-samples t-test

Category	Colour Emotion	Correlation Coefficient, r	Significant Difference between male and female subjects (at 0.001 level of significance)
Chroma Dependent Colour Emotions	Warm-Cool	0.883	Yes
	Vivid-Sombre	0.940	No
	Gaudy-Plain	0.948	No
	Striking-Subdued	0.939	Yes
	Dynamic-Passive	0.900	Yes
Lightness Dependent Colour Emotions	Deep-Pale	0.973	No
	Heavy-Light	0.958	Yes
	Soft-Hard	0.925	Yes
	Strong-Weak	0.935	Yes
Lightness and Chroma Dependent Colour Emotions	Light-Dark	0.951	Yes
	Distinct-Vague	0.924	No
	Transparent-Turbid	0.957	Yes

In Table 4.1, it was found that most of the colour emotions of the male subjects were statistically different from those of the female ones. Among these colour emotion pairs, 'deep-pale', 'vivid-sombre', 'distinct-vague' and 'gaudy-plain' colour emotions were considered as there were no statistically significant difference between the perceptions of the male and female subjects in this study.

4.3.2 Chroma Dependent Colour Emotions

4.3.2.1 Warm-cool colour emotion

The 'warm-cool' colour emotion results for male and female subjects were plotted and are shown in Figure 4.1, and the correlation coefficient of them is illustrated in the figure as well.

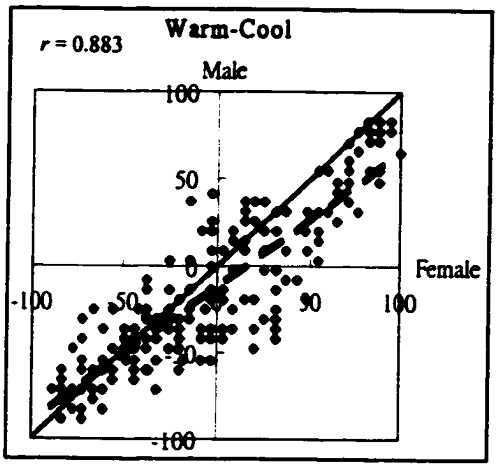

Figure 4.1 Correlation of 'warm-cool' colour emotion of male and female subjects.

The solid line in Figure 4.1 is the 45-degree line of the graph. When the plots are located on this solid line, the colour emotion of the colours given to the male and female subjects is the same. When more plots are close to the 45-degree line, a better correlation is found in the male and female subjects. The broken line in Figure 4.1 shows the general trend of the correlation of the 'warm-cool' colour emotion of male and female subjects. If the broken line lies near or on the solid line, this represents a very good correlation; however, a larger deviation of the broken line from the solid line indicates a lower correlation in the colour emotion of male and female subjects.

In Figure 4.1, the plots of the 'warm-cool' colour emotion of male and female subjects are located quite close to the 45-degree line and the correlation coefficient was found to be 0.833, this represents a quite good correlation in male and female subjects. The broken line illustrates an obviously larger deviation in the 'warm' part, i.e., the portion where both *WC%* of the male and female subjects are positive, than the 'cool' part, i.e., the portion where both *WC%* of male and female subjects are negative. This indicates that those 'warm' colours evoked 'warmer' feeling in the female subjects than the male ones, whereas they had similar perception on the 'cool' colours.

In Table 4.1, a statistically significant difference was found between the 'warm-cool' colour emotion of the male and female subjects in the paired-samples *t*-test. The practical differences in 'warm-cool' colour emotion percentages between the male and female subjects were then assessed. It was found that only 2 colour samples evoked an obviously 'cooler' feeling in the female subjects than the male ones, i.e., $WC_{female}\%$ was found to be 50% less than $WC_{male}\%$. These 2 colour samples were of red and green hue with both medium lightness and chroma. However, there were 13 colour samples assessed to be obviously 'warmer' by the female subjects than the male ones, i.e., $WC_{female}\%$ was 50% larger than $WC_{male}\%$. The hue-angles of these colour samples are all between 113^0 and 243^0 and they were of green hue with slightly yellowish or bluish. The majority were of medium to high lightness, i.e., $L^*>40$, as well as medium to high chroma, i.e., $C^*>20$, (with only one exception in lightness and two in chroma). The average 'warm-cool' colour emotion of all subjects of the above significantly different colours were rather 'neutral', with $WC\%$ between 29% and –29%.

In order to have a clearer presentation of the correlation of 'warm-cool' colour emotion in male and female subjects, their correlation with each colorimetric attribute was studied. Since lightness was found to be not a dominant parameter in the 'warm-cool' colour emotion, only the graphs of their colour emotion percentages against chroma, C^*, and hue-angle, h^0, are illustrated in Figures 4.2 and 4.3.

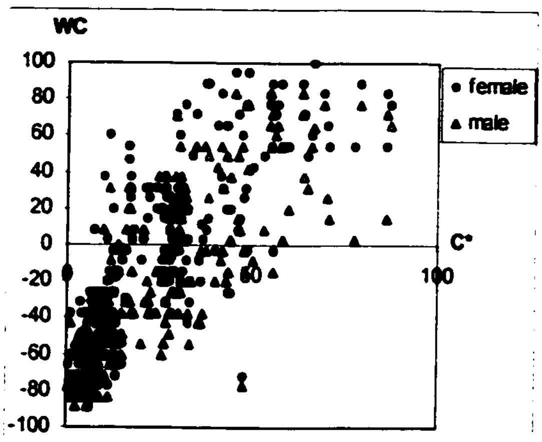

Figure 4.2 Correlation of 'warm-cool' colour emotion of male and female subjects with chroma, C^*, of colour.

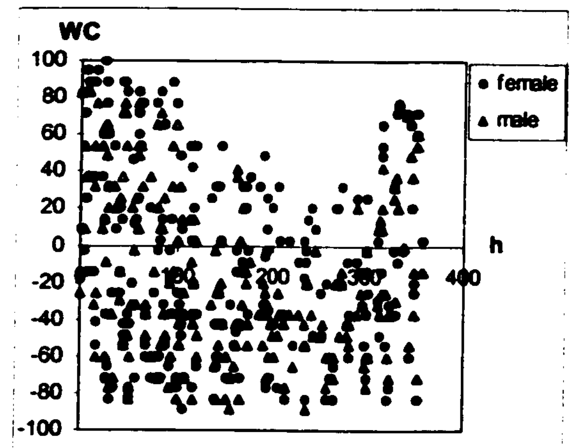

Figure 4.3 Correlation of 'warm-cool' colour emotion of male and female subjects with hue-angle, h^0, of colour.

From Figure 4.2, it may be seen that the colours with a very high chromatic value, i.e., $C^*>70$, normally evoke 'warmer' feeling to the female subjects than the male ones that $WC_{female}\%$ for all of them are larger than 50% whereas some of them give the male subjects a near 'neutral' feeling, i.e. neither 'warm' nor 'cool', with $WC_{male}\%$ approximately equal to 0%. Figure 4.3 shows the influence of hue on the 'warm-cool' colour emotion of male and female subjects. It indicates that, for those colours of hue-angles around 180^0 to 280^0, larger deviations were observed between male and female subjects that some of those colours of green and blue hue induced rather 'warm' or 'neutral' feeling in the minds of the female subjects but obviously 'cool' feeling in the minds of the male subjects.

Hence, female subjects will have a 'warmer' impression not only towards the 'warm' colours but also to the greenish colours than the male ones. In Chapter 3, hue was also found to have influence on the 'warm-cool' colour emotion in that red and yellow colours were assessed to be 'warmer' while green and blue colours were assessed to be 'cooler'. In the experiment, the female subjects assessed those 'cooler' green and blue colours as 'warmer' than the male subjects. In other words, hue influence on the 'warm-cool' colour emotion of male subjects was found to be more obvious than in the case of the female subjects, while the 'warm-cool' colour emotion of female subjects was more chroma-dependent, i.e., higher chroma colours evoked 'warmer' feeling, than in the case of the male subjects.

4.3.2.2 Vivid-sombre colour emotion

The 'vivid-sombre' colour emotion results for male and female subjects were plotted in Figure 4.5, together with the correlation coefficient of them was shown.

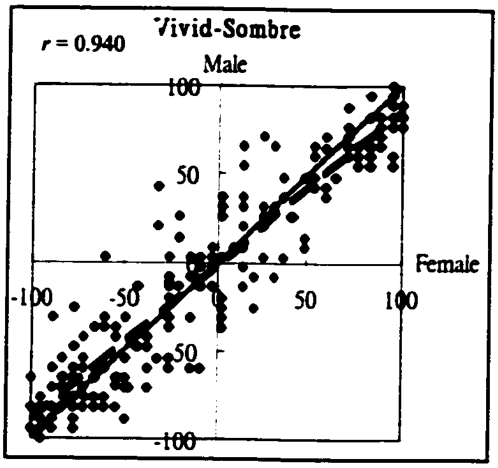

Figure 4.4 Correlation of 'vivid-sombre' colour emotion of male and female subjects.

In Figure 4.4, it may be seen that the plots of the 'vivid-sombre' colour emotion of male and female subjects are located close to the 45-degree line and the correlation coefficient was found to be 0.940, representing a good correlation in male and female subjects. There were only small deviations between the solid 45-degree line and the broken line. The broken line illustrates that for the 'vivid' part, i.e., the portion where both *VS%* of the male and female subjects are positive, the assessment of the female subjects was slightly more 'vivid' than that of the male ones, while for the 'sombre' part, i.e., the portion for both *VS%* of male and female subjects are negative, the assessment of the female subjects was slightly more 'sombre' than the male ones.

No statistically significant difference was found between the 'vivid-sombre' colour emotion of the male and female subjects in the paired-samples *t*-test, as shown in Table 4.1. When their practical differences were analysed, 6 colour samples were found to induce a significantly more 'vivid' feeling in the minds of the female subjects than the male ones, i.e., $VS_{female}\%$ was found to be 50% larger than $VS_{male}\%$. These colours were all of red and yellow hue with hue-angles either larger than 315^0 or smaller than 140^0, and they were of medium-to-high lightness and low-to-medium chroma. With the exception of one colour sample, the above colours evoked a 'sombre' impression to all the subjects in average, i.e., $VS\%$ of these colours was negative. Nevertheless, only 1 colour sample was assessed to be significantly more 'vivid' by the female subjects than the male ones, i.e., $VS_{female}\%$ was 50% larger than $VS_{male}\%$. The average 'vivid-sombre' colour emotion of this colour evoked to all subjects was also 'sombre', and this colour is of yellow hue and very low chroma, C^*=8.23, and very high lightness, L^*=83.44.

The general correlation for the results of the data was good in the' vivid-sombre' colour emotion between male and female subjects, but a slightly larger deviation was found in the case of the reddish and yellowish colours.

4.3.2.3 Gaudy-plain colour emotion

The 'gaudy-plain' colour emotion results for male and female subjects were plotted and the correlation coefficient of them is shown in Figure 4.5.

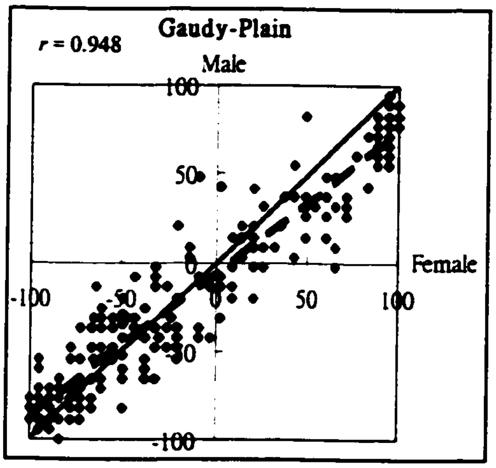

Figure 4.5 Correlation of 'gaudy-plain' colour emotion of male and female subjects.

In Figure 4.5, it may be seen that the plots of the 'gaudy-plain' colour emotion of male and female subjects are located close to the 45-degree line and the correlation coefficient was 0.948, representing a good correlation in male and female subjects. A comparatively larger deviation between the broken line and the solid 45-degree line was observed in the 'gaudy' part, in which both *GP%* of the male and female subjects are positive, and the assessment of the female subjects was more 'gaudy' than that of the male subjects. For the 'plain' part in which both *GP%* of male and female subjects are negative, the deviation was smaller and the assessment of the female subjects was slightly more 'plain' than that of the male ones.

In the paired-samples *t*-test, no statistically significant difference was found between the 'gaudy-plain' colour emotion of the male and female subjects (Table 4.1). When their practical differences were examined, only 3 colour samples were found to induce an obviously different impression between them. A colour sample of red hue with low lightness and medium chroma was assessed to be significantly more 'plain' by the female subjects than in the case the male ones. Two colour samples, one of yellow hue with high lightness and chroma while another sample of green hue with medium lightness and chroma, were assessed to be significantly more 'gaudy' by the female subjects than the male ones. The average assessments of the male and female subjects of the above three colours were slightly 'gaudy', with *GP%* between 20% and 40%.

In conclusion, the correlation in the 'gaudy-plain' colour emotion of male and female was found to be good with only a few colour samples showing practically significant differences between them, while no statistically significant difference was obtained.

4.3.2.4 Striking-subdued colour emotion

The 'striking-subdued' colour emotion results for male and female subjects were plotted and the correlation coefficient of them is shown in Figure 4.6.

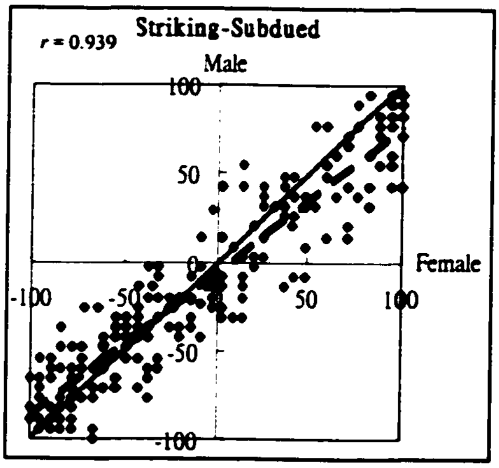

Figure 4.6 Correlation of 'striking-subdued' colour emotion between male and female subjects.

Figure 4.6 illustrates that the plots of the 'striking-subdued' colour emotion of male and female are located quite close to the 45-degree line and the correlation coefficient was found to be 0.939, representing a quite good correlation in the male and female subjects. When the correlation of the broken line and the solid 45-degree line are compared, a larger deviation was observed in the 'striking' part, i.e., the portion where both *SS%* of the male and female subjects are positive, where more female subjects assessed those colours as 'striking' than the male ones. In the 'subdued' part, i.e., the portion where both

SS% of male and female are negative, the deviation was much and this indicates both male and female subjects had a closer 'subdued' impression of those colours.

When the paired-samples t-test was considered, a statistically significant difference was found between the 'striking-subdued' colour emotion of male and female subjects (Table 4.1). In the study of their practical differences, no colour sample was found to induce a significantly more 'subdued' colour emotion in the minds of the female subjects than the male ones, i.e., no colour sample was found to have $SS_{female}\%$ 50% less than $SS_{male}\%$. However, 8 colour samples gave a significantly more 'striking' impression to the female subjects than the male ones. All of these colours had different degrees of lightness and hue, but medium-to-high chroma. The average 'striking-subdued' colour emotion assessments of the male and female subjects of these colours were all 'striking', with *SS%* between 10% and 72%. As a result, a more 'striking' impression was induced in the female's mind when perceiving those 'striking' colours than in the case of the male subjects.

4.3.2.5 Dynamic-passive colour emotion

The 'dynamic-passive' colour emotion results for male and female subjects were plotted and the correlation coefficient of them is illustrated in Figure 4.7.

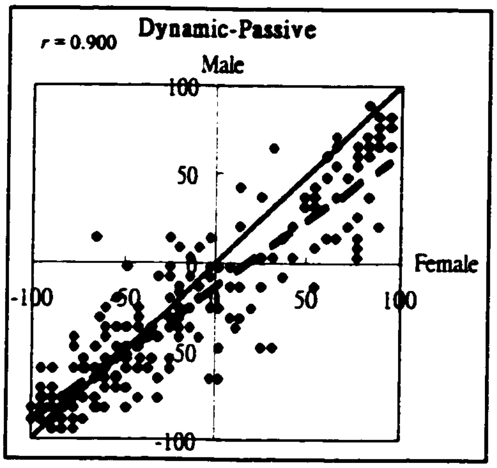

Figure 4.7 Correlation of 'dynamic-passive' colour emotion of male and female subjects.

In Figure 4.7, it may be seen that the plots of the 'dynamic-passive' colour emotion of male and female are located quite close to the 45-degree line and the correlation coefficient was found to be 0.900, representing quite a good correlation in male and female subjects. A large deviation was observed between the broken line and the 45-degree line in the 'dynamic' part, i.e., the portion where both *DyPa%* of the male and female subjects are positive, whereas a closer perception was found in the 'passive' part, i.e., the portion where both *DyPa%* of male and female subjects are negative. This indicates that those 'dynamic' colours evoked a more 'dynamic' impression to the female subjects than the male ones, whereas similar perception towards the 'passive' colours were obtained from them.

A statistically significant difference between the 'dynamic-passive' colour emotion of the male and female subjects was found in the paired-samples t-test, as shown in Table 4.1. When their practical differences were analysed, it was found that only 1 colour sample gave a significantly more 'passive' feeling to the female subjects than the male ones, i.e., $DyPa_{female}$% was found to be at least 50% less than $DyPa_{male}$%. This was a medium lightness and chroma colour in red hue. The $DyPa_{female}$% for this colour sample was equal to –65.7%, i.e., rather 'passive' impression, and the $DyPa_{male}$% was equal to 14.3%, i.e., 'neutral' with slightly 'dynamic' impression, while the average $DyPa$% was equal to –25.7%, i.e., a slightly 'passive' impression. However, there were 14 colour samples assessed to be significantly more 'dynamic' by the female subjects than the male ones, i.e., $DyPa_{female}$% was at least 50% larger than $DyPa_{male}$%. The lightness of these colours were low-to-medium while their chroma were all medium-to-high. Their hue-angles were between 140^0 and 305^0, and they were of green and blue hues. One exceptional colour sample was observed that it was of yellow hue with a very large lightness value. There were various levels of 'dynamic' and 'passive' impressions for the average assessment of male and female subjects for all these significantly different colours, and the $DyPa$% ranged from –35% to 55%.

In order to gain a better understanding of the correlation of 'dynamic-passive' colour emotion in male and female subjects, the correlation with each colorimetric attribute was studied. Since the influence of lightness was found to be not significant on this colour emotion pair, only the graphs of their colour emotion percentages against chroma, C^*, and hue-angle, h^0, are provided in Figures 4.8 and 4.9.

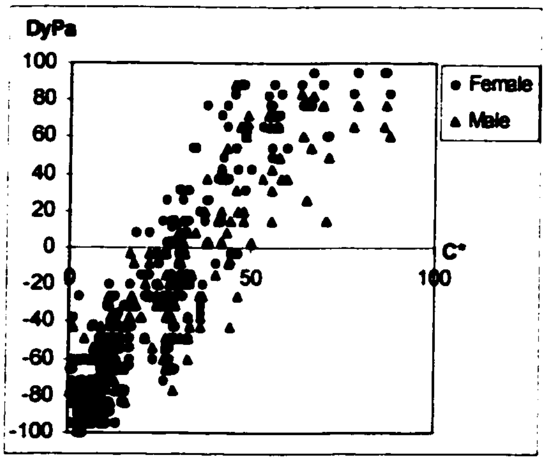

Figure 4.8 Correlation of 'dynamic-passive' colour emotion of male and female subjects with chroma, C^*, of colour.

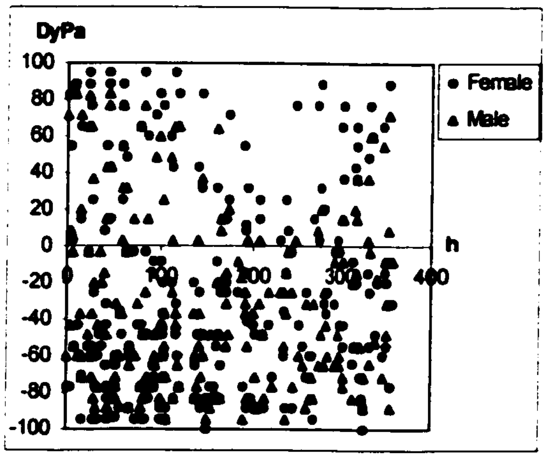

Figure 4.9 Correlation of 'dynamic-passive' colour emotion of male and female subjects with hue-angle, h^0, of colour.

In Figure 4.8, the correlation of 'dynamic-passive' colour emotion in male and female for the low chromatic colours was observed to be good, while for the very high chromatic colours, i.e., $C^*>60$, a slightly more 'dynamic' impression was given to the female subjects than the male ones. Figure 4.9 shows a generally more 'dynamic' impression was given to the female subjects, irrespective of the hue of the colour. In addition, it demonstrates that the 'dynamic-passive' colour emotion of male subjects was more hue dependent than the female subjects that 'dynamic' emotion was induced for the reddish and yellowish colours whereas a 'passive' or 'neutral' impression was induced for the greenish and bluish colours. This is different from the female subjects in that a slightly 'dynamic' impression was given to them when they perceived those greenish and bluish colours with quite high chroma. Therefore, it may be concluded that the hue influence on 'dynamic-passive' colour emotion was more significant for the male subjects, whereas chroma was the dominant parameter for the female subjects in this colour emotion pair.

4.3.3 Lightness Dependent Colour Emotions

4.3.3.1 Deep-pale colour emotion

The 'deep-pale' colour emotion results for male and female subjects were plotted and their correlation coefficient is shown in Figure 4.10.

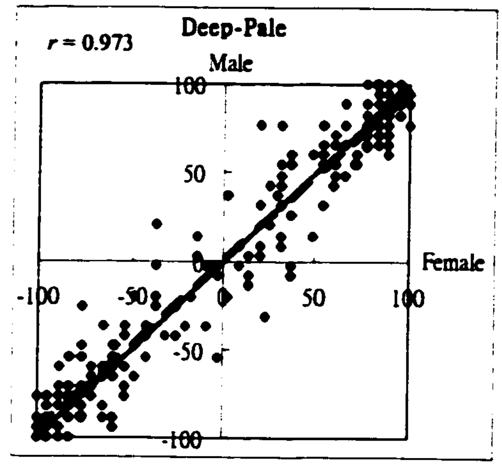

Figure 4.10 Correlation of 'deep-pale' colour emotion of male and female subjects.

Figure 4.10 shows that most of the plots of the 'deep-pale' colour emotion of male and female subjects are located very close to the 45-degree line and the correlation coefficient was found to be 0.973, representing a very strong correlation in them. Almost no deviation was observed between the broken line and the 45-degree line and this indicates the male and female subjects had very similar 'deep-pale' impression for colours, irrespective of whether the colours were 'deep' or 'pale'.

In Table 4.1, no statistically significant difference was found between the 'deep-pale' colour emotion of the male and female subjects in the paired-samples *t*-test. When the practical differences in their colour emotion were assessed, it was found that only 3 colour samples induced an obviously 'paler' impression in the minds of the female subjects than in the case of the male ones, i.e., $DP_{female}\%$ was found to be more than 50% less than $DP_{male}\%$. These colour samples were of green hue with medium lightness and different chroma values. On the other hand, 2 colour samples were assessed to be significantly 'deeper' by the female subjects than the male ones, i.e., $DP_{female}\%$ was at least 50% larger than $DP_{male}\%$. These 2 colour samples were of blue hue with similarly medium lightness and different chroma values. From the above analyses, it may be concluded that a more obvious difference in 'deep-pale' colour emotion between male and female subjects occurred in the case of the colours of medium lightness. Since the 'deep-pale' colour emotion of human beings mainly depends upon the lightness of colour, a definite 'pale' impression is induced for the high lightness colours while a 'deep' impression is induced for the low lightness colours, and those colours with medium lightness induce a various levels of 'deep' to 'pale' impression in the subjects' minds.

4.3.3.2 Heavy-light colour emotion

The 'heavy-light' colour emotion results for male and female subjects were plotted and their correlation coefficient is illustrated in Figure 4.11.

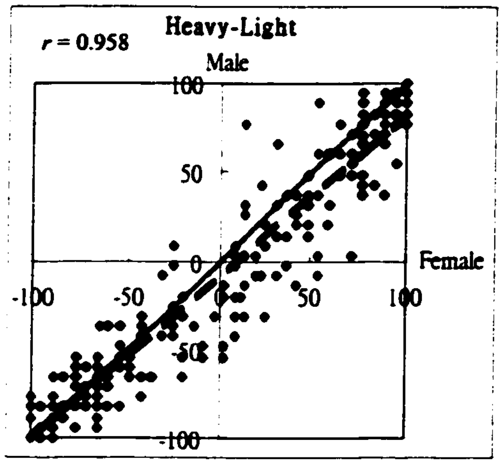

Figure 4.11 Correlation of 'heavy-light' colour emotion of male and female subjects.

In Figure 4.11, the plots of the 'heavy-light' colour emotion of male and female subjects are located close to the 45-degree line and the correlation coefficient was found to be 0.958, representing a good correlation in male and female subejcts. A larger deviation between the broken line and the 45-degree line was observed for the 'heavy' colours since a lower level of 'heavy' impression was induced in minds of the male subjects than in the case of the female ones when perceiving them.

In the paired-samples t-test, a statistically significant difference was found between the 'heavy-light' colour emotion of the male and female subjects (Table 4.1). When their practical differences were evaluated, it was found that only 1 colour sample evoked a significantly 'lighter' impression to the female subjects than the male one, i.e., $HL_{female}\%$ was found to be over 50% less than $HL_{male}\%$. This colour was green in hue with medium lightness and high chroma. For the assessment of significantly 'heavier' by the female subjects than the male ones, 10 colour samples were found to evoke this impression. These colours were of low-to-medium lightness but with different chroma and hue. Hence, it was difficult to judge which factor influenced the deviation of 'heavy-light' colour emotion in the male and female subjects.

4.3.3.3 Soft-hard colour emotion

The 'soft-hard' colour emotion results for male and female subjects were plotted and the correlation coefficient of them is illustrated in Figure 4.12.

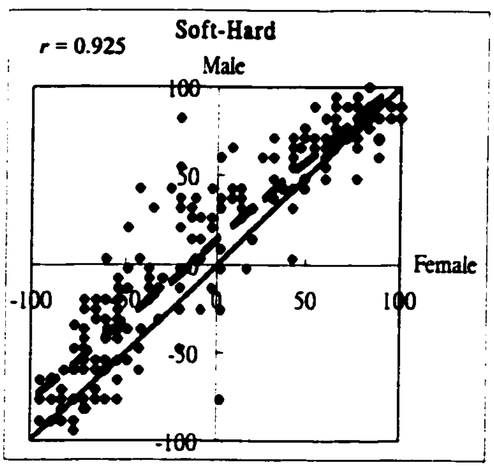

Figure 4.12 Correlation of 'soft-hard' colour emotion of male and female subjects.

From Figure 4.12, it may be seen that the plots of the 'soft-hard' colour emotion for the male and female subjects are located quite close to the 45-degree line and the correlation coefficient was found to be 0.925, representing quite a good correlation in them. A much larger deviation was observed between the broken line and the 45-degree line in the 'hard' part, i.e., the portion in which both *SH%* of the male and female subjects are negative, that a 'harder' impression was induced in the minds of the female subjects than the male ones. The graph indicates that some colours giving 'neutral' or slightly 'hard' impression to the female subjects evoked a 'soft' impression in the male subjects.

In Table 4.1, a statistically significant difference was found between the 'soft-hard' colour emotion of the male and female subjects in the paired-samples *t*-test. When the practical differences in their colour emotion percentages were assessed, it was found that 12 colour samples gave an obviously 'harder' impression to the female subjects than the male ones, whereas only 1 colour sample was found to give an obviously 'softer' impression to the female subjects than the male ones. These 12 colour samples were of different hue, lightness and chroma values; and 3 of them showed a very large difference in 'soft-hard' colour emotion that the $SH_{female}\%$ was found to be over 70% smaller than $SH_{male}\%$. These

3 colours induced slightly 'hard' impression to the female subjects but rather 'soft' impression to the male subjects. The colour which was assessed to be significantly 'softer' by the female subjects was green in hue with medium lightness and high chroma. It gave a very 'hard' impression to the male subjects whereas a neither 'hard' nor 'soft' impression was given to the female subjects.

From the above analyses, it may be concluded that 'harder' impression is generally induced to the female than the male during the perception of different colours.

4.3.3.4 Strong-weak colour emotion

The 'strong-weak' colour emotion results for male and female subjects were plotted and their correlation coefficient is shown in Figure 4.13.

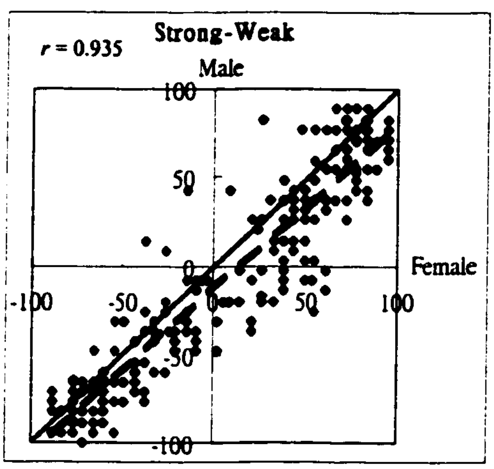

Figure 4.13 Correlation of 'strong-weak' colour emotion of male and female subjects.

In Figure 4.13, it may be seen that the plots of the 'strong-weak' colour emotion of male and female subjects are located quite close to the 45-degree line and the correlation coefficient was found to be 0.935, representing quite a good correlation in male and female subjects. Generally, the $SW_{female}\%$ was found to be larger than the corresponding $SW_{male}\%$ that indicates a 'stronger' impression was induced to the female subjects than the male ones for most of the colours. When the correlation of the broken line and the solid 45-degree line was analysed, a comparatively larger deviation was observed in the 'strong' part, i.e., the portion where both $SW\%$ of the male and female subjects are positive, that more female subjects assessed those colours as 'strong' than the male ones did.

In Table 4.1, a statistically significant difference was found between the 'strong-weak' colour emotion of the male and female subjects in the paired-samples t-test. When their practical differences were examined, 3 colour samples were found to give a significantly 'weaker' colour emotion to the female subjects than the male ones, i.e., $SW_{female}\%$ was found to be at least 50% less than $SW_{male}\%$, and these colours were of different hue with medium lightness and medium-to-high lightness. Nevetheless, there were 11 colour samples that gave a significantly 'stronger' impression to the female subjects than the male ones. These colours had different degrees of chroma and hue, but with medium-to-high lightness. The average 'strong-weak' colour emotion assessments of the male and female subjects of these significantly different colours were quite 'neutral', with *SW%* between -25% and 30%.

For a better presentation of the correlation of 'strong-weak' colour emotion in male and female subjects, their correlation with each colorimetric attribute was studied. Since hue does not have significant influence on 'strong-weak' colour emotion, only the graphs of their colour emotion percentages against lightness, L^*, and chroma, C^*, are illustrated in Figures 4.14 and 4.15.

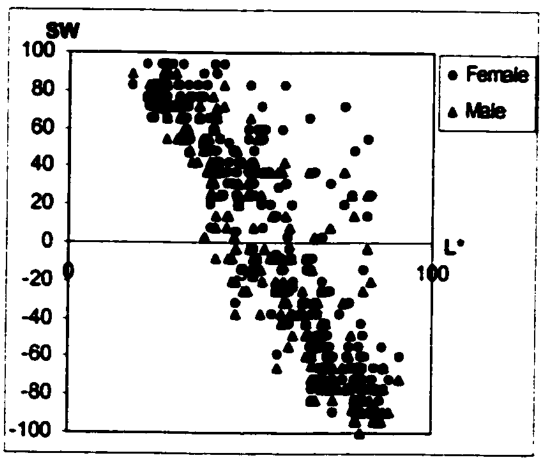

Figure 4.14 Correlation of 'strong-weak' colour emotion of male and female subjects with lightness, L^*, of colour.

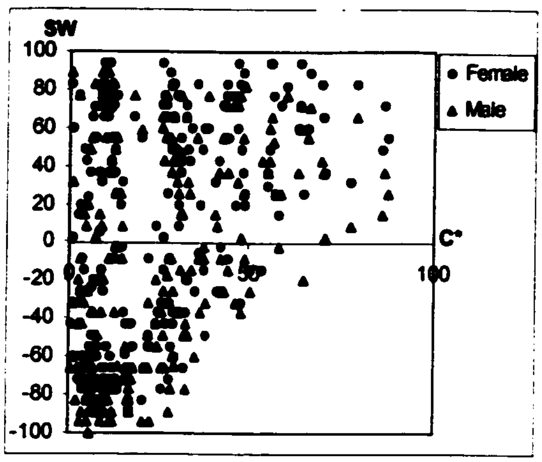

Figure 4.15 Correlation of 'strong-weak' colour emotion of male and female subjects with chroma, C^*, of colour.

In Chapter 3, the dominant parameter influencing the 'strong-weak' colour emotion was found to be lightness of colour, in which high lightness colours were assessed as 'weak' while low lightness colours were assessed as 'strong'. However, chroma was observed to contribute a small influence on this 'strong-weak' colour emotion since high chromatic colours were assessed as 'strong' regardless of its lightness level. Figure 4.14 shows that these high chromatic colours, which deviate from the general trend, gave a 'strong' impression to the female subjects than the male ones. In addition, Figure 4.15 also indicates the female subjects assessed the high chromatic colours to be 'stronger' than the male subjects did. As a result, it may be concluded that the influence of chroma on 'strong-weak' colour emotion was more obvious in the female subjects than the male ones.

4.3.4 Lightness and Chroma Dependent Colour Emotion

4.3.4.1 Light-dark colour emotion

The 'light-dark' colour emotion results for male and female subjects were plotted and the correlation coefficient of them is shown in Figure 4.16.

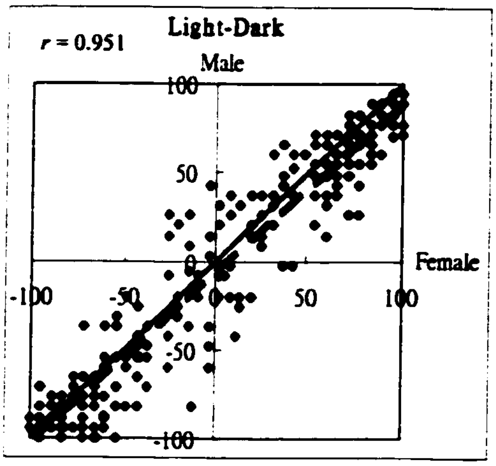

Figure 4.16 Correlation of 'light-dark' colour emotion of male and female subjects.

In Figure 4.16, the plots of the 'light-dark' colour emotion of male and female subjects are located close to the 45-degree line and the correlation coefficient was found to be 0.951, representing a good correlation in them. A slightly larger deviation between the broken line and the solid 45-degree line was observed in the 'light' part, where both *LD%* of the male and female subjects are positive, and the assessment of the female subjects was 'lighter' than the male ones. For the 'dark' part where both *LD%* of male and female subjects are negative, the deviation was very small that the assessment of the female subjects was found to be similar to that of the male ones.

A statistically significant difference was found between the 'light-dark' colour emotion of the male and female subjects in the paired-samples *t*-test, as shown in Table 4.1. When their practical differences were studied, only 1 colour sample was found to induce a significantly 'darker' impression in minds of the female subjects than the male ones. This was a red colour with medium lightness and chroma. However, there were 5 colour samples assessed to be significantly 'lighter' by the female than the male. All these colours were og different hue and chroma values but having medium lightness, except one colour which had larger than 70% difference between LD_{female}% and LD_{male}% was of high lightness. This colour was yellow in hue with very low chroma and it was assessed to be very 'dark' by the male subjects whereas only slightly 'dark' by the female subjects.

4.3.4.2 Distinct-vague colour emotion

The 'distinct-vague' colour emotion results for male and female subjects were plotted and the correlation coefficient of them is illustrated in Figure 4.17.

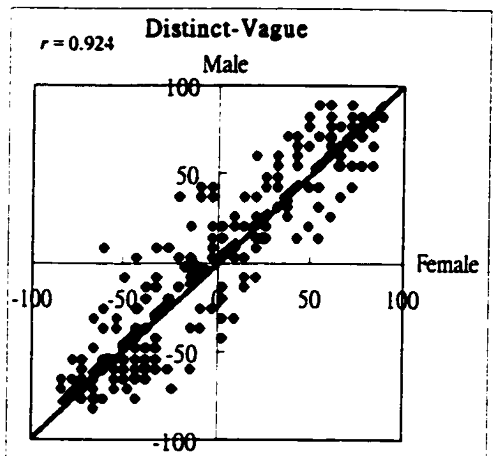

Figure 4.17 Correlation of 'distinct-vague' colour emotion of male and female subjects.

Figure 4.17 illustrates the plots of the 'distinct-vague' colour emotion of male and female subjects are located very close to the 45-degree line and the correlation coefficient was found to be 0.924, representing a good correlation in them. The broken line was very close to the 45-degree line that almost no deviation was observed between them. This indicates the male and female subjects have very similar 'distinct-vague' colour emotion during colour perception in this study.

No statistically significant difference was found between the 'distinct-vague' colour emotion of the male and female subjects in the paired-samples *t*-test (Table 4.1). Only 3 colour samples were found to give a significantly more 'vague' impression to the female subjects than the male ones when their practical differences were analysed. However, no colour sample was found to evoke a significantly more 'distinct' impression to the female subjects than the male ones.

4.3.4.3 Transparent-turbid colour emotion

The 'transparent-turbid' colour emotion results for male and female subjects were plotted and the correlation coefficient of them is illustrated in Figure 4.18.

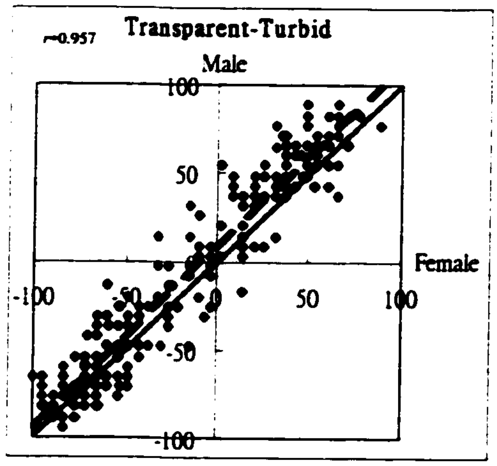

Figure 4.18 Correlation of 'transparent-turbid' colour emotion of male and female subjects.

In Figure 4.18, it may be seen that the plots of the 'transparent-turbid' colour emotion of male and female subjects are located close to the 45-degree line and the correlation coefficient was found to be 0.957, representing a good correlation in them. A deviation was observed between the broken line and the 45-degree line that the 'transparent-turbid' colour emotion of the female subjects was less 'transparent' than that of the male ones, and this deviation was comparatively larger in the 'transparent' part where both *TT%* of male and female subjects are positive.

In the paired-samples *t*-test, a statistically significant difference was found between the 'transparent-turbid' colour emotion of the male and female subjects (Table 4.1). When their practical differences were evaluated, only 1 colour sample was found to give a significantly more 'turbid' impression to the female subjects than the male ones whereas no colour sample was found to evoke a significantly more 'transparent' impression in the female subjects than the male ones. In general, most colours give the female subjects a less 'transparent' impression than in the case of the male ones.

4.4 Conclusions

Generally, good correlations of colour emotions in male and female subjects were found in this study. The best correlation was found in the 'deep-pale' colour emotion that very strong correlation and very similar observations were obtained in the perception of male and female subjects.

During the comparison of colour emotion between them, creative and interesting evaluations were obtained in the 'warm-cool' and 'dynamic-passive' colour emotion pairs. Although they were both categorized as chroma dependent that means chroma of colour is the dominant parameter influencing these emotion pairs, the hue influence on them was found to be more significant for the male subjects that red and yellow colours with high chroma were normally regarded as 'warm' and 'dynamic' whereas green and blue colours were considered as 'cool' and 'passive' colours by the male subjects. However, this sort of hue influence was not so obvious for the female subjects because some green and blue colours were assessed to be rather 'warm' and 'dynamic' by them.

CROSS-CULTURAL AND CROSS–GEOGRAPHICAL COMPARISON OF COLOUR EMOTIONS

5.1 Objectives

- To compare the colour emotion results obtained from different regions, including Japan, Thailand, United Kingdom and Hong Kong.
- To investigate the correlation of colour emotions of different countries through the derived mathematical models.

5.2 Methodology

5.2.1 Visual Assessment

5.2.1.1 Subjects, experimental conditions and questionnaire

For the visual assessments carried out in Hong Kong, the subjects, experimental conditions and questionnaire in the visual assessment for the comparison of colour emotions between genders were the same as those in Section 3.2.1.

The visual assessments in Japan were carried out by 80 subjects aged between 18 and 22 years old. They were asked to assess the colour emotion induced by the colour samples near a north-facing window, i.e., under natural daylight. The colour emotion word pairs in the questionnaires were written in their mother language, Japanese, in order to avoid the misunderstanding or misinterpretation of the meanings of the word pairs through the translation of language (Sato et. al., 1998).

In Thailand, 60 Thai subjects were asked to carry out the visual assessments under illuminant D_{65} in the light cabinet. The colour emotion word pairs in the questionnaires were also written in their mother language, Thai.

Since the visual assessment of the 12 colour emotion pairs of the United Kingdom subjects were not finished, fewer colour emotion pairs were included in this study for analyzing the correlation of colour emotions between the United Kingdom subjects and the other regions' subjects. Two groups of the United Kingdom subjects were invited for doing the visual assessments under Verivide artificial daylight D_{65}. One group had 20 subjects while the other had 30 (Sato et. al., 1998). They aged between 18 and 28 years old. The colour emotion word pairs were written in English.

5.2.1.2 Colour samples

Since about half of the colour samples (114 samples) were used in the visual asssessments of the other regions, the colour emotion results corresponding to those colour samples of the Hong Kong subjects were selected for the comparisons. Among all the 218 colour samples, the notation of colour samples with Munsell hue '5' were used for the cross-cultural comparison whereas those with '10' were eliminated. Those colour samples of neutral colours, i.e., the notations N1, N2, N4, N6, N8 and N9.5, were also included in the 114-sample database.

5.2.2 Calculation of Colour Emotion Percentage

The method for calculating the colour emotion percentage was the same as the two-point method for quantifying colour emotions that was shown in Section 3.2.2.

5.2.3 Cross-Cultural and Cross-Geographical Comparison of Colour Emotions

5.2.3.1 Correlation coefficient and paired-samples *t*-test

The correlation coefficient, *r*, of the colour emotion results obtained from different regions was calculated as a preliminary analysis of the correlation of their colour emotions. Same as Section 4.2.3, if the calculated correlation coefficient, r, was found to be larger than 0.837, this colour emotion pair of the comparing two regions was regarded as sufficiently correlated to undergo further evaluation of their similarity and difference statistically by paired-samples t-test. Otherwise, this colour emotion pair was considered as having low correlation between the subjects of the comparing two regions, and paired-samples t-test was not applicable due to an obvious difference between them. The calculation method of the paired-samples t-test is the same as that in Section 4.2.3.

5.2.3.2 Graphical representation

The graphical representations of the colour emotion percentages obtained from Japan, Thailand and the United Kingdom against those from Hong Kong were compared as further analyses of their correlations.

5.2.3.3 Mathematical models

Mathematical models were derived for quantifying the colour emotions of different regions with the colorimetric attributes, L^*, C^* and h^0, through the optimization by C++ programming. According to the derived mathematical models, the degree of each colorimetric attribute of a colour influencing the selection of colour emotion word within a word pair can be evaluated by the first derivative of the mathematical models with respect to that attribute. If a slight change of that attribute will cause a large difference in the colour emotion, that attribute is considered as having a significant influence to the colour emotion pair being studied.

5.2.3.4 Cross-cultural colour planner

Colour planners were created for representing the colour emotions of different regions towards the same colour. A cross-cultural colour planner shows the colour emotions of two regions for a hue, and in the planner there are a series of iso-lightness and iso-chroma lines that represent the colours of different lightness and chroma of this hue. For example, when the correlation of 'light-dark' colour emotion of the Japanese and Hong Kong subjects of a red colour with high lightness and high chroma is being investigated, the corresponding 'light-dark' values of these regions can be obtained through the projection of the iso-lightness line of L^*=80 or L^*=100 and iso-chroma line of C^*=80 or C^*=100 at the colour planner of hue-angle=0^0. For the simplicity in presentation, only the colour planners of the red colours, with hue-angle=0^0, of each colour emotion pair for the comparisons of different regions with Hong

Kong were shown in this chapter.

5.3 Results and Discussions

5.3.1 Chroma Dependent Colour Emotions

5.3.1.1 Warm-cool colour emotion

Correlation Coefficients and Paired-Samples *t*-Test

The correlation coefficients, *r*, and the results of paired-samples *t*-test of 'warm-cool' colour emotion of the subjects from Japan (JP), Thailand (TH), the United Kingdom (UK) and Hong Kong (HK) are shown in Table 5.1.

Table 5.1

Correlation coefficients and results of paired-samples *t*-test of 'warm-cool' colour emotions of subjects of different regions

WC	Correlation Coefficient, *r*			Significant Difference (at 0.001 level of significance)		
	JP	TH	UK	JP	TH	UK
HK	0.860	0.860	0.714	No	Yes	Not applicable
JP		0.823	0.761		Not applicable	Not applicable
TH			0.837			No

Among the correlation coefficients in Table 5.1, the highest correlation of the 'warm-cool' colour emotion was found between the Hong Kong and Japanese subjects as well as the Hong Kong and Thai subjects. However, the lowest correlation was found between the Hong Kong and the United Kingdom subjects. In order to further examine the correlation of 'warm-cool' colour emotion of these regions with Hong Kong, the graphical plots of the visual assessment results of the above regions were obtained.

In the paired-samples *t*-test, statistically significant differences in the 'warm-cool' colour emotion were found between the subjects of Thailand and those of Hong Kong (Table 5.1), whereas low correlations were found in some of them so that paired-samples *t*-test was not applicable for those comparisons. The practical differences are discussed in the following sections.

<u>Graphical Representation</u>

The plots of the visual assessment results of 'warm-cool' colour emotion of Japan, Thailand and the United Kingdom against those of Hong Kong are shown in Figures 5.1 to 5.3 respectively.

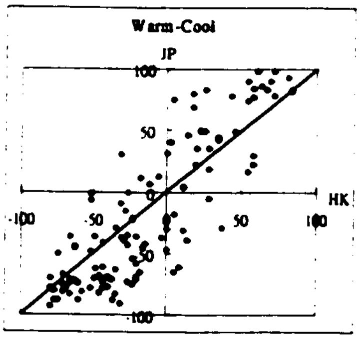

Figure 5.1 The visual assessment results of 'warm-cool' colour emotion of Japanese against Hong Kong subjects.

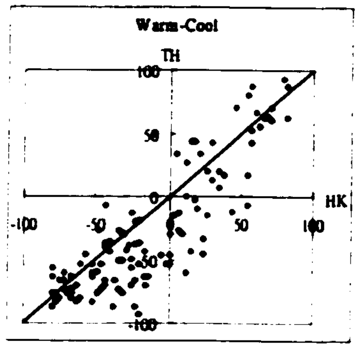

Figure 5.2 The visual assessment results of 'warm-cool' colour emotion of Thai against Hong Kong subjects.

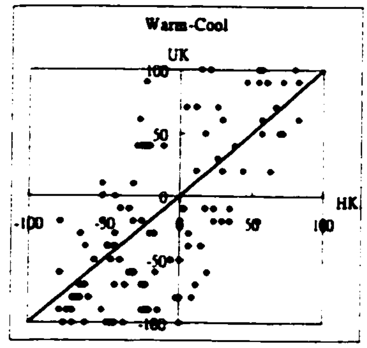

Figure 5.3 The visual assessment results of 'warm-cool' colour emotion of the United Kingdom against Hong Kong subjects.

Figures 5.1 and 5.2 show the plots lie close to the 45-degree lines of the graphs whereas the plots in Figure 5.3 are comparatively more scattered. This suggests that the correlations of the 'warm-cool' colour emotion of the Japanese and Hong Kong subjects as well as that of the Thai and Hong Kong subjects were better than that of the United Kingdom and Hong Kong subjects.

Mathematical Models for Japan, Thailand and the United Kingdom

In order to quantitatively evaluate the influence of the colorimetric attributes on the 'warm-cool' colour emotion of the Japanese, Thai and the United Kingdom subjects, the mathematical models for these relationships were derived by Method I (in Section 3.3.2) and are shown below.

Japan

$$WC_{0\le h<180} = 0.586L^* + 146.268C^{*(0.192)} - 0.517h - 249.076 \quad (5.1a)$$

$$WC_{180\le h<360} = 0.542L^* + 0.217C^{*(1.453)} - 0.283(360^0 - h) - 74.650 \quad (5.1b)$$

Thailand

$$WC_{0\le h<180} = -0.331L^* + 11.159C^{*(0.621)} - 0.389h - 44.654 \quad (5.2a)$$

$$WC_{180\le h<360} = -0.315L^* + 0.016C^{*(2.051)} - 0.321(360^0 - h) - 12.140 \quad (5.2b)$$

The United Kingdom

$$WC_{0\le h<180} = -1.00L^* + 159.561C^{*(0.154)} - 0.724h - 132.989 \quad (5.3a)$$

$$WC_{180\le h<360} = -0.968L^* + 1.202C^{*(0.947)} - 0.442(360^0 - h) + 16.362 \quad (5.3b)$$

Hong Kong (from Section 3.3.2)

$$WC_{0^0\le h<180^0} = 0.154L^* + 39.378C^{*(0.372)} - 0.303h - 113.855 \quad (3.3a)$$

$$WC_{180^0\le h<360^0} = 0.355L^* + 23.476C^{*(0.429)} - 0.159(360^0 - h) - 105.710 \quad (3.3b)$$

From the above equations, the chroma of colour was found to be the most influential attribute on the selection of 'warm-cool' colour emotion of subjects from all the regions under investigation. As the chroma increased, the colour tended to give a 'warmer' impression to the subjects. These observations were the same as those found in the Hong Kong subjects. However, comparatively larger influence of lightness and hue on 'warm-cool' colour emotion of the subjects from the United Kingdom than those of the other regions were obtained in Equation 5.3a and 5.3b. Hence, the influence of chroma on 'warm-cool' colour emotion of the United Kingdom subjects was not as dominant as that on the other regions.

Cross-cultural colour planner

The colour planner for the 'warm-cool' colour emotion of Japanese and Hong Kong subjects during the perception of colours of different lightness and chroma at hue-angle=0^0 is illustrated in Figure 5.4. The colour planners for the Thai and United Kingdom subjects against the Hong Kong subjects are shown in Figures 5.5 and 5.6 respectively.

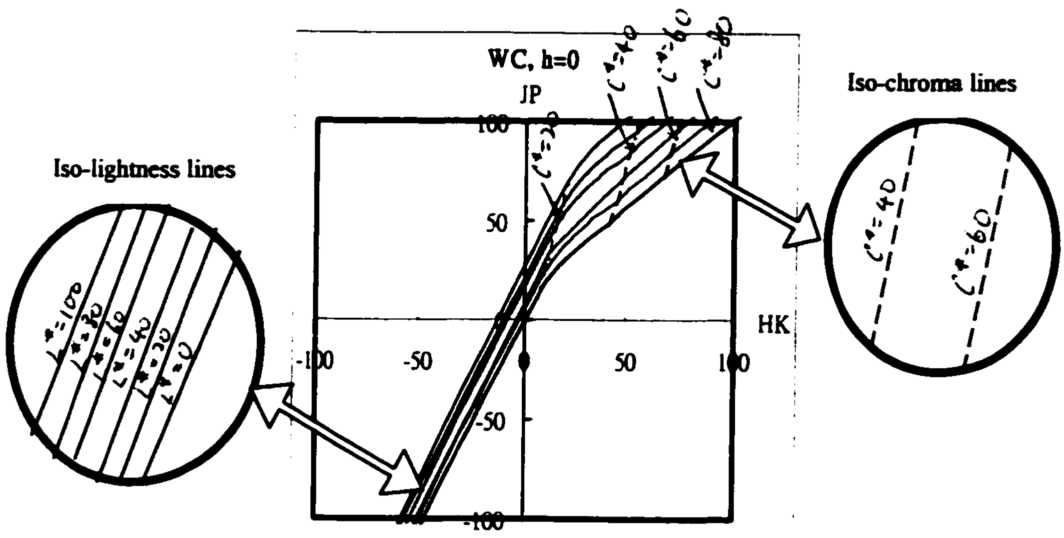

Figure 5.4 Colour planner for the 'warm-cool' colour emotion of Japanese and Hong Kong subjects at h=0°.

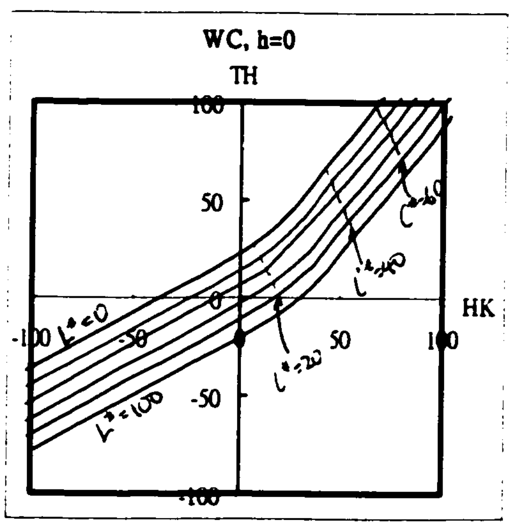

Figure 5.5 Colour planner for the 'warm-cool' colour emotion of Thai and Hong Kong subjects at h=0°.

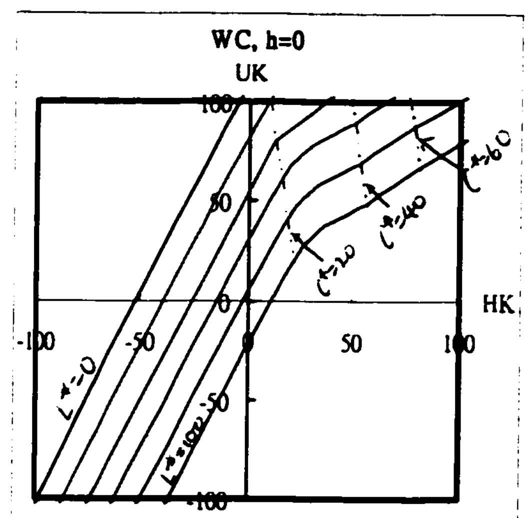

Figure 5.6 Colour planner for the 'warm-cool' colour emotion of the United Kingdom and Hong Kong subjects at h=0°.

From the above cross-cultural colour planners, if the range of iso-lightness lines or the range of iso-chroma lines covers a larger area, it indicates a lower correlation of colour emotion between these two regions; whereas if the iso-lightness and/or iso-chroma lines are very close to each other, this represents a high correlation of colour emotion between these two regions. Figure 5.4 shows the iso-lightness lines in the 'cool' emotion part of the colour planner, i.e., the negative side of the 'warm-cool' colour emotion of both regions, are very close to each other, indicating a high correlation of the Japanese and Hong Kong subjects towards the 'cool' emotion. However, when the same 'cool' red colour were perceived by them, a 'cooler' emotion was given to the Japanese subjects than to the Hong Kong subjects, e.g., those colours giving *WC*=-100 to the Japanese gave approximately *WC*=-50 (lower level of 'cooler') to the Hong Kong subjects.

Although the covering ranges of the iso-lines for the 'warm-cool' colour emotion of Thai and Hong Kong subjects (Figure 5.5) were slightly larger than that of Japanese and Hong Kong subjects (Figure 5.4), an almost direct indication of 'warm' colour emotion between Thai and Hong Kong subjects, i.e., the positive side of the 'warm-cool' colour emotion of both regions, was observed in the planner. Since the slopes of the iso-lightness lines in the 'warm' emotion part were almost equal to 1, a direct projection of 'warm' colour emotion was found between these two regions. For example, if a red colour evoked a very 'warm' impression, i.e., *WC*=100, to the Hong Kong subjects, this colour normally gave a 'warm' impression to the Thai with *WC*= 80 to 100, which could be directly determined in Figure 5.5.

However, a lower correlation of the 'warm-cool' colour emotion between the United Kingdom and Hong Kong subjects was observed in the planner which is shown in Figure 5.6. The iso-lightness lines were rather apart from each other, representing a low correlation. For example, when a colour gave a very 'warm' emotion, i.e., WC=100, to the subjects in the United Kingdom, a range of WC values from −10 to 100, with the perception of slightly 'cool' to 'neutral' and to very 'warm', was obtained from the Hong Kong subjects.

As a result, from the above evaluations, the correlations of 'warm-cool' colour emotion of the Japanese and Thai with the Hong Kong subjects were found to be better than that of the United Kingdom with Hong Kong.

5.3.1.2 Vivid-sombre colour emotion

Correlation Coefficients and Paired-Samples t-Test

The correlation coefficients, r, and the results of paired-samples t-test of 'vivid-sombre' colour emotion of the subjects from Japan (JP), Thailand (TH), the United Kingdom (UK) and Hong Kong (HK) are shown in Table 5.2.

Table 5.2

Correlation coefficients and results of paired-samples *t*-test of 'vivid-sombre' coloure emotions of subjects of different regions

VS	Correlation Coefficient, *r*			Significant Difference (at 0.001 level of significance)		
	JP	TH	UK	JP	TH	UK
HK	0.923	0.917	0.900	Yes	No	Yes
JP		0.831	0.889		Not applicable	No
TH			0.765			Not applicable

Of the correlation coefficients in Table 5.2, the highest correlation of the 'vivid-sombre' colour emotion was found between the Hong Kong and Japanese subjects, whereas the lowest correlation was found between the Thai and the United Kingdom subjects. In general, the correlations of this colour emotion pair of different regions with Hong Kong were assessed as good since all the correlation coefficients were larger than 0.900.

In the paired-samples *t*-test, statistically significant differences in the 'vivid-sombre' colour emotion were found between the subjects of Hong Kong and those of Japan and the United Kingdom (Table 5.2), whereas low correlations were found in some of them so that paired-samples *t*-test was not applicable for those comparisons. As stated by Hopkins et al. (1996), if there are many pairs in the test or if two variables correlate highly, even small, trivial differences in means can result in large *t*-ratios, and thus highly significant mean difference. Since the statistically significantly different pairs in this analysis had high correlation coefficients, both were found to be larger than 0.900, their statistical differences might be due to this reason.

Graphical Representation

The plots of the visual assessment results of 'vivid-sombre' colour emotion of Japan, Thailand and the United Kingdom against those of Hong Kong are shown in Figure 5.7 to Figure 5.9 respectively.

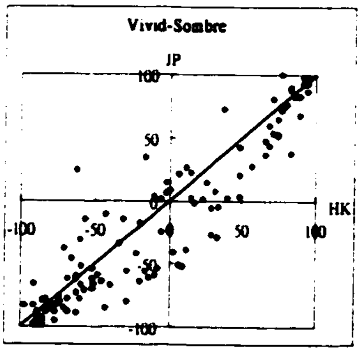

Figure 5.7 The visual assessment results of 'vivid-sombre' colour emotion of Japanese against Hong Kong subjects.

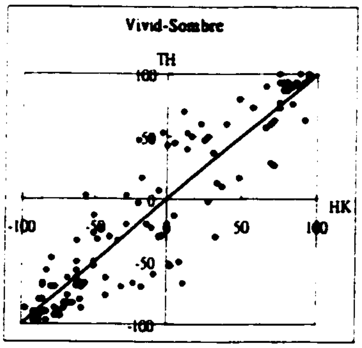

Figure 5.8 The visual assessment results of 'vivid-sombre' colour emotion of Thai against Hong Kong subjects.

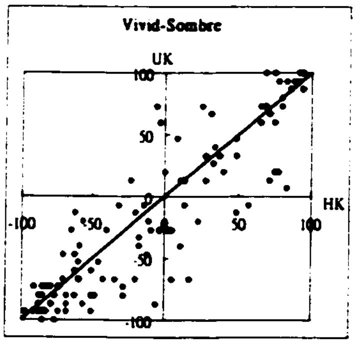

Figure 5.9 The visual assessment results of 'vivid-sombre' colour emotion of the United Kingdom against Hong Kong subjects.

In Figures 5.1 to 5.3, it may be seen that the plots are close to the 45-degree lines of the graphs, in between the plots are more concentrated to lie along the 45-degree line in Figure 5.7 whereas the plots are slightly more scattered in Figure 5.9. This indicated the 'vivid-sombre' colour emotion of Japanese, Thai and United Kingdom subjects had high correlation with that of the Hong Kong subjects. For the rating of the correlation of these regions, the correlation of Japanese and Hong Kong subjects was the best but that of the United Kingdom and Hong Kong subjects was the worst in this comparison.

Mathematical Models for Japan, Thailand and the United Kingdom

The mathematical models of the 'vivid-sombre' colour emotion of the Japanese, Thai and the United Kingdom subjects were derived and are shown below. Since the hue influence was not significant in this colour emotion pair, only one mathematical model, without split of hue-angles into 0^0 to 180^0 and 180^0 to 360^0, was derived for each region.

Japan

$$VS = 0.242L^* + 2.489C^* + 0.150h - 118.671 \qquad (5.4)$$

Thailand

$$VS = 1.566L^{*} + 2.542C^{*} + 0.098h - 174.990 \tag{5.5}$$

The United Kingdom

$$VS = -0.077L^{*} + 2.794C^{*} + 0.123h - 102.406 \tag{5.6}$$

Hong Kong (from Section 3.3.2)

$$VS = 0.774L^{*} + 17.036C^{*(0.591)} + 0.097h - 172.145 \tag{3.7}$$

From the above equations, the chroma of colour was found to be the dominant parameter influencing the selection of 'vivid-sombre' colour emotion of subjects from all the regions under investigation. As the chroma increased, the colour tended to give a more 'vivid' impression to the subjects, which was the same as the finding of the Hong Kong subjects. However, in Equation 5.5, the lightness of colour had a greater influence on the 'vivid-sombre' colour emotion of the Thai subjects than the other regions. Hence, the 'vivid-sombre' colour emotion of the Thai was not only influenced by the chroma of colour, but also by the lightness.

Cross-cultural colour planner

The colour planners for the 'vivid-sombre' colour emotion of Japanese, Thai and the United Kingdom subjects compared with Hong Kong subjects during the perception of colours of different lightness and chroma at hue-angle=0^0 are illustrated in Figures 5.10 to 5.12 respectively.

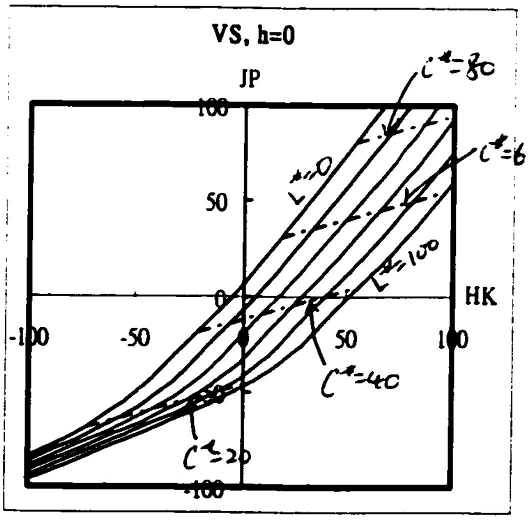

Figure 5.10 Colour planner for the 'vivid-sombre' colour emotion of Japanese and Hong Kong subjects at h=0^0.

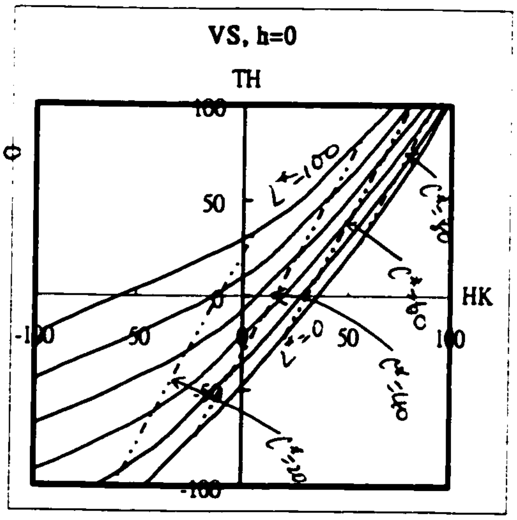

Figure 5.11 Colour planner for the 'vivid-sombre' colour emotion of Thai and Hong Kong subjects at h=0^0.

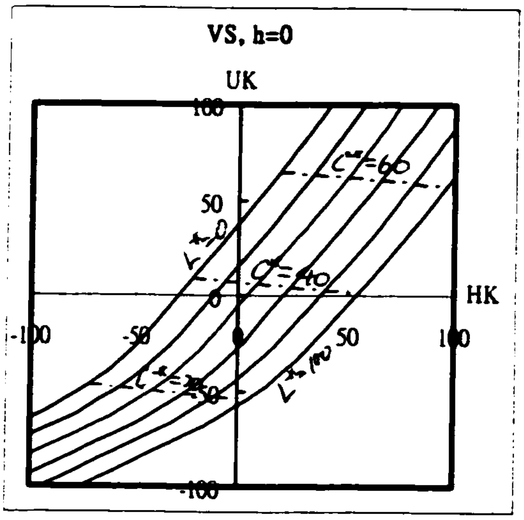

Figure 5.12 Colour planner for the 'vivid-sombrel' colour emotion of the United Kingdom and Hong Kong subjects at $h=0^{\circ}$.

Figure 5.10 shows the colour planner for 'vivid-sombre' colour emotion of the Japanese and Hong Kong subjects, in which a higher correlation between these two regions was found in the 'sombre' part of the planner, i.e., the negative side of the 'vivid-sombre' colour emotion of both regions, because the area of the range of iso-lightness lines may be seen to be smaller in the 'sombre' part. In the case of a comparison between 'vivid-sombre' colour emotion of Thai and Hong Kong subjects, Figure 5.11 illustrates a higher correlation in the 'vivid' part while a larger deviation in the 'sombre' part. However, for the colour emotion pair between the United Kingdom and Hong Kong subjects, a comparatively lower correlation was found in Figure 5.12 as the range of iso-lightness lines cover a larger area, irrespective of whether it is in the 'vivid' or 'sombre' part.

As a result, from the above investigation, the correlations of 'vivid-sombre' colour emotion of the Japanese and Thai with those of the Hong Kong subjects were better than those of the United Kingdom with Hong Kong.

5.3.1.3 Gaudy-plain colour emotion

Correlation Coefficients and Paired-Samples *t*-Test

The correlation coefficients, *r*, and the results of paired-samples *t*-test of 'gaudy-plain' colour emotion of the subjects from Japan (JP), Thailand (TH) and Hong Kong (HK) are shown in Table 5.3.

Table 5.3

Correlation coefficients and results of paired-samples *t*-test of 'gaudy-plain' colour emotions of subjects of different regions

GP	**Correlation Coefficient, *r***		**Significant Difference** (at 0.001 level of significance)	
	JP	**TH**	**JP**	**TH**
HK	0.930	0.926	Yes	Yes
JP		0.831		Not applicable

Of the correlation coefficients shown in Table 5.3, large correlation coefficients, i.e., larger than 0.9, were found between Japanese and Hong Kong subjects as well as Thai and Hong Kong subjects. This suggested that the Japanese and Thai had good correlation of 'gaudy-plain' colour emotion with the Hong Kong subjects. A lower correlation was found between Japanese and Thai subjects, so their colour perception of 'gaudy-plain' was inferior when compared with the Hong Kong subjects, and the paired-samples *t*-test was not applicable for the comparison of the Japanese and Thai of 'gaudy-plain' colour emotion.

In the paired-samples *t*-test, statistically significant differences in the 'gaudy-plain' colour emotion were found between the subjects of any two regions among the Asian regions in this study (Table 5.3). Their practical differences are discussed in the following sections.

Graphical Representation

The plots of the visual assessment results of 'gaudy-plain' colour emotion of Japan and Thailand against those of Hong Kong are shown in Figures 5.13 and 5.14 respectively.

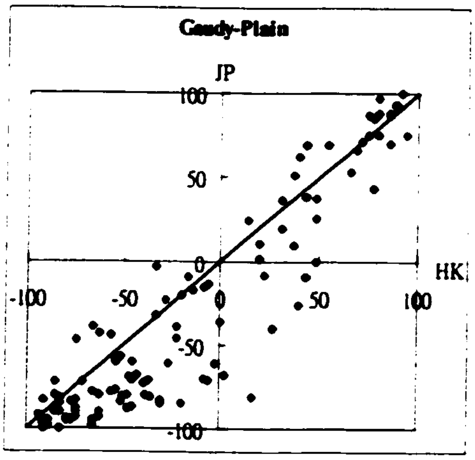

Figure 5.13 The visual assessment results of 'gaudy-plain' colour emotion of Japanese against Hong Kong subjects.

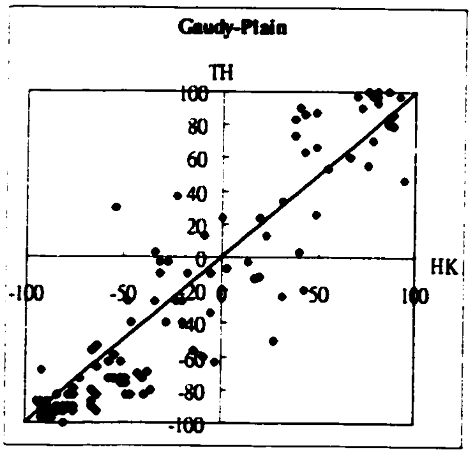

Figure 5.14 The visual assessment results of 'gaudy-plain' colour emotion of Thai against Hong Kong subjects.

Figures 5.13 and 5.14 show the correlation of the 'gaudy-plain' colour emotion of the Japanese and Hong Kong subjects as well as the Thai and Hong Kong subjects are good since the plots are located close to each 45-degree line. When comparing the two graphs above, a comparatively larger deviation of plots to the 45-degree line was found in Figure 5.13 that for the colours assessed by the Hong Kong subjects as 'neutral', i.e., near the part of GP=0 which means neither 'gaudy' nor 'plain' emotion was perceived, were assessed as rather 'plain' by the Japanese.

Mathematical Models for Japan and Thailand

In order to quantitatively evaluate the influence of the colorimetric attributes on the 'gaudy-plain' colour emotion of the Japanese and Thai subjects, the mathematical models for these relationships were derived and are shown below.

Japan

$$GP_{0\leq h<180} = 0.419L^{*} + 0.841C^{*(1.258)} - 0.086h - 117.931 \qquad (5.7a)$$

$$GP_{180\leq h<360} = 0.156L^{*} + 1.556C^{*(1.205)} - 0.015(360^{0} - h) - 102.701 \qquad (5.7b)$$

Thailand

$$GP_{0\leq h<180} = 0.052L^{*} + 3.043C^{*} - 0.112h - 100.227 \qquad (5.8a)$$

$$GP_{180\leq h<360} = 0.471L^{*} + 3.408C^{*} - 0.080(360^{0} - h) - 119.498 \qquad (5.8b)$$

Hong Kong (from Section 3.3.2)

$$GP_{0^{0}\leq h<180^{0}} = -0.332L^{*} + 4.574C^{*(0.867)} - 0.081h - 73.973 \qquad (3.8a)$$

$$GP_{180^{0}\leq h<360^{0}} = -0.114L^{*} + 13.195C^{*(0.664)} - 0.005(360^{0} - h) - 103.481 \qquad (3.8b)$$

From the above equations, the chroma of colour was found to be the most influential attribute on the selection of 'gaudy-plain' colour emotion of subjects from Japan and Thailand. As the chroma increased, the colour tended to give a more 'gaudy' impression to the subjects. These observations were the same as those found in the case of the Hong Kong subjects.

Cross-cultural colour planner

The colour planner for the 'gaudy-plain' colour emotion of Japanese and Hong Kong subjects during the perception of colours of different lightness and chroma at hue-angle=0^0 is illustrated in Figure 5.15. The colour planners for the Thai and the Hong Kong subjects is shown in Figure 5.16.

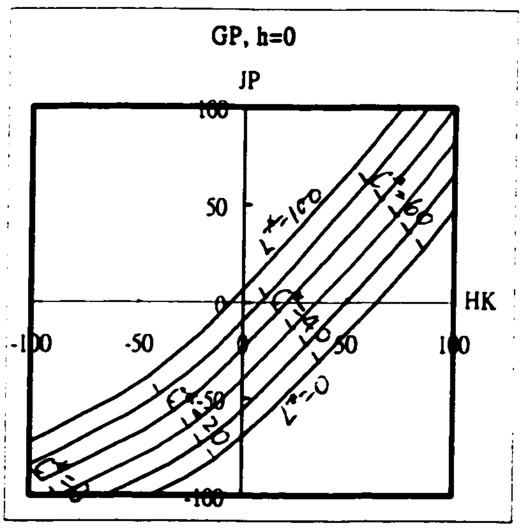

Figure 5.15 Colour planner for the 'gaudy-plain' colour emotion of Japanese and Hong Kong subjects at h=0^0.

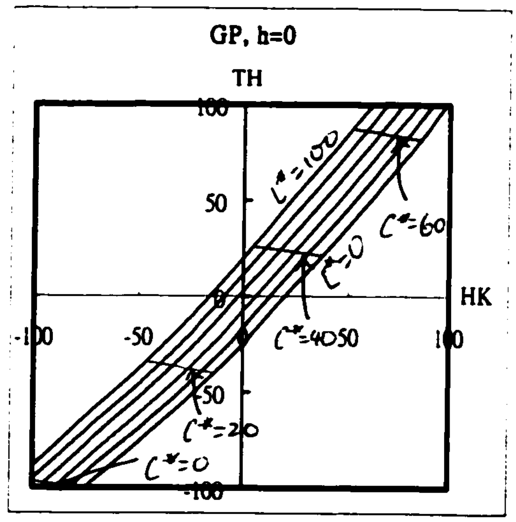

Figure 5.16 Colour planner for the 'gaudy-plain' colour emotion of Thai and Hong Kong subjects at h=0^0.

In Figure 5.16, a narrower area of the range of iso-lightness lines is found that represents a better correlation is obtained between the Thai and Hong Kong subjects for the 'gaudy-plain' colour emotion of the red colours, i.e., hue-angle=0^0. A comparatively larger area of range of iso-lightness lines is shown in Figure 5.15 of the colour planner of Japanese and Hong Kong subjects that illustrates a poorer correlation between them for the red colours.

5.3.1.4 Striking-subdued colour emotion

Correlation Coefficients and Paired-Samples *t*-Test

The correlation coefficients, *r*, and the results of paired-samples *t*-test of 'striking-subdued' colour emotion of the subjects from Japan (JP), Thailand (TH) and Hong Kong (HK) are shown in Table 5.4.

Table 5.4

Correlation coefficients and results of paired-samples *t*-test of 'striking-subdued' colour emotions of subjects of different regions

SS	Correlation Coefficient, *r*		Significant Difference (at 0.001 level of significance)	
	JP	TH	JP	TH
HK	0.926	0.851	Yes	Yes
JP		0.741		Not applicable

The correlation coefficients of 'striking-subdued' colour emotion of the three Asian regions were assessed to vary quite considerably, as shown in Table 5.4. The highest correlation was found between the Hong Kong and Japanese subjects, with r=0.926. The lowest correlation was found between the Japanese and Thai subjects, with r=0.741, and no paired-samples *t*-test was involved for this comparison.

In the paired-samples t-test, statistically significant differences in the 'striking-subdued' colour emotion were found between the subjects of any two regions among the Asian regions in this study (Table 5.4). Their practical differences are discussed in the following sections.

Graphical Representation

The plots of the visual assessment results of 'striking-subdued' colour emotion of Japan and Thailand against Hong Kong are shown in Figures 5.17 and 5.18 respectively.

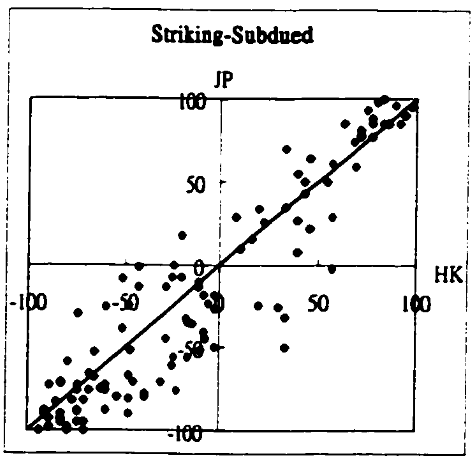

Figure 5.17 The visual assessment results of 'striking-subdued' colour emotion of Japanese against Hong Kong subjects.

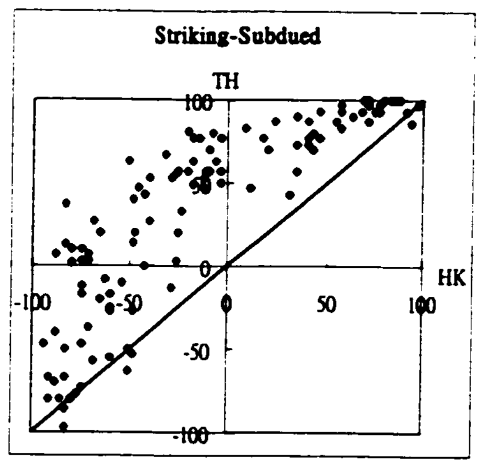

Figure 5.18 The visual assessment results of 'striking-subdued' colour emotion of Thai against Hong Kong subjects.

Figure 5.17 shows a good correlation of 'striking-subdued' colour emotion of Japanese and Hong Kong subjects whereas Figure 5.18 shows the correlation of this colour emotion pair between the Thai and Hong Kong subjects is insignificant. Many colour samples which were assessed as 'neutral' or 'subdued' by the Hong Kong subjects were assessed as 'striking' by the Thai subjects.

Mathematical Models for Japan, Thailand and the United Kingdom

In order to quantitatively evaluate the influence of the colorimetric attributes on the 'striking-subdued' colour emotion of the Japanese and Thai subjects, the mathematical models for these relationships were derived and are shown below.

Japan

$$SS_{0 \leq h < 180} = 0.125L^* + 2.526C^* - 0.042h - 100.377 \qquad (5.9a)$$

$$SS_{180 \leq h < 360} = -0.575L^* + 3.071C^* - 0.044(360^0 - h) - 47.163 \qquad (5.9b)$$

Thailand

$$SS_{0 \leq h < 180} = -1.648L^* + 8.075C^{*(0.704)} + 0.016h + 46.061 \qquad (5.10a)$$

$$SS_{180 \leq h < 360} = -1.719L^* + 13.064C^{*(0.528)} + 0.111(360^0 - h) + 54.533 \qquad (5.10b)$$

Hong Kong (from Section 3.3.2)

$$SS_{0^0 \leq h < 180^0} = -0.750L^* + 2.847C^{*(0.961)} - 0.052h - 35.564 \qquad (3.9a)$$

$$SS_{180^0 \leq h < 360^0} = -0.748L^* + 10.597C^{*(0.684)} + 0.060(360^0 - h) - 54.801 \qquad (3.9b)$$

From the above equations, it may be seen that the chroma of colour was the most influential attribute to the selection of 'striking-subdued' colour emotion of subjects from Japan and Thailand. As the chroma increased, the colour tended to give a more 'striking' impression to the subjects. These observations equaled with those for the Hong Kong subjects. However, a comparatively larger proportion of influence of lightness on 'striking-subdued' colour emotion of the subjects from Thailand than the other regions was obtained using Equation 5.10a and 5.10b. As the lightness of colour increased, so a more 'subdued' impression was induced in the minds of the Thai subjects. Therefore, the 'striking-subdued' colour emotion of the Thai was not only influenced by the chroma of colour, but also by the lightness.

Cross-cultural colour planner

The colour planners for the 'striking-subdued' colour emotion of Japanese and Thai subjects compared with Hong Kong subjects during the perception of colours of different lightness and chroma at hue-angle=0^0 are illustrated in Figures 5.19 and 5.20 respectively.

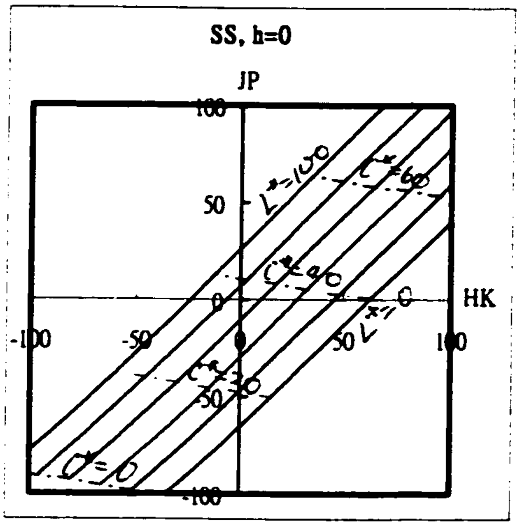

Figure 5.19 Colour planner for the 'striking-subdued' colour emotion of Japanese and Hong Kong subjects at h=0°.

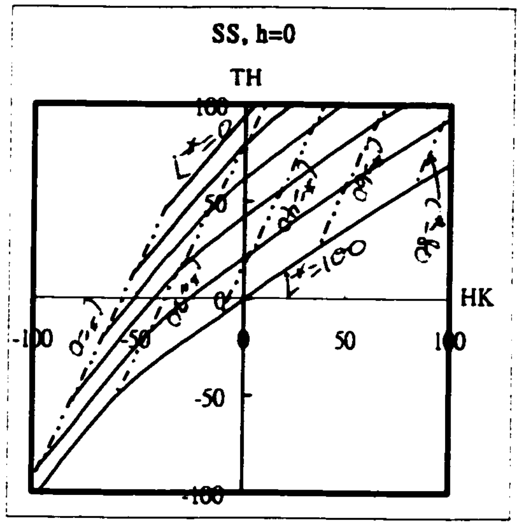

Figure 5.20 Colour planner for the 'striking-subdued' colour emotion of Thai and Hong Kong subjects at h=0°.

Figure 5.20 illustrates that the colours of low lightness, around L^*=0-40, and low chroma, around C^*=0-30, gave either a 'neutral' or 'subdued' impression to the Hong Kong subjects but they gave a 'striking' impression to the Thai subjects. For the 'striking-subdued' colour planner of Japanese and Hong Kong subjects (Figure 5.19), the deviation was not as obvious as that for the Thai and Hong Kong subjects.

5.3.1.5 Dynamic-passive colour emotion

Correlation Coefficients and Paired-Samples t-Test

The correlation coefficients, r, and the results of paired-samples t-test of 'dynamic-passive' colour emotion of the subjects from Japan (JP), Thailand (TH), the United Kingdom (UK) and Hong Kong (HK) are shown in Table 5.5.

Table 5.5

Correlation coefficients and results of paired-samples t-test of 'dynamic-passive' colour emotions of subjects of different regions

DyPa	Correlation Coefficient, r			Significant Difference (at 0.001 level of significance)		
	JP	TH	UK	JP	TH	UK
HK	0.955	0.864	0.889	Yes	Yes	No
JP		0.786	0.926		Not applicable	Yes
TH			0.646			Not applicable

The correlation coefficients of 'dynamic-passive' colour emotion of the above regions were found to vary considerably, from 0.646 to 0.955, as shown in Table 5.5. The correlation between the Hong Kong and Japanese subjects was found to be very high, with r=0.955, whereas the lowest correlation was found between the Thai and the United Kingdom subjects, with r=0.646. When comparing the correlation coefficients of the three regions with Hong Kong, the one between Japan and Hong Kong was the highest whereas the one between Thailand and Hong Kong was the lowest.

In the results of paired-samples t-test shown in Table 5.5, while low correlations were found in some of them so that paired-samples t-test was not applicable for those comparisons, statistically significant differences in the 'dynamic-passive' colour emotion were found between the subjects of almost all regions, except between the subjects of the United Kingdom and those of Hong Kong. Their practical differences are discussed in the following sections.

Graphical Representation

The plots of the visual assessment results of 'dynamic-passive' colour emotion of Japan, Thailand and the United Kingdom against those of Hong Kong are shown in Figures 5.21 to 5.23 respectively.

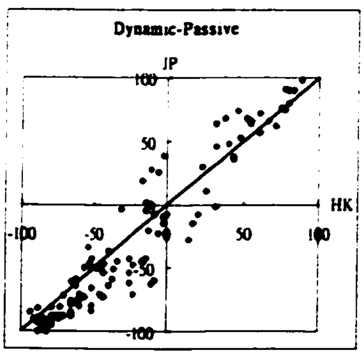

Figure 5.21 The visual assessment results of 'dynamic-passive' colour emotion of Japanese against Hong Kong subjects.

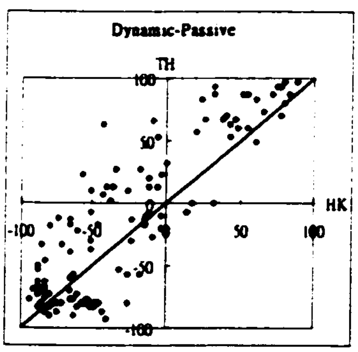

Figure 5.22 The visual assessment results of 'dynamic-passive' colour emotion of Thai against Hong Kong subjects.

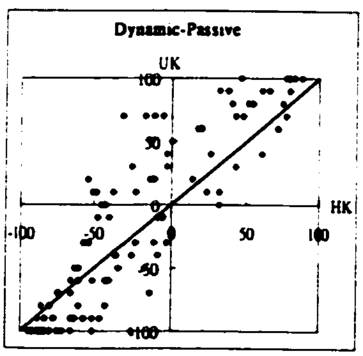

Figure 5.23 The visual assessment results of 'dynamic-passive' colour emotion of the United Kingdom against Hong Kong subjects.

Figure 5.21 shows that the plots lie very close to the 45-degree line of the graph and this indicates the correlation of 'dynamic-passive' colour emotion between Japanese and Hong Kong subjects is very good. The plots in Figure 5.23 are slightly more scattered than the ones in Figure 5.21, hence the correlation of 'dynamic-passive' colour emotion between the United Kingdom and Hong Kong subjects was good but not as good as between the Japanese and Hong Kong subjects. However, the deviation of the plots from the 45-degree line in the colour planner of the Thai and Hong Kong subjects was quite large (Figure 5.22), hence the correlation of 'dynamic-passive' colour emotion between them was the lowest of the above comparisons.

Mathematical Models for Japan, Thailand and the United Kingdom

The mathematical models for the 'dynamic-passive' colour emotion of the Japanese, Thai and the United Kingdom subjects were derived and are shown below.

Japan

$$DyPa_{0\leq h<180} = -0.350L^* + 1.272C^{*(1.159)} - 0.100h - 68.468 \qquad (5.11a)$$

$$DyPa_{180\leq h<360} = -0.719L^* + 1.109C^{*(1.231)} - 0.034(360^0 - h) - 44.616 \qquad (5.11b)$$

Thailand

$$DyPa_{0\leq h<180} = 0.717L^* + 2.537C^* - 0.090h - 113.535 \qquad (5.12a)$$

$$DyPa_{180\leq h<360} = 1.332L^* + 3.232C^* + 0.036(360^0 - h) - 156.540 \qquad (5.12b)$$

The United Kingdom

$$DyPa_{0\leq h<180} = -1.265L^{*} + 2.781C^{*} - 0.051h - 26.003 \qquad (5.13a)$$

$$DyPa_{180\leq h<360} = -1.545L^{*} + 3.136C^{*} + 0.083(360^{0} - h) + 9.006 \qquad (5.13b)$$

Hong Kong (from Section 3.3.2)

$$DyPa_{0^{0}\leq h<180^{0}} = -0.296L^{*} + 3.162C^{*(0.931)} - 0.073h - 68.835 \qquad (3.10a)$$

$$DyPa_{180^{0}\leq h<360^{0}} = -0.120L^{*} + 4.385C^{*(0.864)} + 0.032(360^{0} - h) - 84.791 \qquad (3.10b)$$

From the above equations, it may be seen that the chroma of colour was also the most influential attribute to the selection of 'dynamic-passive' colour emotion of subjects of the above regions. As the chroma increased, so the colour tended to give a more 'dynamic' emotion to the subjects. These observations were the same as those for the Hong Kong subjects. However, Equations 5.13a and 5.13b show larger proportions of influence on the lightness on 'dynamic-passive' colour emotion of the subjects from the United Kingdom than the other regions. As the lightness increased, the colour tended to induce a more 'passive' emotion to the United Kingdom subjects. In other words, the 'dynamic-passive' colour emotion of the United Kingdom subjects was not only influenced by the chroma, but also by the lightness.

Cross-cultural colour planner

The colour planners for the 'dynamic-passive' colour emotion of Japanese, Thai and the United Kingdom subjects against that of the Hong Kong subjects during the perception of colours of different lightness and chroma at hue-angle=0^0 are illustrated in Figures 5.24 to 5.26 respectively.

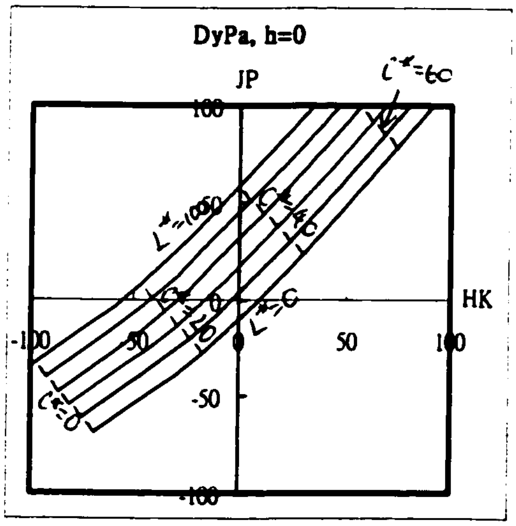

Figure 5.24 Colour planner for the 'dynamic-passive' colour emotion of Japanese and Hong Kong subjects at h=0^0.

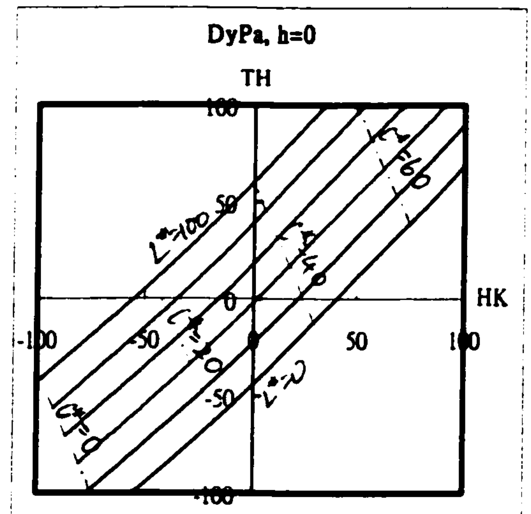

Figure 5.25 Colour planner for the 'dynamic-passive' colour emotion of Thai and Hong Kong subjects at h=0^0.

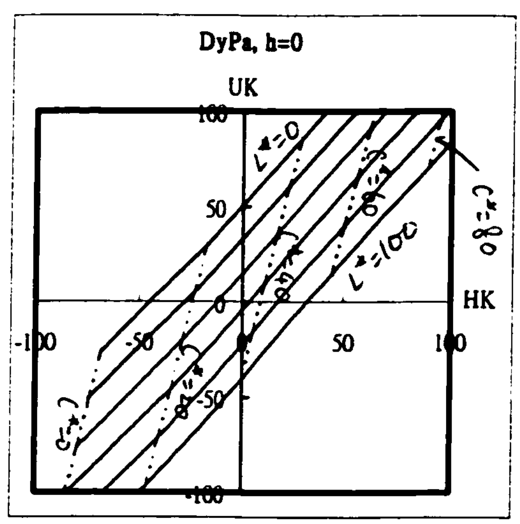

Figure 5.26 Colour planner for the 'dynamic-passive' colour emotion of the United Kingdom and Hong Kong subjects at h=0^0.

Figures 5.24 to 5.26 show that the smallest area covered by the range of iso-lightness lines was observed in the colour planner of the Japanese and Hong Kong subjects whereas larger area may be seen in the colour planner of the Thai and Hong Kong subjects. This indicates that the correlation of 'dynamic-passive' colour emotion of the Japanese and Hong Kong subjects was found to be better than that of the Thai and Hong Kong subjects.

5.3.2 Lightness Dependent Colour Emotion

5.3.2.1 Deep-pale colour emotion

Correlation Coefficients and Paired-Samples *t*-Test

The correlation coefficients, *r*, and the results of paired-samples *t*-test of 'deep-pale' colour emotion of the subjects from Japan (JP), Thailand (TH), the United Kingdom (UK) and Hong Kong (HK) and are shown in Table 5.6.

Table 5.6

Correlation coefficients and results of paired-samples *t*-test of 'deep-pale' colour emotions of subjects of different regions

DP	**Correlation Coefficient, *r***			**Significant Difference** (at 0.001 level of significance)		
	JP	**TH**	**UK**	**JP**	**TH**	**UK**
HK	0.951	0.844	0.874	No	Yes	Yes
JP		0.813	0.911		Not applicable	Yes
TH			0.818			Not applicable

The correlations of the 'deep-pale' colour emotion for the four regions were found to be quite good, as the correlation coefficients being larger than 0.8. Of the correlation coefficients in Table 5.6, the highest correlation for the 'deep-pale' colour emotion was that for the Hong Kong and Japanese subjects (r=0.951) whereas the lowest correlation was between the Japanese and Thai subjects (r=0.813). When rating the correlation of 'deep-pale' colour emotion of the other regions with Hong Kong, the highest was for the Japanese subjects while the next was for the United Kingdom subjects (r=0.874), and the lowest one was for the Thai subjects (r=0.844).

In the paired-samples t-test, no statistically significant difference was found in the 'deep-pale' colour emotion of the subjects of Hong Kong and Japan, whereas significant differences were found in the case of the comparisons of the other regions, irrespective of those having low correlations that paired-samples t-test was not applicable (Table 5.6). Their practical differences are discussed in the following sections.

<u>Graphical Representation</u>

The plots of the visual assessment results of 'striking-subdued' colour emotion of Japan, Thailand and the United Kingdom against Hong Kong are shown in Figures 5.27 to 5.29 respectively.

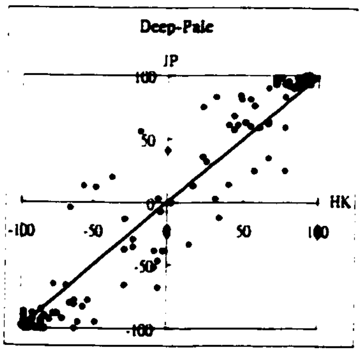

Figure 5.27 The visual assessment results of 'deep-pale' emotion of Japanese against Hong Kong subjects.

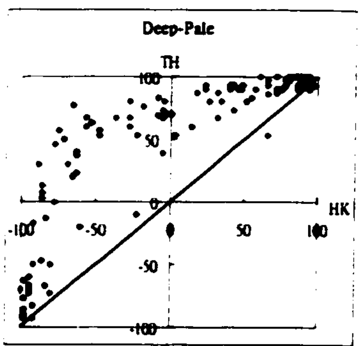

Figure 5.28 The visual assessment results of 'deep-pale' colour emotion of Thai against Hong Kong subjects.

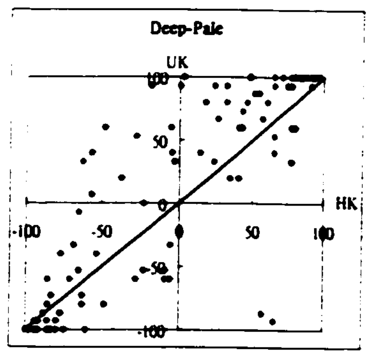

Figure 5.29 The visual assessment results of 'deep-pale' colour emotion of the United Kingdom against Hong Kong subjects.

Of the three figures above, the graph of the visual assessment results of 'deep-pale' colour emotion of Japanese against Hong Kong subjects was found to have the best correlation since the plots are located close to the 45-degree line, which is shown in Figure 5.27. However, the poorest correlation was found between the Thai and Hong Kong subjects as a large deviation of the plots with the 45-degree line was observed as may be seen in Figure 5.28. In Figure 5.29, the plots of the 'deep-pale' colour emotion of the United Kingdom and Hong Kong subjects show a slight scattering around the 45-degree line and this indicates that the correlation of the Hong Kong and United Kingdom data was not as good as that for the Japanese.

Mathematical Models for Japan, Thailand and the United Kingdom

The mathematical models for the 'deep-pale' colour emotion of the Japanese, Thai and the United Kingdom subjects were derived and are shown below.

Japan

$$DP_{0\le h<180} = -3.619L^* + 1.269C^* + 0.076h + 167.223 \quad (5.14a)$$

$$DP_{180\le h<360} = -3.952L^* + 0.375C^* + 0.071(360^0 - h) + 191.924 \quad (5.14b)$$

Thailand

$$DP_{0\le h<180} = -2.926L^* + 1.196C^* + 0.037h + 178.615 \quad (5.15a)$$

$$DP_{180\le h<360} = -2.308L^* + 0.326C^* + 0.049(360^0 - h) + 158.927 \quad (5.15b)$$

The United Kingdom

$$DP_{0\le h<180} = -3.583L^* + 1.564C^* - 0.007h + 173.036 \quad (5.16a)$$

$$DP_{180\le h<360} = -3.665L^* + 1.102C^* + 0.258(360^0 - h) + 158.839 \quad (5.16b)$$

Hong Kong (from Section 3.3.2)

$$DP_{0^0\le h<180^0} = -3.590L^* + 0.451C^* + 0.040h + 189.467 \quad (3.5a)$$

$$DP_{180^0\le h<360^0} = -3.674L^* - 0.216C^* + 0.098(360^0 - h) + 189.127 \quad (3.5b)$$

Using Equations 5.14a to 5.16b, it was found that the lightness of colour was the most influential attribute influencing the selection of 'deep-pale' colour emotion of subjects of the above regions and a similar finding was evident in the case of the Hong Kong subjects. As the lightness increased, the colour tended to give a 'paler' impression to the subjects. However, the above equations showed larger proportions of influence of chroma on the 'deep-pale' colour emotion of the subjects from the above three regions than the equations derived for the Hong Kong subjects. As the chroma increased, so the colour tended to give a 'deeper' impression to them, and this was slightly different from the perception of the Hong Kong subjects that the influence of the chroma was not so obvious.

Cross-cultural colour planner

The colour planners for the 'deep-pale' colour emotion of the Japanese, Thai and United Kingdom subjects against that of the Hong Kong subjects during the perception of colours of different lightness and chroma at hue-angle=0^0 are illustrated in Figures 5.30 to 5.32 respectively.

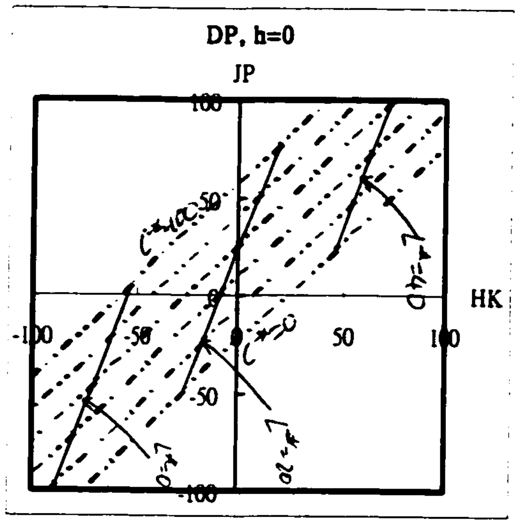

Figure 5.30 Colour planner for the 'deep-pale' colour emotion of Japanese and Hong Kong subjects at h=0°.

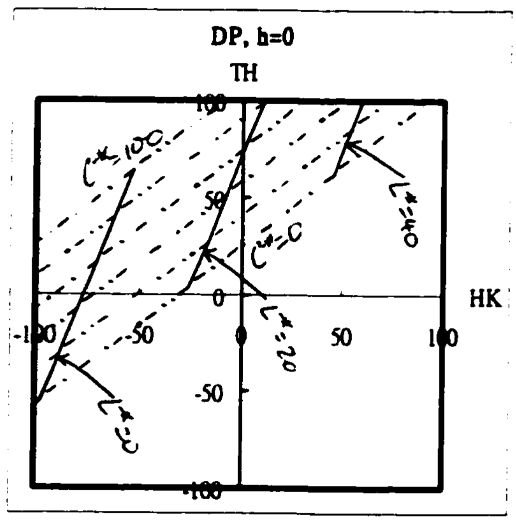

Figure 5.31 Colour planner for the 'deep-pale' colour emotion of Thai and Hong Kong subjects at h=0°.

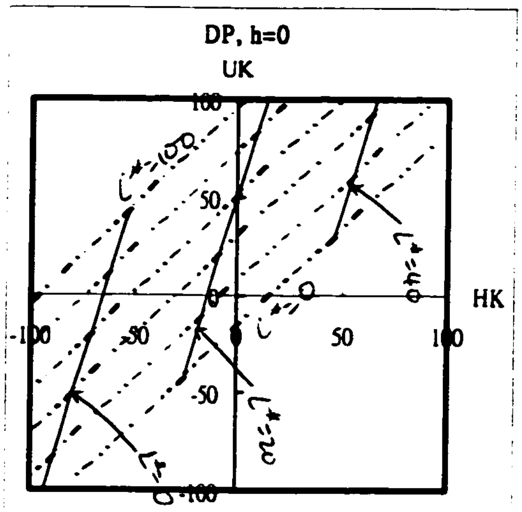

Figure 5.32 Colour planner for the 'deep-pale' colour emotion of the United Kingdom and Hong Kong subjects at h=0°.

From the graphs above, it may be seen that Figure 5.30 shows the best correlation of the 'deep-pale' colour emotion of the Hong Kong subjects with the Japanese ones than with the subjects of other regions because a smaller area of the range of iso-chroma lines was obtained. In Figures 5.31 and 5.32, it is demonstrated that the Hong Kong subjects consistently had 'paler' impressions of some red colours than the Thai and the United Kingdom subjects, and the tendency was more obvious in the correlation with the Thai subjects. Most of the colours which gave a 'pale' impression to the Hong Kong subjects gave a 'deep' impression to the Thai subjects, as shown in Figure 5.31, and thus the correlation of the 'deep-pale' colour emotion of the Hong Kong subjects with the Thai subjects was found to be the worst of all regions studied.

5.3.2.2 Heavy-light colour emotion

Correlation Coefficients and Paired-Samples *t*-Test

The correlation coefficients, *r*, and the results of paired-samples *t*-test of 'heavy-light' colour emotion of the subjects from Japan (JP), Thailand (TH) and Hong Kong (HK) are shown in Table 5.7.

Table 5.7

Correlation coefficients and results of paired-samples *t*-test of 'heavy-light' colour emotions of subjects of different regions

HL	**Correlation Coefficient, *r***		**Significant Difference** (at 0.001 level of significance)	
	JP	**TH**	**JP**	**TH**
HK	0.973	0.912	No	Yes
JP		0.900		Yes

The correlation of 'heavy-light' colour emotion of the three Asian regions was good and the correlation coefficients were all larger than 0.9, as shown in Table 5.7. The highest correlation was found between the Hong Kong and Japanese subjects, with r=0.973, which represented a very high correlation between them; whereas the lowest correlation was found between the Japanese and Thai subjects, with r=0.900, and this correlation was also quite good.

In the paired-samples t-test, no statistically significant difference was found in the 'heavy-light' colour emotion of the subjects of Japan and Hong Kong, whereas significant differences were found in the case of the subjects of Thai and Hong Kong, and those of Thai and Japan (Table 5.7). Their practical differences were discussed in the following sections.

Graphical Representation

The plots of the visual assessment results of 'heavy-light' colour emotion of Japan and Thailand against Hong Kong are shown in Figures 5.33 and 5.34 respectively.

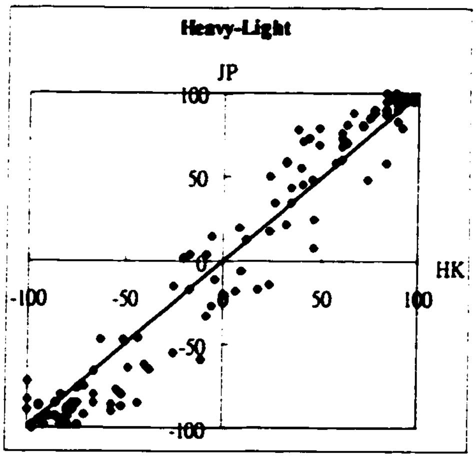

Figure 5.33 The visual assessment results of 'heavy-light' colour emotion of Japanese against Hong Kong subjects.

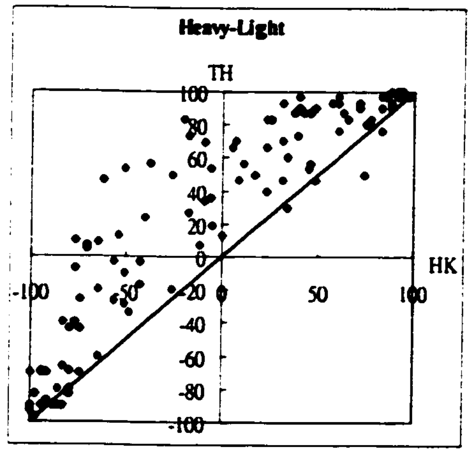

Figure 5.34 The visual assessment results of 'heavy-light' colour emotion of Thai against Hong Kong subjects.

Figure 5.33 shows a very good correlation between the Japanese and Hong Kong subjects towards 'heavy-light' colour emotion since all the visual assessment plots are located very close to the 45-degree line. A lower correlation was observed between this colour emotion pair of the Hong Kong and Thai subjects because a larger derivation of plots with the 45-degree line is shown in Figure 5.34.

Mathematical Models for Japan and Thailand

The mathematical models for the 'heavy-light' colour emotion of the Japanese and Thai subjects were derived and are shown below.

Japan

$$HL_{0\leq h<180} = -3.760L^* + 0.121C^* + 0.046h + 208.301 \quad (5.17a)$$

$$HL_{180\leq h<360} = -3.730L^* - 0.495C^* + 0.020(360^0 - h) + 204.099 \quad (5.17b)$$

Thailand

$$HL_{0\leq h<180} = -3.261L^* + 0.470C^* + 0.042h + 200.591 \quad (5.18a)$$

$$HL_{180\leq h<360} = -2.739L^* - 0.323C^* - 0.016(360^0 - h) + 185.908 \quad (5.18b)$$

Hong Kong (from Section 3.3.2)

$$HL_{0^0\leq h<180^0} = -3.340L^* + 0.476C^* + 0.037h + 175.467 \quad (3.6a)$$

$$HL_{180^0\leq h<360^0} = -3.477L^* - 0.264C^* + 0.072(360^0 - h) + 182.866 \quad (3.6b)$$

From the Equations 5.17a to 5.18b, the lightness of colour was found to be the most influential attribute on the selection of 'heavy-light' colour emotion of the Japanese and Thai subjects. This finding was the same as the Hong Kong subjects that the lightness was the dominant parameter in the 'heavy-light' colour emotion. As the lightness increased, so the colour tended to induce a 'lighter' impression in the minds of the subjects.

<u>Cross-cultural colour planner</u>

The colour planners for the 'heavy-light' colour emotion of the Japanese and

Thai subjects against that of the Hong Kong subjects during the perception of colours of different lightness and chroma at hue-angle=0^0 are illustrated in Figures 5.35 and 5.36 respectively.

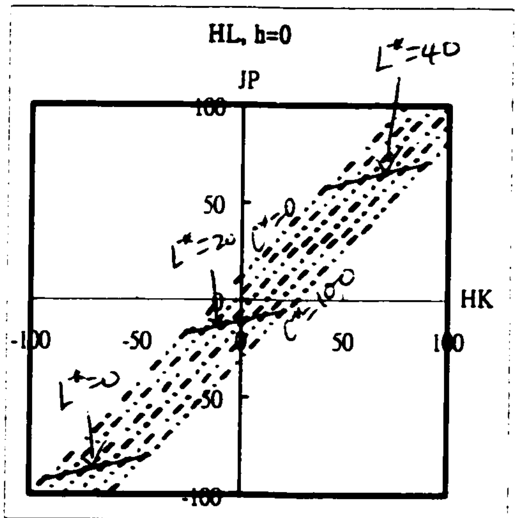

Figure 5.35 Colour planner for the 'heavy-light' colour emotion of Japanese and Hong Kong subjects at h=0^0.

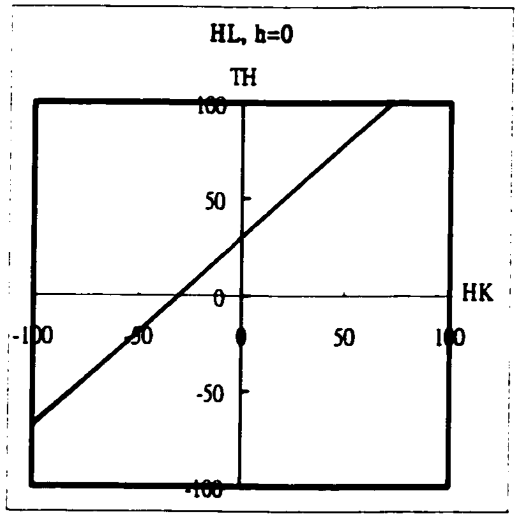

Figure 5.36 Colour planner for the 'heavy-light' colour emotion of Thai and Hong Kong subjects at h=0^0.

Figure 5.35 shows a high correlation of 'heavy-light' colour emotion between the Japanese and Hong Kong subjects in the red colour planner because the area of the ranges of the iso-chroma lines was small and the agreement of 'heavy' or 'light' emotion of the colours between these two regions was assessed as good. For the correlation of the Thai and Hong Kong subjects of this colour emotion pair, Figure 5.36 illustrates an almost straight-line relationship between them. This means irrespective of the magnitude of lightness or chroma of a red colour, a definite relationship of 'heavy-light' colour emotion between the Hong

Kong and Thai subjects was obtained. For the relationship, the perception of the Thai subjects was found to be 'heavier' than that of the Hong Kong subjects, since those colours giving HL=50 to the Hong Kong subjects gave HL=80 to the Thai subjects, i.e., a 'heavier' impression, while those colours giving HL=-100 to the Hong Kong subjects gave HL=-60 to the Thai subjects, i.e., a lower level of 'light' impression, as shown in Figure 5.36.

5.3.2.3 Soft-hard colour emotion

Correlation Coefficients and Paired-Samples *t*-Test

The correlation coefficients, *r*, and the results of paired-samples *t*-test of 'soft-hard' colour emotion of the subjects from Japan (JP), Thailand (TH), the United Kingdom (UK) and Hong Kong (HK) are shown in Table 5.8.

Table 5.8

Correlation coefficients and results of paired-samples *t*-test of 'soft-hard' colour emotions of subjects of different regions

SH	Correlation Coefficient, *r*			Significant Difference (at 0.001 level of significance)		
	JP	TH	UK	JP	TH	UK
HK	0.881	0.925	0.857	No	Yes	Yes
JP		0.879	0.817		No	Not applicable
TH			0.784			Not applicable

Among the correlation coefficients in Table 5.8, the highest correlation of the 'soft-hard' colour emotion was found between the Hong Kong and Thai subjects, with r=0.925, while the lowest correlation was found between the Thai and United Kingdom subjects, with r=0.784. The correlations of this colour emotion pair between other regions and Hong Kong were found to be quite good, with r=0.857-0.925, in which the best correlation was observed with the Thai subjects whereas the least correlation was found with the United Kingdom subjects.

In the results of paired-samples t-test shown in Table 5.8, statistically significant differences in the 'soft-hard' colour emotion were only found between the subjects of Hong Kong and Thailand, and those of Hong Kong and the United Kingdom. No statistically significant difference was found between the subjects of the other regions in this study, whereas paired-samples t-test was not applicable to some of the comparisons due to the low correlations between them.

Graphical Representation

The plots of the visual assessment results of 'soft-hard' colour emotion of Japan, Thailand and the United Kingdom against Hong Kong are shown in Figures 5.37 to 5.39 respectively.

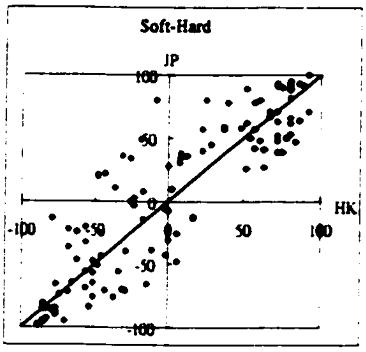

Figure 5.37 The visual assessment results of 'soft-hard' colour emotion of Japanese against Hong Kong subjects.

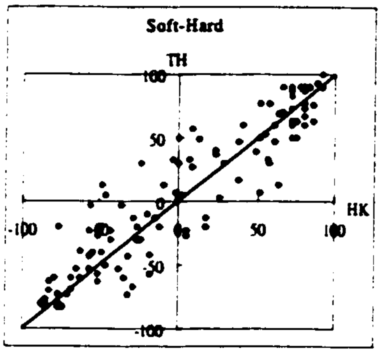

Figure 5.38 The visual assessment results of 'soft-hard' colour emotion of Thai against Hong Kong subjects.

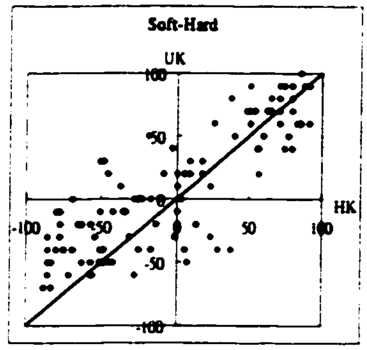

Figure 5.39 The visual assessment results of 'soft-hard' colour emotion of the United Kingdom against Hong Kong subjects.

In Figures 5.37 and 5.38, it may be seen that good correlations with less scattering of plots were found in both the graphs showing the correlation of 'soft-hard' colour emotion between the Japanese and Hong Kong subjects as well as between the Thai and Hong Kong subjects. A comparatively more scattered plotting was obtained in the correlation of this colour emotion pair between the United Kingdom and Hong Kong subjects as shown in Figure 5.39.

Mathematical Models for Japan, Thailand and the United Kingdom

The mathematical models for the 'soft-hard' colour emotion of the Japanese, Thai and the United Kingdom subjects were derived and are shown below.

Japan

$SH_{0\leq h<180} = 2.694L^* + 0.469C^* - 0.128h - 141.826$ (5.19a)

$SH_{180\leq h<360} = 3.035L^* + 0.898C^* - 0.106(360^0 - h) - 175.914$ (5.19b)

Thailand

$SH_{0\leq h<180} = 2.722L^* - 0.122C^* - 0.062h - 145.988$ (5.20a)

$SH_{180\leq h<360} = 2.884L^* + 1.242C^* - 0.095(360^0 - h) - 174.424$ (5.20b)

The United Kingdom

$SH_{0\leq h<180} = -2.039L^* + 0.849C^* + 0.158h + 63.037$ (5.21a)

$SH_{180\leq h<360} = -2.175L^* + 0.126C^* - 0.017(360^0 - h) + 107.399$ (5.21b)

Hong Kong (from Section 3.3.2)

$SH_{0^0\leq h<180^0} = 2.900L^* - 0.510C^* - 0.051h - 146.700$ (3.13a)

$SH_{180^0\leq h<360^0} = 2.953L^* + 0.424C^* - 0.020(360^0 - h) - 159.795$ (3.13b)

The above equations illustrate that lightness of colour was found to be the most influential attribute to the selection of 'soft-hard' colour emotion of all the regions under investigation (Equation 5.19a to Equation 5.21b). This finding was the same as in the case of the Hong Kong subjects that lightness was the dominant parameter in the 'soft-hard' colour emotion. As the lightness increased, so the colour tended to induce a 'softer' impression in the minds of all subjects.

Cross-cultural colour planner

The colour planners for the 'soft-hard' colour emotion of the Japanese, Thai and the United Kingdom subjects against that of the Hong Kong subjects during the perception of colours of different lightness and chroma at hue-angle=0^0 are illustrated in Figures 5.40 to 5.42 respectively.

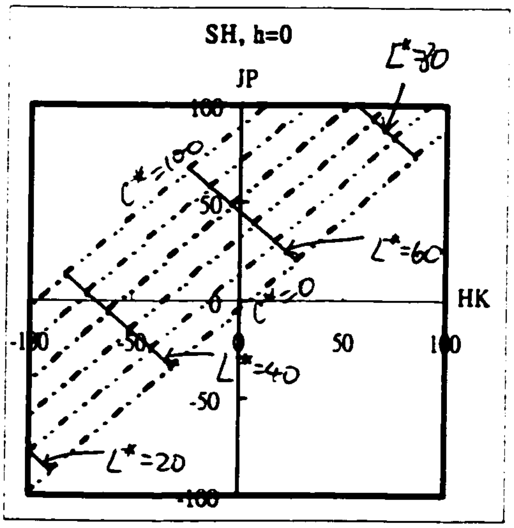

Figure 5.40 Colour planner for the 'soft-hard' colour emotion of Japanese and Hong Kong subjects at h=0^0.

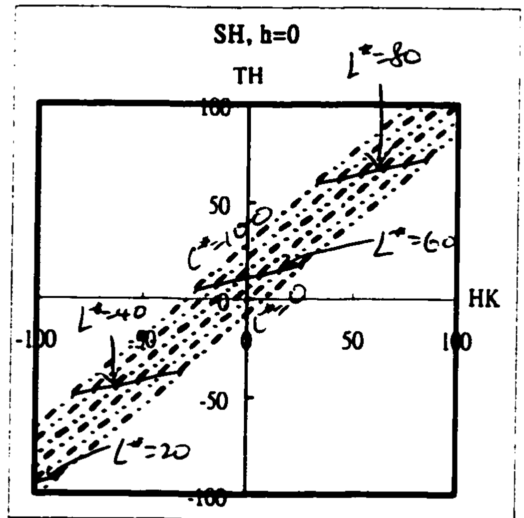

Figure 5.41 Colour planner for the 'soft-hard' colour emotion of Thai and Hong Kong subjects at h=0^0.

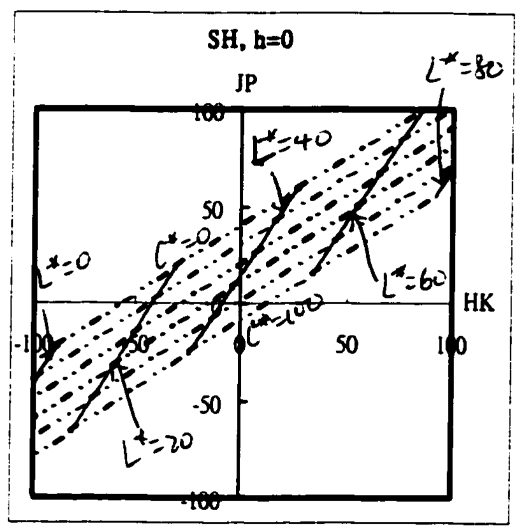

Figure 5.42 Colour planner for the 'soft-hard' colour emotion of the United Kingdom and Hong Kong subjects at h=0^0.

Of the three colour planners shown in Figure 5.40 to Figure 5.42, the best correlation was found in the 'soft-hard' colour emotion between the Thai and Hong Kong subjects. This is because the area of the range of iso-chroma lines was the smallest and their 'soft-hard' colour emotion was very similar to each other. For example, when a colour gave a very 'soft' impression to the Hong Kong subjects, i.e., around SH=90 to 100, it also gave a similar extent of 'soft' impression to the Thai subjects, i.e., around SH=80 to 100, as shown in Figure 5.41. The areas of the range of iso-chroma lines in Figure 5.40 and 5.42 are larger than that in Figure 5.41 so that the correlations of the Japanese and the United Kingdom subjects with Hong Kong subjects were worse than that of the Thai with Hong Kong subjects towards the 'soft-hard' perception of red colours. Although a larger area was found in Figure 5.40 between Japanese and Hong Kong subjects, their correlation was not considered to be worse than the correlation between the United Kingdom and Hong Kong subjects because colours gave much 'harder' impressions to the Hong Kong subjects than to the United Kingdom subjects, especially in the 'hard' part, i.e., both the SH values of the Hong Kong and the United Kingdom are negative, as shown in Figure 5.42. For example, those red colours giving very 'hard' perceptions to the Hong Kong subjects, with SH=-100, gave lower levels of 'hard' impression to the United Kingdom subjects, with SH=-25 to -75.

5.3.2.4 Strong-weak colour emotion

Correlation Coefficients and Paired-Samples *t*-Test

The correlation coefficients, *r*, and the results of paired-samples *t*-test of 'strong-weak' colour emotion of the subjects from Japan (JP), Thailand (TH) and Hong Kong (HK) are shown in Table 5.9.

Table 5.9

Correlation coefficients and results of paired-samples *t*-test of 'strong-weak' colour emotions of subjects of different regions

SW	Correlation Coefficient, *r*		Significant Difference (at 0.001 level of significance)	
	JP	TH	JP	TH
HK	0.928	0.887	Yes	Yes
JP		0.752		Not applicable

The correlation coefficients of 'strong-weak' colour emotion of the three Asian regions were assessed to vary quite considerably, as shown in Table 5.9. The highest correlation was found between the Hong Kong and Japanese subjects, with r=0.928, whereas the lowest correlation was found between the Japanese and Thai subjects, with r=0.752, and paired-samples *t*-test was not applicable for this comparison.

In the paired-samples t-test, statistically significant differences were found in the 'strong-weak' colour emotion between the subjects of all Asian regions in this study (Table 5.3). Their practical differences are discussed in the following sections.

Graphical Representation

The plots of the visual assessment results of 'strong-weak' colour emotion of Japan and Thailand against Hong Kong are shown in Figures 5.43 and 5.44 respectively.

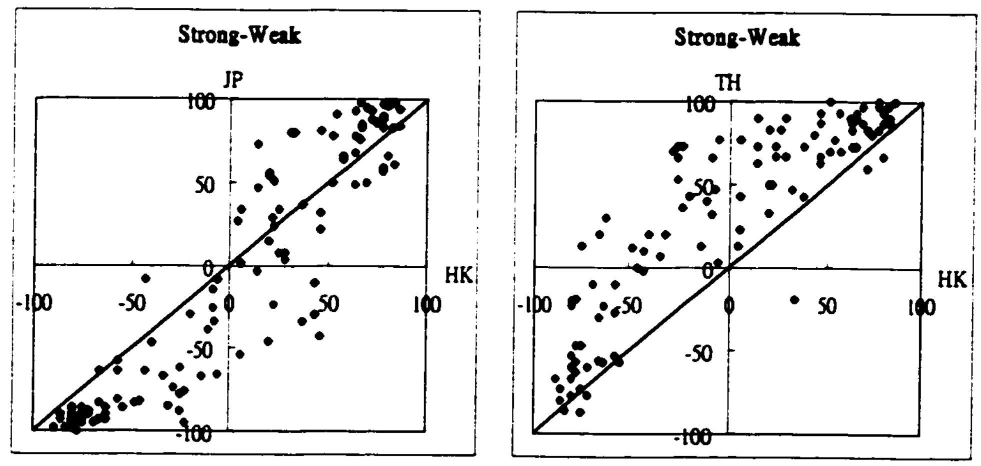

Figure 5.43 The visual assessment results of 'strong-weak' colour emotion of Japanese against Hong Kong subjects.

Figure 5.44 The visual assessment results of 'strong-weak' colour emotion of Thai against Hong Kong subjects.

In Figure 5.43, although a small amount of colours gave rather 'weak' impression to the Japanese, i.e., with SW around −50, whereas they gave quite 'strong' impression to the Hong Kong subjects, i.e., with *SW* around 50, the general correlation of 'strong-weak' colour emotion between them was found to be quite good. For the correlation of the Hong Kong subjects with the Thai, the correlation was not as good as with the Japanese. Figure 5.44 shows a larger deviation of 'strong-weak' colour emotion from the 45-degree line between the Thai and Hong Kong subjects. Most of the colours induced stronger impression to the Thai than the Hong Kong subjects.

Mathematical Models for Japan and Thailand

The mathematical models for the 'strong-weak' colour emotion of the Japanese and Thai subjects were derived and are shown below.

Japan

$$SW_{0\leq h<180} = -2.513L^* + 1.959C^* + 0.023h + 78.718 \quad (5.22a)$$

$$SW_{180\leq h<360} = -3.225L^* + 1.415C^* + 0.061(360^0 - h) + 128.632 \quad (5.22b)$$

Thailand

$$SW_{0\leq h<180} = -2.823L^* + 0.845C^* + 0.105h + 164.162 \quad (5.23a)$$

$$SW_{180\leq h<360} = -2.267L^* - 0.011C^* - 0.006(360^0 - h) + 162.905 \quad (5.23b)$$

Hong Kong (from Section 3.3.2)

$$SW_{0^0 \leq h < 180^0} = -2.625L^* + 1.185C^* + 0.053h + 116.320 \quad (3.14a)$$

$$SW_{180^0 \leq h < 360^0} = -2.758L^* + 0.353C^* + 0.050(360^0 - h) + 135.877 \quad (3.14b)$$

Although the dominant parameter in the 'strong-weak' colour emotion pair of the Hong Kong subjects was the lightness, the chroma of colour was also found to have some influences to the selection of this colour emotion pair. Equations 5.22a and 5.22b show that the 'strong-weak' colour emotion of the Japanese was not only influenced by the lightness of colour, the chroma also had some effects on it. As the lightness increased, a 'weaker' impression was evoked; while increasing the chroma resulted in giving a 'stronger' impression to the Japanese and Hong Kong subjects. However, the mathematical models for the 'strong-weak' colour emotion of the Thai in Equations 5.23a and 5.23b show that the dominant parameter was solely the lightness of colour, and the influence of the chroma was not significant.

Cross-cultural colour planner

The colour planners for the 'strong-weak' colour emotion of the Japanese and Thai subjects against that of the Hong Kong subjects during the perception of colours of different lightness and chroma at hue-angle=0^0 are illustrated in Figures

5.45 and 5.46 respectively.

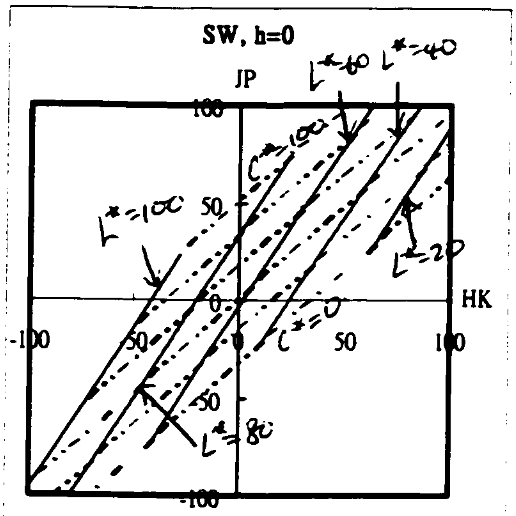

Figure 5.45 Colour planner for the 'strong-weak' colour emotion of Japanese and Hong Kong subjects at h=0°.

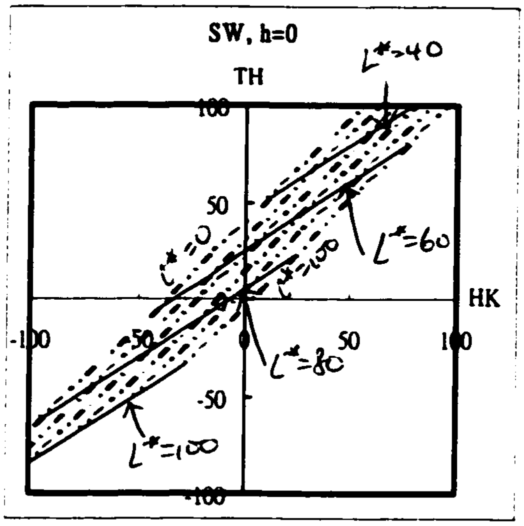

Figure 5.46 Colour planner for the 'strong-weak' colour emotion of Thai and Hong Kong subjects at h=0°.

Figure 5.45 illustrates a large area of range of iso-lightness and iso-chroma lines in the colour planner, representing the correlation of 'strong-weak' colour emotion between the Japanese and Hong Kong subjects for red colours was not that good. Although a smaller area was found in Figure 5.46 between the Thai and Hong Kong subjects, their correlation was not observed to be better than the one between the Japanese and Hong Kong subjects because the same colours gave a much 'stronger' impression to the Thai than to the Hong Kong subjects. For examples, when a colour gave a very 'strong' impression to the Thai subjects, with SW=100, it gave a 'weaker' impression to the Hong Kong subjects, with SW around 60 to 95; and when another colour evoked a very 'weak' impression to the

Hong Kong subjects, with *SW*=-100, the Thai subjects received a 'stronger' impression, with *SW* around –65 to –80, during the perception of the same colour.

5.3.3 Lightness and chroma dependent colour emotions

5.3.3.1 Light-dark colour emotion

Correlation Coefficients and Paired-Samples *t*-Test

The correlation coefficients, *r*, and the results of paired-samples *t*-test of 'light-dark' colour emotion of the subjects from Japan (JP), Thailand (TH), the United Kingdom (UK) and Hong Kong (HK) are shown in Table 5.10.

Table 5.10

Correlation coefficients and results of paired-samples *t*-test of 'light-dark' colour emotions of subjects of different regions

LD	Correlation Coefficient, *r*			Significant Difference (at 0.001 level of significance)		
	JP	TH	UK	JP	TH	UK
HK	0.958	0.909	0.557	Yes	Yes	Not applicable
JP		0.946	0.632		Yes	Not applicable
TH			0.698			Not applicable

From the correlation coefficients in Table 5.10, it was found that a much better correlation of the 'light-dark' colour emotion was observed between those Asian regions than the correlation of them with the United Kingdom subjects.

Those correlation coefficients between the Asians ranged from 0.909 to 0.958, in which the best correlation was found between the Japanese and Hong Kong subjects while the least correlation was found between the Thai and Hong Kong subjects. However, the correlations of the 'light-dark' colour emotion of the Asians with the United Kingdom subjects were found to be much lower that they ranged from 0.557 to 0.698 only. Hence, their correlations were too low that paired-samples *t*-test was not applicable for analysing the statistical difference between them.

Graphical Representation

The plots of the visual assessment results of 'light-dark' colour emotion of Japan, Thailand and the United Kingdom against Hong Kong are shown in Figures 5.47 to 5.48 respectively.

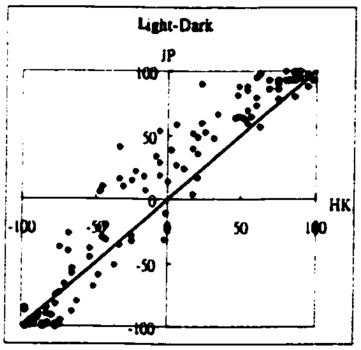

Figure 5.47 The visual assessment results of 'light-dark' colour emotion of Japanese against Hong Kong subjects.

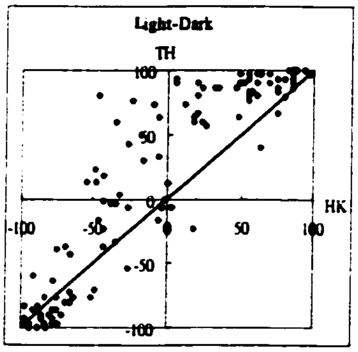

Figure 5.48 The visual assessment results of 'light-dark' colour emotion of Thai against Hong Kong subjects.

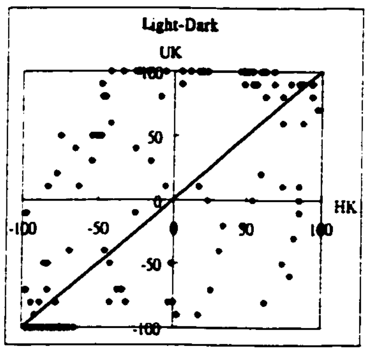

Figure 5.49 The visual assessment results of 'light-dark' colour emotion of the United Kingdom against Hong Kong subjects.

Of the three figures above, it is very obvious that the best correlation of 'light-dark' colour emotion was found between the Japanese and Hong Kong subjects, as shown in Figure 5.47, because the plots of them are located very close to the 45-degree line of the graph. Figure 5.48 shows a poorer correlation of this colour emotion pair between the Thai and Hong Kong subjects since the plots are more scattered in the graph and some of the colours were assessed as 'lighter' by the Thai than the Hong Kong subjects. However, a very scattered plotting was obtained in the correlation between the United Kingdom and Hong Kong subjects, which is shown in Figure 5.49. It may be concluded that almost no significant correlation was found between the 'light-dark' colour emotion of the United Kingdom and Hong Kong subjects.

Mathematical Models for Japan, Thailand and the United Kingdom

The mathematical models for the 'light-dark' colour emotion of the Japanese, Thai and the United Kingdom subjects were derived and are shown below. Since hue influence was not obvious in the 'light-dark' colour emotion of all the regions in this study, only one mathematical model, without splitting of hue-angles, was derived for each region.

Japan

$$LD = 2.577L^{*} + 2.163C^{*} + 0.114h - 209.187 \quad (5.24)$$

Thailand

$$LD = 2.897L^{*} + 1.909C^{*} + 0.070h - 205.263 \quad (5.25)$$

The United Kingdom

$$LD = 3.844L^{*} - 0.041C^{*} + 0.029h - 207.787 \quad (5.26)$$

Hong Kong (from Section 3.3.2)

$$LD = 2.111L^{*} + 2.021C^{*} + 0.082h - 187.082 \quad (3.4)$$

Equations 5.24 and 5.25 indicate that similar extent of influence of the lightness and chroma on the 'light-dark' colour emotion of the Japanese and Thai subjects was found. This observation was the same as that in the Hong Kong subjects. As either the chroma or lightness of colour increased, so a 'lighter' impression was induced in the minds of the Japanese, Thai and Hong Kong subjects. However, a very different observation was found in the 'light-dark' colour emotion of the United Kingdom subjects, in which the 'light-dark' emotion was mainly influenced by the lightness of colour, and irrespective of whether changing the chroma or hue had no impact on their selection of 'light' or 'dark'. Definitely a lighter perception was induced in the minds of the United Kingdom subjects as the lightness of colour increased.

Cross-cultural colour planner

The colour planners for the 'light-dark' colour emotion of the Japanese, Thai and the United Kingdom subjects against that of the Hong Kong subjects during the perception of colours of different lightness and chroma at hue-angle=0^0 are illustrated in Figures 5.50 to 5.52 respectively.

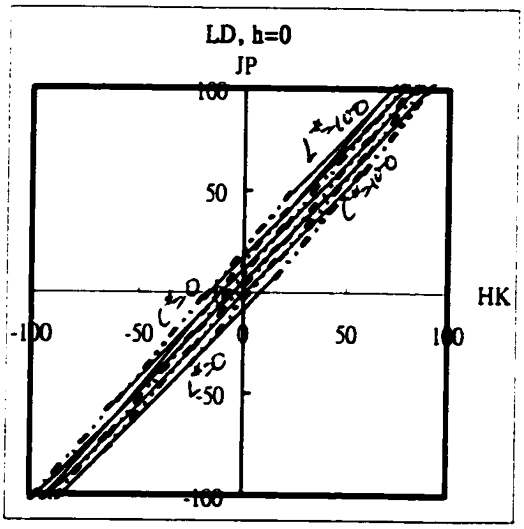

Figure 5.50 Colour planner for the 'light-dark' colour emotion of Japanese and Hong Kong subjects at h=0^0.

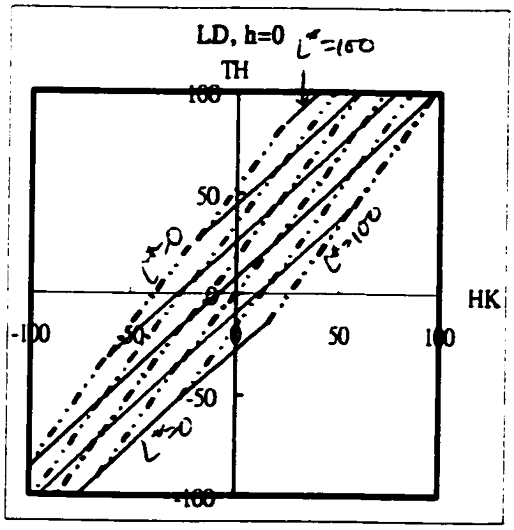

Figure 5.51 Colour planner for the 'light-dark' colour emotion of Thai and Hong Kong subjects at h=0^0.

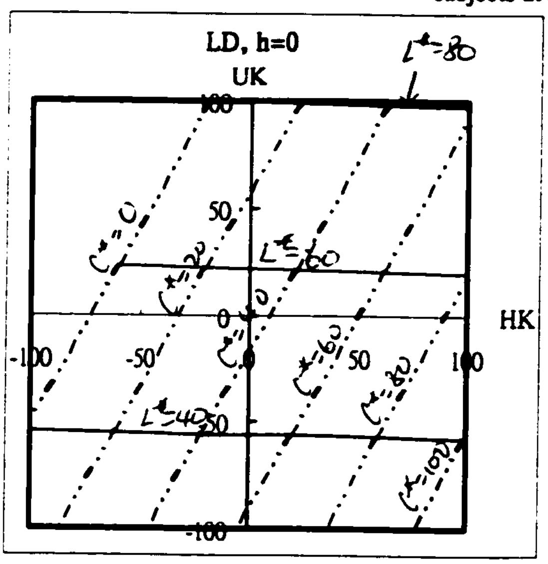

Figure 5.52 Colour planner for the 'light-dark' colour emotion of the United Kingdom and Hong Kong subjects at h=0^0.

Of the three figures above, the best correlation of 'light-dark' colour emotion was found between the Japanese and Hong Kong subjects since the smallest area of the range of iso-lightness and iso-chroma lines was obtained in the planner (Figure 5.50). The area of the range of iso-lines of the colour planner in Figure 5.51 was assessed to be slightly bigger than the one in Figure 5.50, so that the correlation of 'light-dark' colour emotion was lower between the Thai and Hong Kong subjects. In Figure 5.52, the range of iso-lines cover a very large area in the planner and this represents the correlation of this colour emotion pair between the United Kingdom and Hong Kong subjects was very poor.

As a result, it can be concluded that the subjects of the three Asian regions showed a good correlation of 'light-dark' colour emotion among them while their individual correlation with the subjects of the United Kingdom were very poor. The reason was that the 'light-dark' colour emotion of the Asians was influenced by both the lightness and chroma of colour whereas only lightness was the dominant parameter in this colour emotion pair of the United Kingdom subjects.

5.3.3.2 Distinct-vague colour emotion

Correlation Coefficients and Paired-Samples *t*-Test

The correlation coefficients, *r*, and the results of paired-samples *t*-test of 'distinct-vague' colour emotion of the subjects from Japan (JP), Thailand (TH), the United Kingdom (UK) and Hong Kong (HK) are shown in Table 5.11.

Table 5.11

Correlation coefficients and results of paired-samples *t*-test of 'distinct-vague' colour emotions of subjects of different regions

DV	Correlation Coefficient, *r*			Significant Difference (at 0.001 level of significance)		
	JP	TH	UK	JP	TH	UK
HK	0.304	0.586	0.421	Not applicable	Not applicable	Not applicable
JP		0.822	0.848		Not applicable	Yes
TH			0.871			No

Table 5.11 shows that poor correlations were found in the 'distinct-vague' colour emotion of the subjects from the other regions and those from Hong Kong. The correlation coefficients ranged from 0.304 to 0.586, in which the poorest correlation was obtained between the Japanese and Hong Kong subjects. However, the correlation coefficients between the other three regions, Japan, Thailand and the United Kingdom, were found to be quite good and they ranged from 0.822 to

0.871.

Since the correlations of the 'distince-vague' colour emotion of the subjects of Hong Kong and those of the other regions were very low, paired-samples *t*-test was not applicable. Table 5.11 shows no statistically significant difference was found between the subjects of Thailand and the United Kingdom while statistical difference was significant between the subjects of Japan and the United Kingdom.

Graphical Representation

The plots of the visual assessment results of 'distinct-vague' colour emotion of Japan, Thailand and the United Kingdom against Hong Kong are shown in Figure 5.53 to 5.55 respectively.

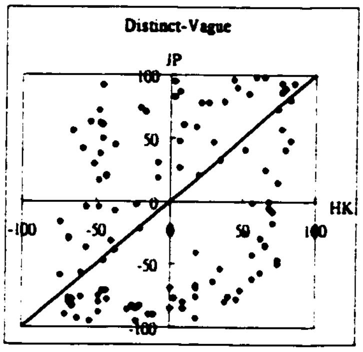

Figure 5.53 The visual assessment results of 'distinct-vague' colour emotion of Japanese against Hong Kong subjects.

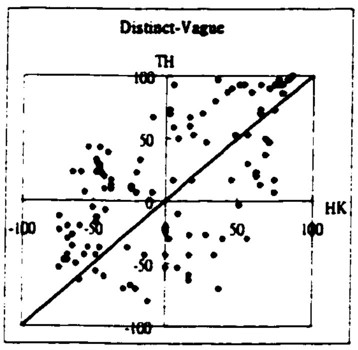

Figure 5.54 The visual assessment results of 'distinct-vague' colour emotion of Thai against Hong Kong subjects.

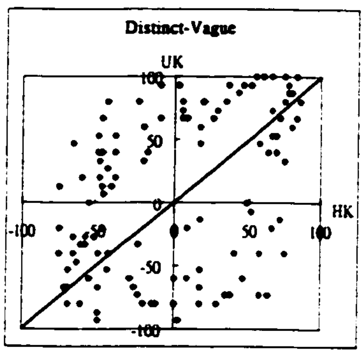

Figure 5.55 The visual assessment results of 'distinct-vague' colour emotion of the United Kingdom against Hong Kong subjects.

Figures 5.53 to 5.55 show three very scattered plots of 'distinct-vague' colour emotion of the subjects of the other three regions with Hong Kong. The plots are so widely distributed that no significant correlation was observed between them.

Mathematical Models for Japan, Thailand and the United Kingdom

The mathematical models for the 'distinct-vague' colour emotion of the Japanese, Thai and the United Kingdom subjects were derived and are shown below.

Japan

$$DV_{0\leq h<180} = -1.084L^* + 0.193C^{*(1.551)} + 0.026h + 2.925 \qquad (5.27a)$$

$$DV_{180\leq h<360} = -2.151L^* + 1.031C^{*(1.181)} + 0.156(360^0 - h) + 55.673 \qquad (5.27b)$$

Thailand

$$DV_{0\leq h<180} = -0.185L^* + 4.226C^{*(0.838)} + 0.032h - 42.172 \qquad (5.28a)$$

$$DV_{180\leq h<360} = -0.515L^* + 2.004C^{*(1.042)} + 0.177(360^0 - h) - 23.269 \qquad (5.28b)$$

The United Kingdom

$$DV_{0\leq h<180} = -0.745L^* + 16.037C^{*(0.588)} + 0.029h - 58.844 \qquad (5.29a)$$

$$DV_{180\leq h<360} = -1.008L^* + 11.651C^{*(0.686)} + 0.186(360^0 - h) - 35.698 \qquad (5.29b)$$

Hong Kong (from Section 3.3.2)

$$DV = 1.762L^* + 1.468C^* + 0.101h - 148.556 \tag{3.11}$$

The mathematical model for the 'distinct-vague' colour emotion of the Hong Kong subjects shows that this emotion pair was influenced by both the lightness and chroma of colour. As either the lightness or chroma increased, a more 'distinct' impression was given to the Hong Kong subjects. However, the above mathematical models (Equations 5.27a to 5.29b) indicate that a negative effect of lightness was observed in this colour emotion pair of the other three regions. In other words, the Japanese, Thai and the United Kingdom subjects received different extents of 'vaguer' impressions when perceiving colours of higher lightness. Equations 5.27a and 5.27b illustrate the 'distinct-vague' colour emotion of Japanese was both influenced by the lightness and chroma of colour, while Equations 5.28a to 5.29b show that this colour emotion pair of Thai and the United Kingdom subjects was mainly affected by the chroma of colour. As the chroma of colour increased, a more 'distinct' impression will be given to all subjects, irrespective of which regions concerned in this study.

Cross-cultural colour planner

The colour planners for the 'distinct-vague' colour emotion of the Japanese, Thai and the United Kingdom subjects against Hong Kong subjects during the perception of colours of different lightness and chroma at hue-angle=0^0 are illustrated in Figures 5.56 to 5.58 respectively.

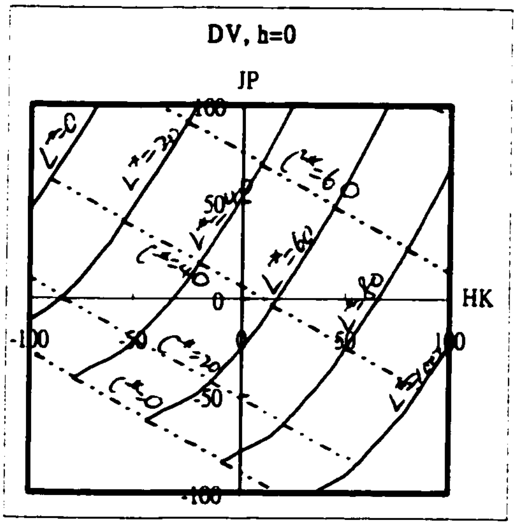

Figure 5.56 Colour planner for the 'distinct-vague' colour emotion of Japanese and Hong Kong subjects at h=0^0.

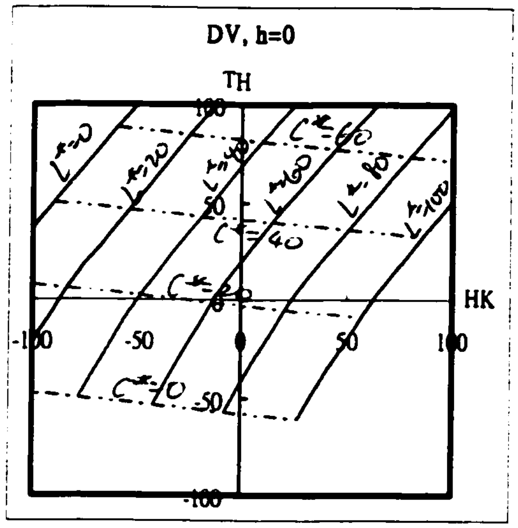

Figure 5.57 Colour planner for the 'distinct-vague' colour emotion of Thai and Hong Kong subjects at h=0^0.

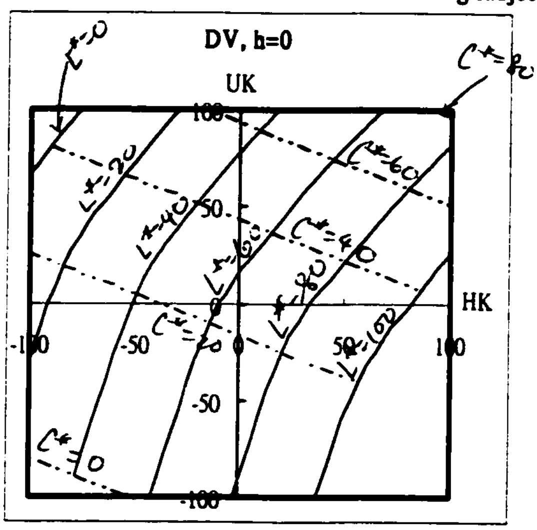

Figure 5.58 Colour planner for the 'distinct-vague' colour emotion of the United Kingdom and Hong Kong subjects at h=0^0.

Figures 5.56 to 5.58 illustrate that the areas of the range of iso-lines almost cover the whole colour planners. This indicates there was no correlation of 'distinct-vague' colour emotion between the subjects of the three other regions with those of Hong Kong. The large difference may be due to the error in language translation of English words 'distinct' and 'vague' to the Cantonese words since the correlation coefficients of 'distinct-vague' colour emotion among the Japanese, Thai and United Kingdom subjects were quite good as shown in Table 5.11 (all correlation coefficients of them were found to be larger than 0.8).

5.3.3.3 Transparent-turbid colour emotion

Correlation Coefficients and Paired-Samples *t*-Test

The correlation coefficients, *r*, and the results of paired-samples *t*-test of 'transparent-turbid' colour emotion of the subjects from Japan (JP), Thailand (TH) and Hong Kong (HK) are shown in Table 5.12.

Table 5.12

Correlation coefficients and results of paired-samples *t*-test of 'transparent-turbid' colour emotions of subjects of different regions

TT	**Correlation Coefficient, *r***		**Significant Difference** (at 0.001 level of significance)	
	JP	**TH**	**JP**	**TH**
HK	0.935	0.943	No	No
JP		0.868		No

In Table 5.12, it may be seen that the correlation coefficients of 'transparent-turbid' colour emotion of the three asian regions were quite good, especially the correlations with the Hong Kong subjects. The best correlation was found between the Hong Kong and Thai subjects, with r=0.943, and the correlation of Hong Kong subjects with the Japanese was also found to be good, with r=0.935. The correlation coefficient of the 'transparent-turbid' colour emotion between Japanese and Thai subjects was found to be slightly weaker, with r=0.868, but this correlation was also considered as quite good. In the comparison of the results obtained from paired-samples *t*-test, no statistically significant difference was found between subjects of any two regions among the Asian regions concerned in this study.

Graphical Representation

The plots of the visual assessment results of 'transparent-turbid' colour emotion of Japan and Thailand against Hong Kong are shown in Figures 5.57 and 5.58 respectively.

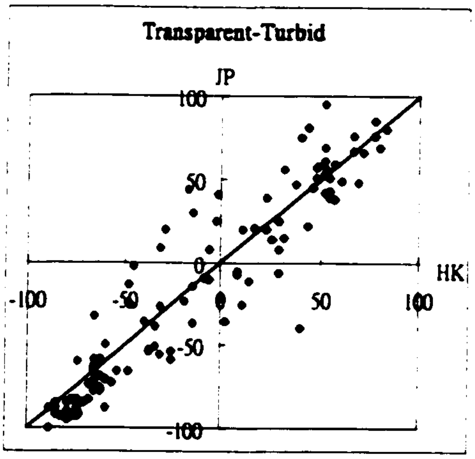

Figure 5.59 The visual assessment results of 'transparent-turbid' colour emotion of Japanese against Hong Kong subjects.

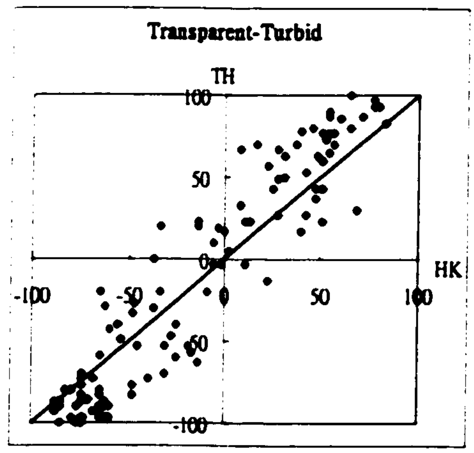

Figure 5.60 The visual assessment results of 'transparent-turbid' colour emotion of Thai against Hong Kong subjects.

The plots in Figures 5.59 and 5.60 are located very close to the 45-degree lines of both graphs. This demonstrates that the correlations of 'transparent-turbid' colour emotion of the Japanese and Thai subjects were very good with the Hong Kong subjects.

Mathematical Models for Japan and Thailand

The mathematical models for the 'transparent-turbid' colour emotion of the Japanese and Thai subjects were derived and are shown below.

Japan

$$TT_{0\leq h<180} = 2.203L^* + 1.113C^* + 0.096h - 192.123 \quad (5.30a)$$

$$TT_{180\leq h<360} = 1.791L^* + 2.508C^* + 0.073(360^0 - h) - 160.707 \quad (5.30b)$$

Thailand

$$TT = 2.786L^* + 1.359C^* + 0.058h - 212.233 \quad (5.31)$$

Hong Kong (from Section 3.3.2)

$$TT = 2.227L^* + 1.097C^* + 0.100h - 181.715 \quad (3.12)$$

From the above equations, since the lightness and chroma of colour had similar extent of influence on the 'transparent-turbid' colour emotion of the Japanese and Thai subjects, they were both regarded as the dominant parameters on this colour emotion pair (Equation 5.30a to Equation 5.31). This finding was the same as that in the case of the Hong Kong subjects. As either the lightness or chroma increased, the colour tended to evoke a more 'transparent' impression to the subjects of these three Asian regions.

Cross-cultural colour planner

The colour planners for the 'transparent-turbid' colour emotion of the

Japanese and Thai subjects against that of the Hong Kong subjects during the perception of colours of different lightness and chroma at hue-angle=0^0 are illustrated in Figures 5.61 and 5.62 respectively.

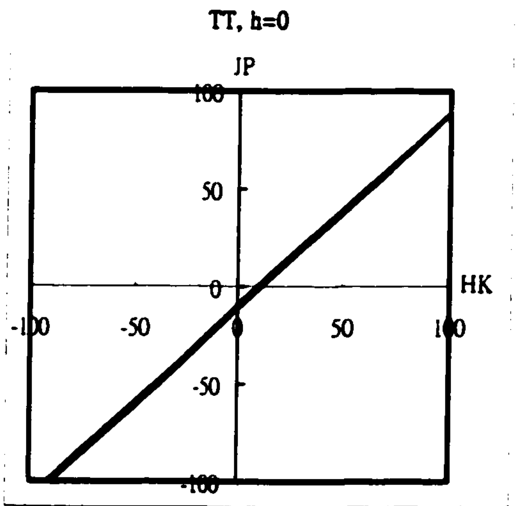

Figure 5.61 Colour planner for the 'transparent-turbid' colour emotion of Japanese and Hong Kong subjects at h=0^0.

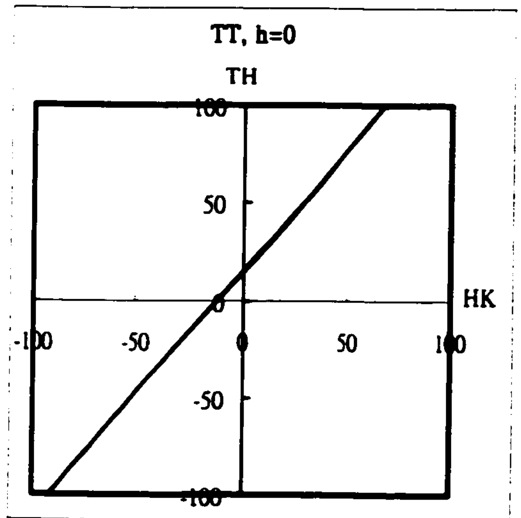

Figure 5.62 Colour planner for the 'transparent-turbid' colour emotion of Thai and Hong Kong subjects at h=0^0.

Figures 5.61 and 5.62 show the iso-lines of both graphs are very close to each other so that it can be concluded that there were directly correlations between the 'transparent-turbid' colour emotion of the Japanese and Hong Kong subjects as well as between the Thai and Hong Kong subjects when perceiving red colours. Figure 5.61 illustrates that the Hong Kong subjects consistently had more 'transparent' colour emotion towards the same colours than the Japanese subjects. Figure 5.62 illustrates that for the colours in the 'transparent' side, i.e., both TT

for Thai and Hong Kong are in positive values, they gave slightly more 'transparent' impressions to the Thai subjects than to the Hong Kong subjects, while for those colours in the 'turbid' side, i.e., both *TT* for Thai and Hong Kong are in negative values, they gave slightly more 'turbid' impressions to the Thai subjects than to the Hong Kong subjects.

5.4 Conclusions

5.4.1 The Best and Worst Correlated Colour Emotions between Subjects of Two Regions

Of all the colour emotion pairs between all the regions in this study, the best correlated colour emotion pair between the subjects of two different regions was found in the 'heavy-light' pair between the Japanese and Hong Kong subjects. The worst correlated colour emotion pair was found in the 'distinct-vague' pair between the Japanese and Hong Kong subjects.

5.4.2 The Best and Worst Correlated Colour Emotions among All Regions

Two colour emotion pairs were found to have the best correlation in general, i.e., they have good and average correlation between all the regions under investigation. They are the 'heavy-light' and 'trasnparent-turbid' colour emotion pairs. The correlation coefficients of 'heavy-light' pair between all the Asians were all above 0.9, while no statistically significant difference was found in the 'transparent-turbid' pair of all the Asians and they showed good correlations in the colour planners. Hence, it may be concluded that the Japanese, Thai and Hong Kong Chinese have similar 'heavy-light' and 'transparent-turbid' impressions during colour perception. However, since no visual assessment data of 'heavy-light' and 'transparent-turbid' colour emotion pairs have been received from the United Kingdom, another pair was selected for having very good correlations between subjects from all regions, including the United Kingdom. This very good correlated pair was found to be the 'deep-pale' colour emotion pair that the correlation coefficients between all the regions were all larger than 0.8.

The worst correlated colour emotion pair was found to be the 'distinct-vague' colour emotion pair. Very poor correlation of this colour emotion pair was obtained between the subjects of every other region with the Hong Kong subjects. The reason of this may be due to a wrong translation of this colour emotion pair from English to Cantonese or a different interpretation of the meanings of this word pairs by the Hong Kong subjects as the ones from the other regions. Moreover, 'light-dark' colour emotion pair was found to be another pair which had quite a poor correlation of the three Asian regions with the United Kingdom. The correlations of this pair between all the three Asian regions were found to be good that all the correlation coefficients were larger than 0.9; however, when compared with the United Kingdom results, the correlation coefficients were found to be much lower, which were between 0.5 to 0.7. The reason was that all Asians in this study considered that 'light-dark' colour emotion was influenced by both the lightness and chroma of colour, while the United Kingdom subjects thought that lightness was the dominant parameter in this colour emotion pair.

5.4.3 The Best and Worst Correlated Regions

When the correlation of all colour emotion pairs between each two regions was studied, the best correlated regions was found to be Japan and Hong Kong that, except the 'distinct-vague' colour emotion pair, they illustrated a very good correlation in every colour emotion pair. In addition, it was found that the correlation of colour emotion between the United Kingdom and Hong Kong was not as good as the correlations between the other two Asian regions and Hong Kong.

COMPARISON OF 2-POINT AND 7-POINT VISUAL ASSESSMENT METHODS

6.1 Objectives

- To analyse the influence of each standard colour specification on colour emotion using the 7-point method.
- To compare the results obtained from the 2-point and 7-point methods.

6.2 Methodology

6.2.1 Visual Assessment of 7-Point Method

The 2-point method, which was used for the derivation of mathematical models (in Chapter 3) and comparison of the effects of the influential factors (in Chapters 4 and 5), was done by the selection of either one opponent word in each pair, without any neutral point, i.e., 0 point. This method can avoid subjects standing on some colour samples, which do not give any impression to them, by forcing them to select either one of the word in each colour emotion pair.

However, it is worthwhile to investigate the colour emotions of subjects by providing a scale with more divisions, so that the subjects can select a grade which represents a more appropriate level of their emotion during the perception of the colour sample. Since the 7-point method allows the subjects to give a neutral assessment, i.e., 0 point, and there are more subdivided grades, which include 'very', 'moderately', and 'slightly' indicating different levels of colour emotion evoked, , this assessment method was also carried out in this study for the comparison of the results obtained from the 2-point method.

6.2.1.1 Subjects

All subjects in the visual assessments of 7-point method were also native Hong Kong Chinese aged around twenty. 20 subjects, half of whom were male and half female, participated in these visual assessments. As was the case for the 2-point method, they were asked to take the Isihara Colour Blindness Test before doing the visual assessment in order to ensure their normality of their colour vision.

6.2.1.2 Colour samples

About half of the colour samples in the 2-point method, i.e., 114 colour samples, were used in the 7-point method. The reason for reducing the number of sample was that some of them gave similar colour perception to the subjects. Hence, the notation of colour samples with Munsell hue '5' were retained whereas those with '10' were eliminated. For example, '5R1' was analysed using both the 2-point and 7-point visual assessment methods, whereas '10R1' was only assessed in the 2-point visual assessment. However, the neutral colour samples, i.e., N1, N2, N4, N6, N8 and N9.5, were analysed using both of these methods.

6.2.1.3 Experimental conditions

The experimental conditions were the same as for the 2-point method, as discussed in Section 3.2.1.3.

6.2.1.4 Questionnaire

Twelve pairs of colour emotions were also being analysed as for the 2-point method. However, the grading of each colour emotion pair was not divided into two points, i.e., the +1 and –1 points, but into seven points instead, i.e., +3 point, +2 point, +1 point, 0 point, -1 point, -2 point, and -3 point. The meaning of each point for each colour emotion pair is shown in Table 6.1.

Table 6.1

<u>The meanings of corresponding points in selection of colour emotion in the 7-point method</u>

Colour Emotion Pair	Point given to the selection of this colour emotion word						
	+3 Very	+2 Moderately	+1 Slightly	0 Neutral	-1 Slightly	-2 Moderately	-3 Very
Warm-Cool	Very Warm	Moderately Warm	Slightly Warm	No Special feeling towards the corresponding colour emotion pair of the colour sample	Slightly Cool	Moderately Cool	Very Cool
Light-Dark	Very Light	Moderately Light	Slightly Light		Slightly Dark	Moderately Dark	Very Dark
Deep-Pale	Very Deep	Moderately Deep	Slightly Deep		Slightly Pale	Moderately Pale	Very Pale
Heavy-Light	Very Heavy	Moderately Heavy	Slightly Heavy		Slightly Light	Moderately Light	Very Light
Vivid-Sombre	Very Vivid	Moderately Vivid	Slightly Vivid		Slightly Sombre	Moderately Sombre	Very Sombre
Gaudy-Plain	Very Gaudy	Moderately Gaudy	Slightly Gaudy		Slightly Plain	Moderately Plain	Very Plain
Striking-Subdued	Very Striking	Moderately Striking	Slightly Striking		Slightly Subdued	Moderately Subdued	Very Subdued
Dynamic-Passive	Very Dynamic	Moderately Dynamic	Slightly Dynamic		Slightly Passive	Moderately Passive	Very Passive
Distinct-Vague	Very Distinct	Moderately Distinct	Slightly Distinct		Slightly Vague	Moderately Vague	Very Vague
Transparent-Turbid	Very Transparent	Moderately Transparent	Slightly Transparent		Slightly Turbid	Moderately Turbid	Very Turbid
Soft-Hard	Very Soft	Moderately Soft	Slightly Soft		Slightly Hard	Moderately Hard	Very Hard
Strong-Weak	Very Strong	Moderately Strong	Slightly Strong		Slightly Weak	Moderately Weak	Very Weak

6.2.2 Method for Quantifying Colour Emotions

The calculation method of the colour emotion percentage was similar to that of the 2-point method. Since a maximum of 3 points could be selected for a colour emotion pair, the calculation formula was divided by 3 so that the maximum value of colour emotion was 100% and the minimum value was −100%. The calculation of colour emotion percentage for a specific colour sample in the 7-point method was listed as below:

Colour Emotion Percentage = (total points obtained from visual assessment / 3 x no. of subjects) x 100% (6.1)

6.2.3 Graphical Representation

6.2.3.1 Correlation between 2-point and 7-point methods

The graphs showing the correlation between the visual assessment results obtained from 2-point and 7-point methods were plotted and analysed. A 45^0 line was also drawn on the graph so that, if there was a high correlation between the two methods of a colour emotion pair, the plots approached lying very close to or on the line.

6.2.3.2 Colour emotion against colorimetric attribute

The relationships between the colour emotions for each of the colorimetric attributes were plotted on graphs and analysed according to the 2-point method. In cases where a linear proportion plotting or a specific trend was obtained, the colour emotion pair had a direct or significant correlation with the colour attribute. On the other hand, if the points in the graphs were scattered, the colour emotion pair and that colorimetric attribute had no significant relationship.

6.3 Results and Discussions

6.3.1 Comparison between 2-point and 7-point Methods and Correlation of Colour Emotion and Colorimetric Attribute

The graphs comparing the visual assessment results obtained from the 2-point and 7-point methods and showing the correlation between colour emotion and each colorimetric attribute were plotted and are illustrated as follows.

Warm-Cool Colour Emotion

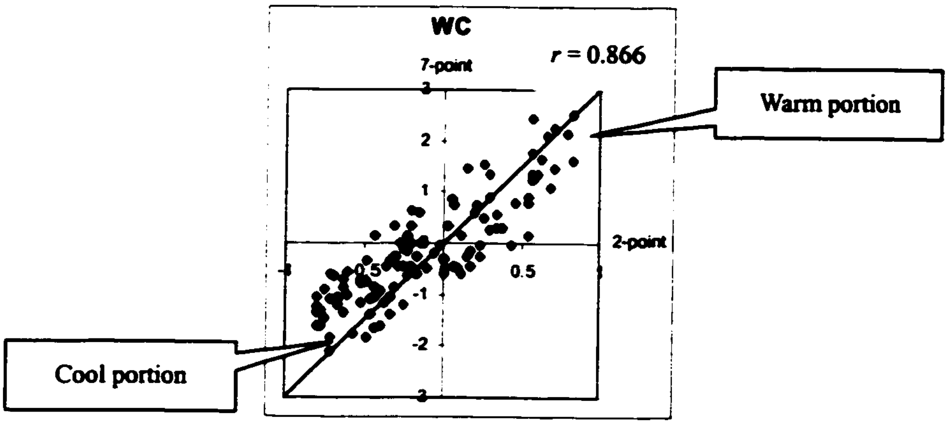

Figure 6.1 Correlation of 7-point and 2-point visual assessment methods of Warm-Cool colour emotion, *WC*

The correlation coefficient, *r*, was found to be 0.866 between the 2-point and 7-point methods. In the 'cool' portion of Figure 6.1, i.e., the portion where both 2-point and 7-point methods have negative values, the colours were assessed to be 'cooler' in the 2-point method than those in the 7-point one.

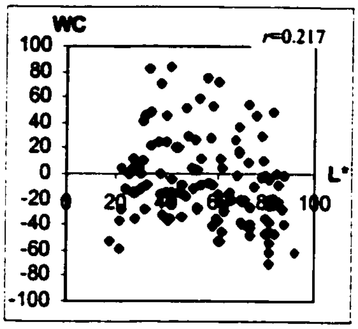

Figure 6.2 Correlation of Warm-Cool colour emotion, *WC*, with lightness, L^*, in 7-point method

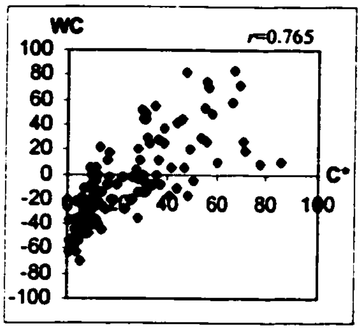

Figure 6.3 Correlation of Warm-Cool colour emotion, *WC*, with chroma, C^*, in 7-point method

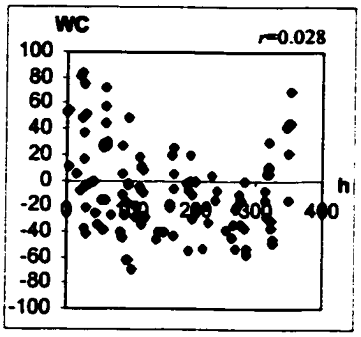

Figure 6.4 Correlation of Warm-Cool colour emotion, *WC*, with hue, h^0, in 7-point method

Figures 6.2 to 6.4 show the correlation of 'warm-cool' colour emotion with the three colorimetric attributes in the 7-point method. When comparing these with those obtained from 2-point method, which are shown in Figures 3.2 to 3.4, the same performances in these two methods were found with lightness and hue, i.e., a scattered graph was obtained and no correlation was found with lightness (Figure 6.2) whereas 'cooler' emotions were always induced when perceiving green and blue colours than perceiving red and yellow colours for the analysis of the correlation of 'warm-cool' with hue (Figure 6.4). However, the correlation with chroma was found to be slightly less significant in the 7-point method than in the 2-point method. Since a high correlation with chroma was found in the 2-point method that 'warm' emotion was normally induced for the high chromatic colours while 'cool' emotion was always induced for the low chromatic colours, the same trend was expected to be found in the 7-point method. However, in the high chromatic part of the 7-point method, some colours were found to be not as 'warm' as expected (Figure 6.3).

Light-Dark Colour Emotion

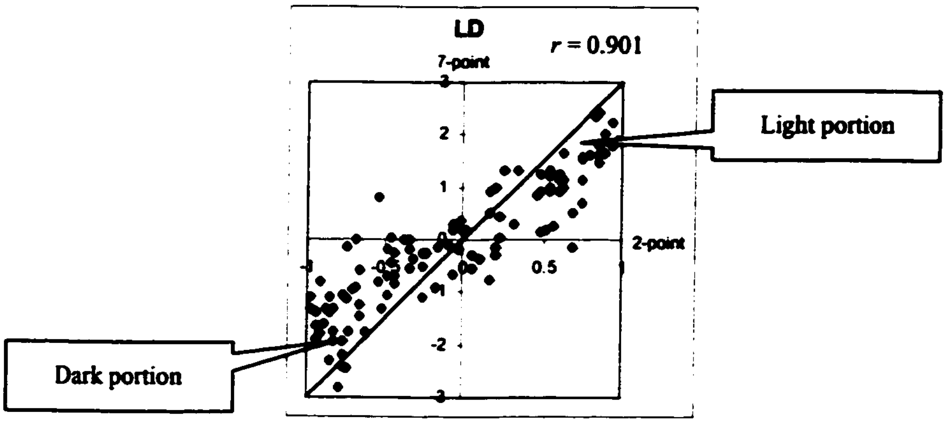

Figure 6.5 Correlation of 7-point and 2-point visual assessment methods of Light-Dark colour emotion, *LD*

The correlation coefficient, *r*, was found to be 0.901 between the 2-point and 7-point methods. In the 'light' portion of Figure 6.5, i.e., the portion where both 2-point and 7-point methods have positive values, the colours were assessed to be 'lighter' in the 2-point method than those in the 7-point one; while in the 'dark' portion, i.e., the portion where both 2-point and 7-point methods have negative values, the colours were assessed to be 'darker' in the 2-point method.

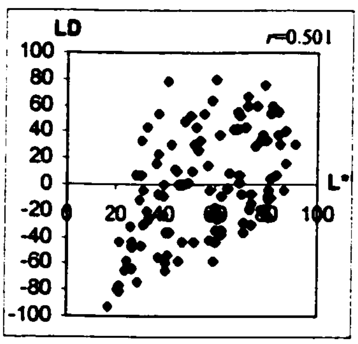

Figure 6.6 Correlation of Light-Dark colour emotion, *LD*, with lightness, L^*, in 7-point method

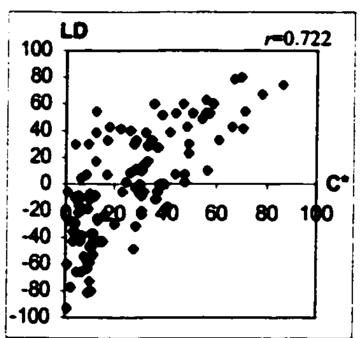

Figure 6.7 Correlation of Light-Dark colour emotion, *LD*, with chroma, C^*, in 7-point method

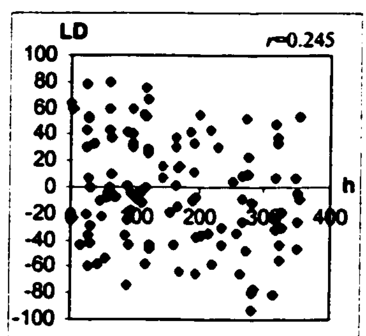

Figure 6.8 Correlation of Light-Dark colour emotion, *LD*, with hue, h^0, in 7-point method

Figures 6.6 to 6.8 demonstrate the correlation of 'light-dark' colour emotion with the three colorimetric attributes in the 7-point method. In the comparison with those obtained from 2-point method, which are shown in Figures 3.5 to 3.7, it was found that similar plottings occurred with lightness and hue, i.e., a detectable trend was obtained with lightness (Figure 6.6) in that the value of 'light-dark' increased as the lightness increased, while a scattered graph was obtained with hue (Figure 6.8). When the correlation of 'light-dark' colour emotion was compared with chroma in the 7-point method as shown in Figure 6.7, a higher correlation was found than in the case of the 2-point method. A more obvious trend was observed that a 'light' emotion was given to the subjects when they were assessing the colour with high chroma.

Deep-Pale Colour Emotion

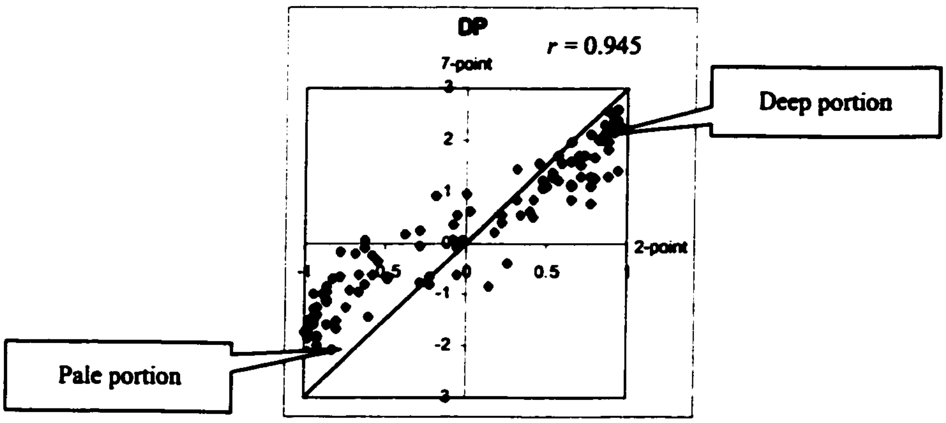

Figure 6.9 Correlation of 7-point and 2-point visual assessment methods of Deep-Pale colour emotion, *DP*

The correlation coefficient, r, was found to be 0.945 between the 2-point and 7-point methods. Figure 6.9 illustrates that the colours in the 7-point method were assessed to give a lower level of 'deep' to the subjects in the 'deep' portion but a lower level of 'pale' in the 'pale' portion than the 2-point method.

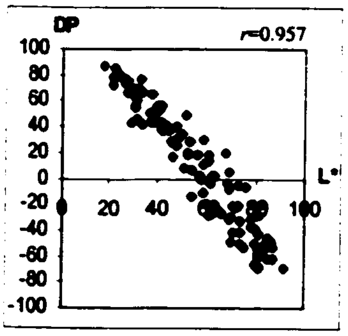

Figure 6.10 Correlation of Deep-Pale colour emotion, DP, with lightness, L^*, in 7-point method

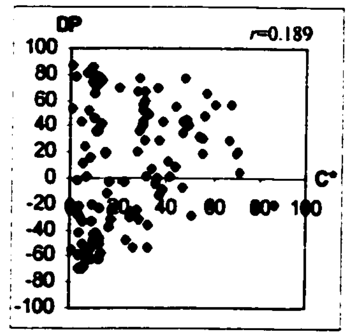

Figure 6.11 Correlation of Deep-Pale colour emotion, DP, with chroma, C^*, in 7-point method

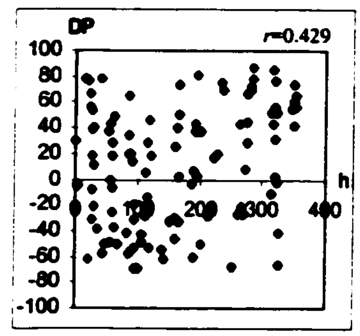

Figure 6.12 Correlation of Deep-Pale colour emotion, DP, with hue, h^0, in 7-point method

Figures 6.10 to 6.12 show the correlation of 'deep-pale' colour emotion with the three colorimetric attributes in the 7-point method. These figures were found to be similar to those obtained from the 2-point method, which are shown in Figures 3.8 to 3.10. Of the three colorimetric attributes, 'deep-pale' colour emotion was found to show a very good correlation with lightness because a very straight plotted line with negative slope was found in the graph of 'deep-pale' colour emotion against lightness (Figure 6.10). Hence, as the lightness of colour increased, a 'pale' impression was induced in the subjects' minds.

<u>Heavy-Light Colour Emotion</u>

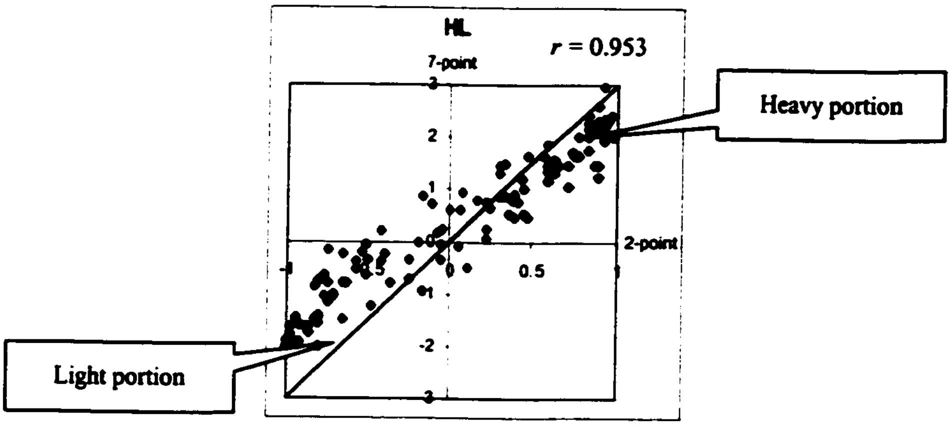

Figure 6.13 Correlation of 7-point and 2-point visual assessment methods of Heavy-Light colour emotion, *HL*

A large correlation coefficient, 0.953, was found between the 2-point and 7-point methods of 'heavy-light' colour emotion. Figure 6.13 indicates that the range of 'heavy-light' assessment was found to be wider in the 2-point method than that in the 7-point method, which was the same finding as the 'light-dark' and 'deep-pale' pairs. In the 'heavy' portion, the same colour was assessed to be 'heavier' in the 2-point method than that in the 7-point method, while a 'lighter' evaluation was obtained in the 2-point method for the same colour in the 'light' portion.

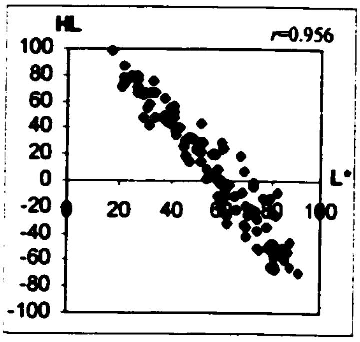

Figure 6.14 Correlation of Heavy-Light colour emotion, HL, with lightness, L^*, in 7-point method

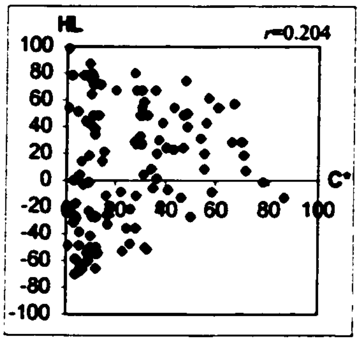

Figure 6.15 Correlation of Heavy-Light colour emotion, HL, with chroma, C^*, in 7-point method

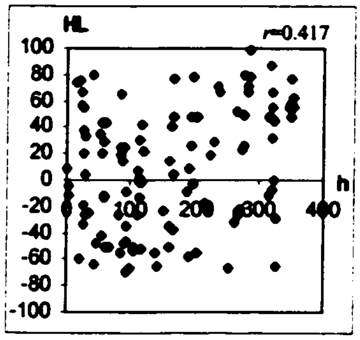

Figure 6.16 Correlation of Heavy-Light colour emotion, HL, with hue, h^o, in 7-point method

Figures 6.14 to 6.16 show the correlation of 'heavy-light' colour emotion with the three colorimetric attributes in the 7-point method and these figures were found to be similar to those obtained from the 2-point method (Figures 3.11 to 3.12). Of these figures, a very good correlation with lightness was found with the 'heavy-light' colour emotion since a very straight plotted line with negative slope was obtained in the graph of 'heavy-light' colour emotion against lightness (Figure 6.14). Hence, it may be concluded that a 'light' impression was induced in the subjects' minds during the perception of colours with high lightness.

Vivid-Sombre Colour Emotion

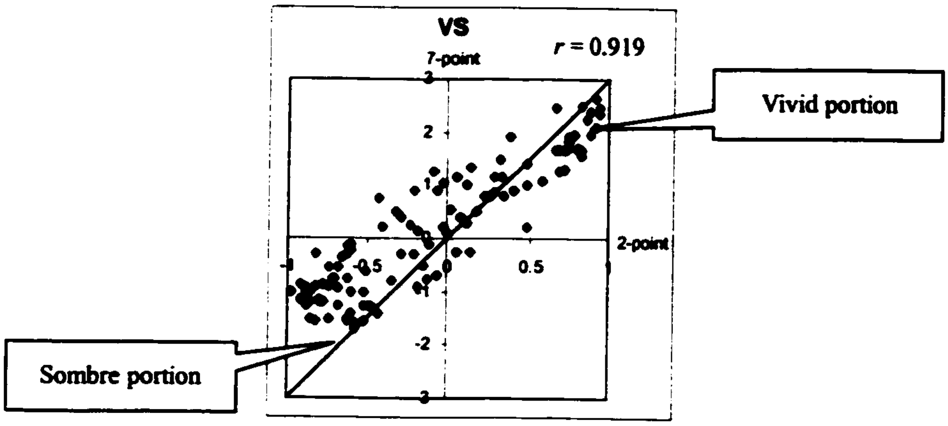

Figure 6.17 Correlation of 7-point and 2-point visual assessment methods of Vivid-Sombre colour emotion, *VS*

The correlation coefficient, *r*, between the 2-point and 7-point methods of 'vivid-sombre' colour emotion was found to be 0.919. In the 'vivid' portion, the 7-point method assessment was found to be slightly less 'vivid' than in the 2-point method for the same colour, as shown in Figure 6.17. However, a significant deviation between the 2-point and 7-point method was found in the 'sombre' portion since the assessment in the 7-point method was less 'sombre' than the 2-point method.

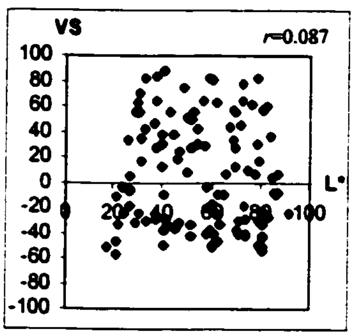

Figure 6.18 Correlation of Vivid-Sombre colour emotion, *VS*, with lightness, L^*, in 7-point method

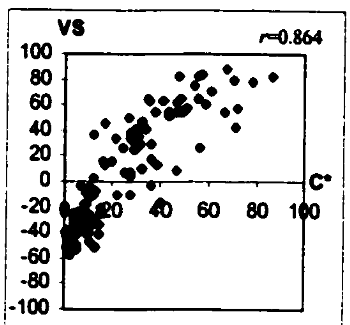

Figure 6.19 Correlation of Vivid-Sombre colour emotion, *VS*, with chroma, C^*, in 7-point method

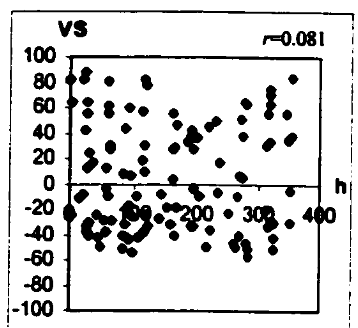

Figure 6.20 Correlation of Vivid-Sombre colour emotion, *VS*, with hue, h^o, in 7-point method

The correlations of 'vivid-sombre' colour emotion in the 7-point method with lightness and chroma, which are shown in Figures 6.18 and 6.19, were found to be similar as the correlations in the 2-point method, which are shown in Figures 3.14 and 3.15. A scattered plot was found both in the graphs of 'vivid-sombre' against lightness (Figure 3.14 and Figure 6.18) whereas a good correlation was found with chroma in these two methods (Figure 3.15 and Figure 6.19), in which colours with high chroma tended to give a 'vivid' feeling while colours with low chroma gave a 'sombre' feeling to the subjects. When the correlations of 'vivid-sombre' colour emotion with hue in the 2-point and 7-point methods were compared, it was found that the correlation was more significant in the 7-point method because less 'vivid' emotion was obtained in the hue angles between 150^0 and 250^0, which were the greenish and bluish regions. In other words, the subjects assessed the reddish and yellowish colours as a higher level of 'vivid' than the greenish and bluish colours in the 7-point method.

Gaudy-Plain Colour Emotion

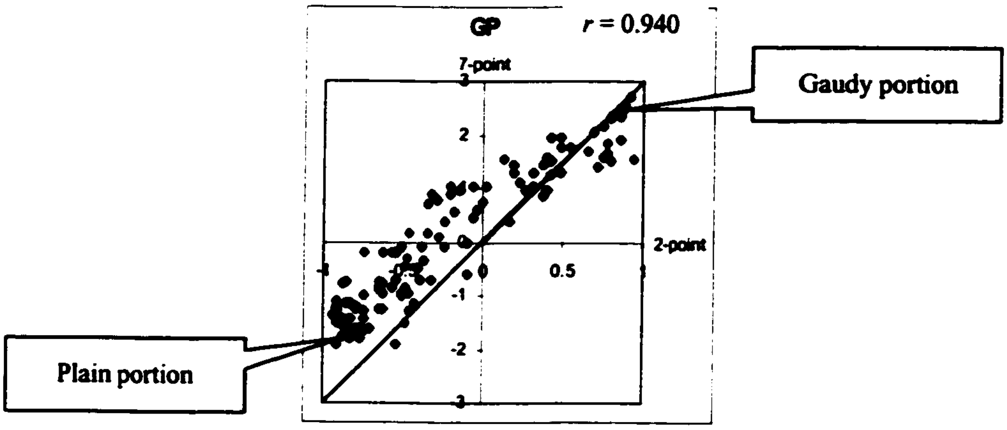

Figure 6.21 Correlation of 7-point and 2-point visual assessment methods of Gaudy-Plain colour emotion, *GP*

A large correlation coefficient, 0.940, was found between the 2-point and 7-point methods of 'gaudy-plain' colour emotion. Figure 6.21 shows that many colours were assessed to be more 'gaudy' in the 7-point method than in the 2-point method, with the exception that those assessed to be very 'gaudy' in the 2-point method (> +0.7 'GP' value) were assessed to have a lower level of 'gaudy' in the 7-point one.

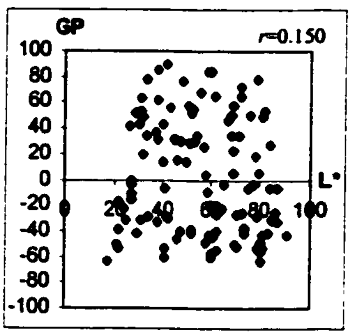

Figure 6.22 Correlation of Gaudy-Plain colour emotion, *GP*, with lightness, L^*, in 7-point method

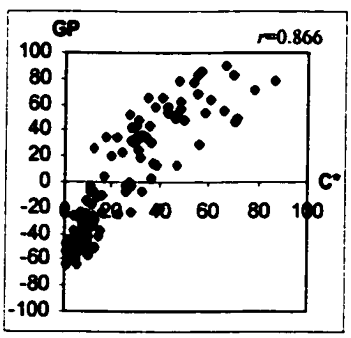

Figure 6.23 Correlation of Gaudy-Plain colour emotion, *GP*, with chroma, C^*, in 7-point method

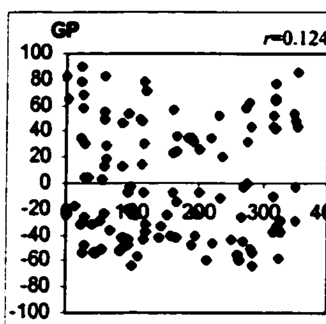

Figure 6.24 Correlation of Gaudy-Plain colour emotion, *GP*, with hue, h^0, in 7-point method

Similar correlations with the colorimetric attributes were found in the 7-point method and the 2-point method of the 'gaudy-plain' colour emotion. Figure 6.22 illustrates a scattered plot of 'gaudy-plain' colour emotion against lightness and it was similar to the 2-point method that is shown in Figure 3.17. This indicates that no significant correlation was found between 'gaudy-plain' colour emotion and lightness. However, a significant and almost directly proportional correlation was found between 'gaudy-plain' colour emotion and chroma, which is illustrated in both the 2-point method (Figure 3.18) and 7-point method (Figure 3.23). For the correlation with hue, the findings in the 7-point method were observed to be similar to those in the 2-point method that a lower degree of 'gaudy' emotion was assessed for the colours with hue angle between 150^0 and 250^0, which were the greenish and bluish regions.

Striking-Subdued Colour Emotion

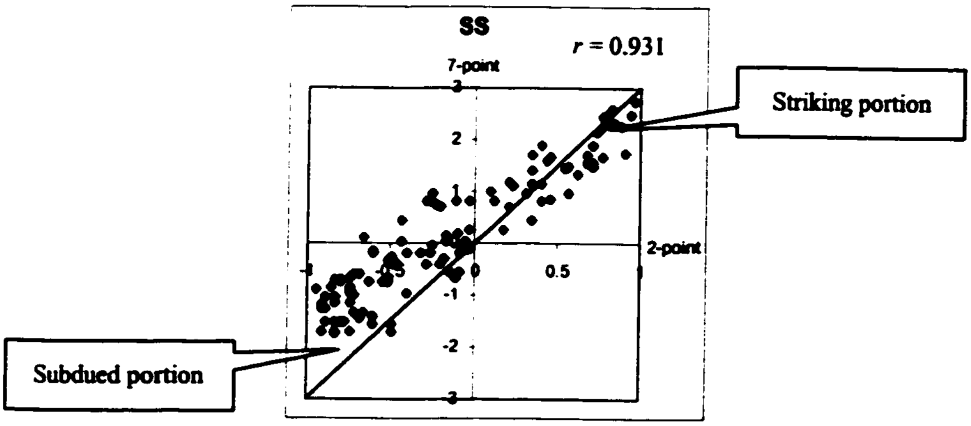

Figure 6.25 Correlation of 7-point and 2-point visual assessment methods of Striking-Subdued colour emotion, *SS*

The correlation coefficient, r, between the 2-point and 7-point methods of 'striking-subdued' colour emotion was found to be 0.931. Figure 6.25 shows that, in the 'striking' portion, the assessment of colour towards the 'striking-subdued' emotion was similar in the case of both the 2-point and 7-point method, whereas in the 'subdued' portion, the assessment of the 7-point method was found to have a lower level of 'subdued' than the 2-point method when considering the perception of the same colour.

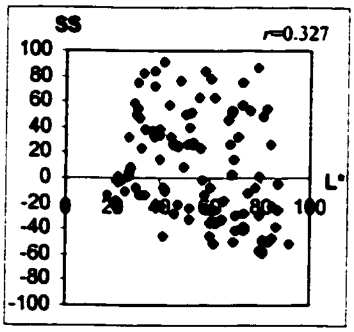

Figure 6.26 Correlation of Striking-Subdued colour emotion, *SS*, with lightness, L^*, in 7-point method

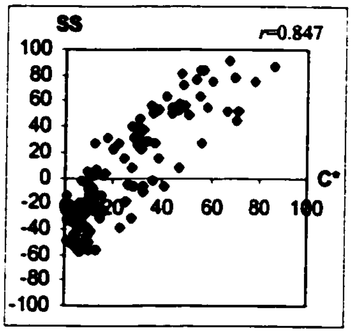

Figure 6.27 Correlation of Striking-Subdued colour emotion, *SS*, with chroma, C^*, in 7-point method

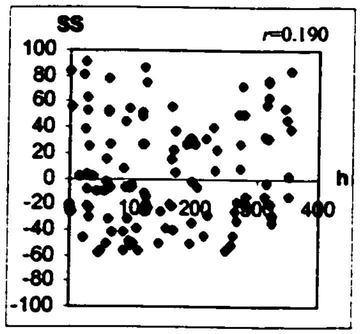

Figure 6.28 Correlation of Striking-Subdued colour emotion, *SS*, with hue, h^o, in 7-point method

When the correlations of 'striking-subdued' colour emotion with the three colorimetric attributes between 2-point and 7-point methods were compared, similar findings were found for the correlation with lightness and chroma, which are shown in Figures 3.20 and 6.26, and Figures 3.21 and 6.27 respectively. No significant correlation was found between 'striking-subdued' colour emotion and lightness, whereas an almost directly proportional correlation was found with chroma. When the comparison with hue was considered, a more obvious observation that a lower degree of 'striking' assessment was found for the colours with hue angle between 150^0 and 250^0, i.e., greenish and bluish colours, in the 7-point method than that in the 2-point method.

Dynamic-Passive Colour Emotion

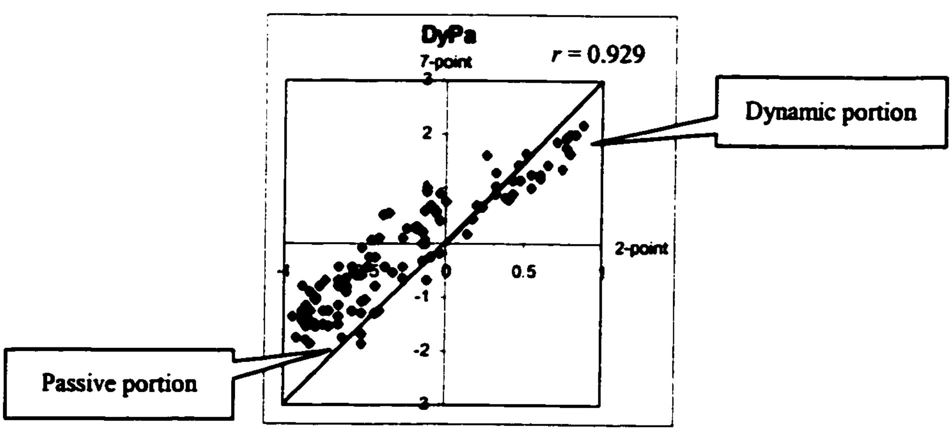

Figure 6.29 Correlation of 7-point and 2-point visual assessment methods of Dynamic-Passive colour emotion, *DyPa*

The correlation coefficient between the 2-point and 7-point methods of 'dynamic-passive' colour emotion was found to be 0.929. As was the case for most of the other pairs, the range of 'dynamic-passive' assessment was found to be wider in the 2-point method than the case in the 7-point method, as shown in Figure 6.29. In the 'dynamic' portion, the same colour was assessed to be slightly more 'dynamic' in the 2-point method than that in the 7-point method, while in the 'passive' portion a much more 'passive' evaluation was obtained in the 2-point method than the 7-point method for the same colour.

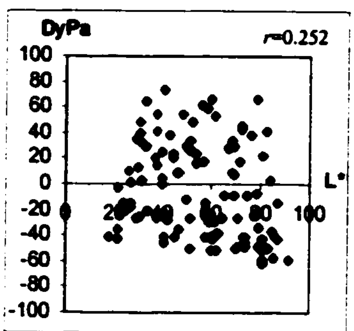

Figure 6.30 Correlation of Dynamic-Passive colour emotion, *DyPa*, with lightness, L^*, in 7-point method

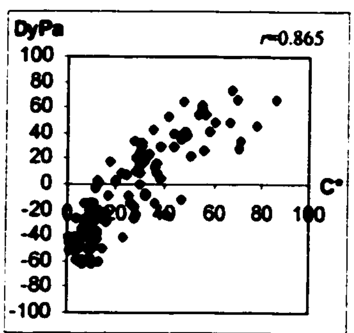

Figure 6.31 Correlation of Dynamic-Passive colour emotion, *DyPa*, with chroma, C^*, in 7-point method

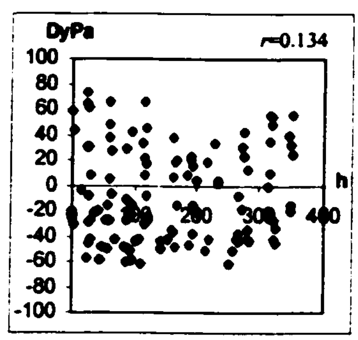

Figure 6.32 Correlation of Dynamic-Passive colour emotion, *DyPa*, with hue, h^o, in 7-point method

The correlations of 'dynamic-passive' colour emotion in the 7-point method with lightness and chroma, which are shown in Figures 6.30 and 6.31, were also found to be similar to those in the 2-point method, which are shown in Figures 3.23

and 3.24. A scattered plot, which indicates no significant correlation, was found both in the graphs of 'dynamic-passive' against lightness for the two methods (Figures 3.14 and 6.18) whereas a good correlation was found with chroma in both the methods (Figures 3.15 and 6.19), in which colours with high chroma tended to give a 'dynamic' impression while colours with low chroma gave a 'passive' impression to the subjects. When comparing the correlations of 'dynamic-passive' colour emotion with hue between the two methods, since the reddish and yellowish colours, with hue angles from 0^0 to 120^0 and from 330^0 to 360^0, in the 7-point method were not assessed to be as 'dynamic' as the 2-point method, a less significant correlation with hue was obtained using the 7-point method.

Distinct-Vague Colour Emotion

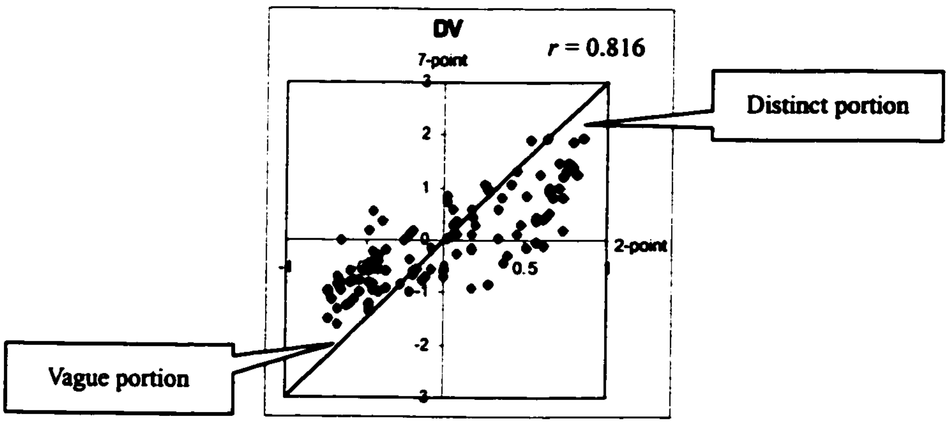

Figure 6.33 Correlation of 7-point and 2-point visual assessment methods of Distinct-Vague colour emotion, DV

The correlation coefficient, *r*, between the 2-point and 7-point methods of 'distinct-vague' colour emotion was found to be 0.816. Figure 6.33 shows that the range of 'distinct-vague' assessment in the 7-point method was found to be much narrower than in the 2-point method, i.e., in the 'distinct' portion, most of the colours were assessed to be much less 'distinct' in the 7-point method than that in the 2-point method, while in the 'vague' portion, a much less 'vague' evaluation was obtained in the 7-point method than the 2-point method for most of the colours.

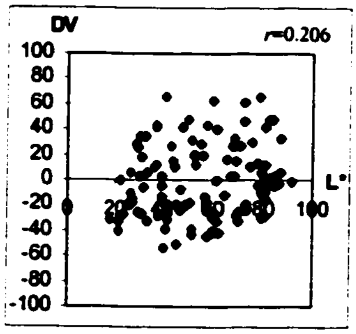

Figure 6.34 Correlation of Distinct-Vague colour emotion, *DV*, with lightness, L^*, in 7-point method

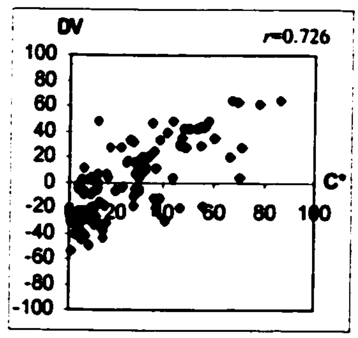

Figure 6.35 Correlation of Distinct-Vague colour emotion, *DV*, with chroma, C^*, in 7-point method

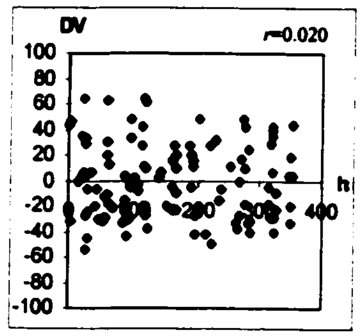

Figure 6.36 Correlation of Distinct-Vague colour emotion, *DV*, with hue, h^0, in 7-point method

When the correlations of 'distinct-vague' colour emotion and colorimetric attributes between the 2-point and 7-point method were compared, obvious differences were found in the correlation with lightness and chroma. Figure 6.34 illustrates a scattered plot of 'distinct-vague' colour emotion against lightness, indicating no significant correlation was found with lightness in the 7-point method, but a trend was observed in the 2-point method that as the lightness of colour increased, the induced emotion generally tended to be 'distinct' (Figure 3.26). While an obvious correlation with chroma was obtained in the 7-point method in that a directly proportional relationship was found between 'distinct-vague' and chroma (Figure 6.35), a less significant correlation with a variety of 'distinct' and 'vague' emotions were obtained in the low chroma region of the 2-point method (Figure 3.27). For the comparison of the correlation with hue, no significant correlation was found using both methods (Figures 3.28 and 6.36).

Transparent-Turbid Colour Emotion

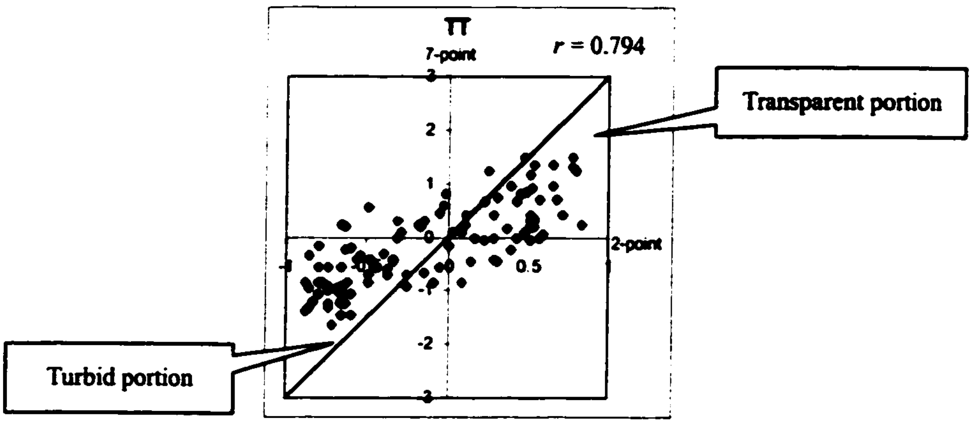

Figure 6.37 Correlation of 7-point and 2-point visual assessment methods of Transparent-Turbid colour emotion, *TT*

Of all colour emotion pairs, the worst correlation between the 2-point and 7-point methods was found to be the 'transparent-turbid' pair that the correlation coefficient was found to be 0.794. A significantly narrower of the range of 'transparent-turbid' assessment was found in the 7-point method than that in the 2-point method (Figure 6.37). In the 'transparent' portion, most of the colours were assessed to be less 'transparent' in the 7-point method than those in the 2-point method, while in the 'turbid' portion, most of the colours were assessed to be less 'turbid' in the 7-point method than those assessments in the 2-point method.

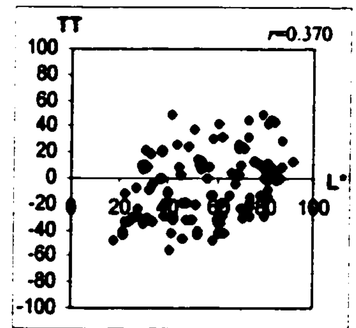

Figure 6.38 Correlation of Transparent-Turbid colour emotion, TT, with lightness, L^*, in 7-point method

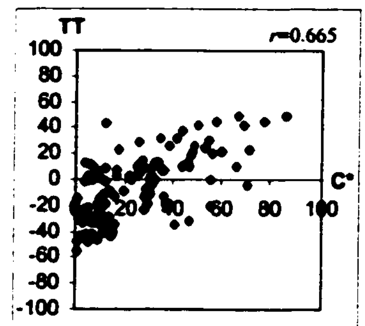

Figure 6.39 Correlation of Transparent-Turbid colour emotion, TT, with chroma, C^*, in 7-point method

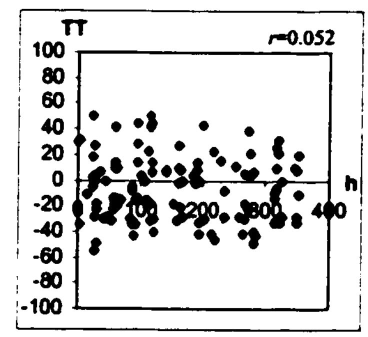

Figure 6.40 Correlation of Transparent-Turbid colour emotion, TT, with hue, h^o, in 7-point method

Significant differences were found in the correlation of 'transparent-turbid' colour emotion and lightness as well as chroma between the 2-point and 7-point methods. Figure 6.38 shows that almost no correlation was found between 'transparent-turbid' colour emotion and lightness in the 7-point method, whereas a trend was found in the 2-point method that as the lightness increased, a 'transparent' impression was evoked (Figure 3.29). For the correlation with chroma, a more obvious correlation was found in the 7-point method, which is illustrated in Figure 6.39, that the 'transparent-turbid' value increased as the chroma of colour increased. However, various 'transparent' and 'turbid' colour emotions were found in the low chroma portion of the 2-point method (Figure 3.30). When the correlations of 'transparent-turbid' colour emotion and hue using these two methods were compared, no significant difference was found since scattered plots were obtained in both graphs, which are shown in Figures 3.31 and 6.40 for the 2-point method and 7-point method respectively.

Soft-Hard Colour Emotion

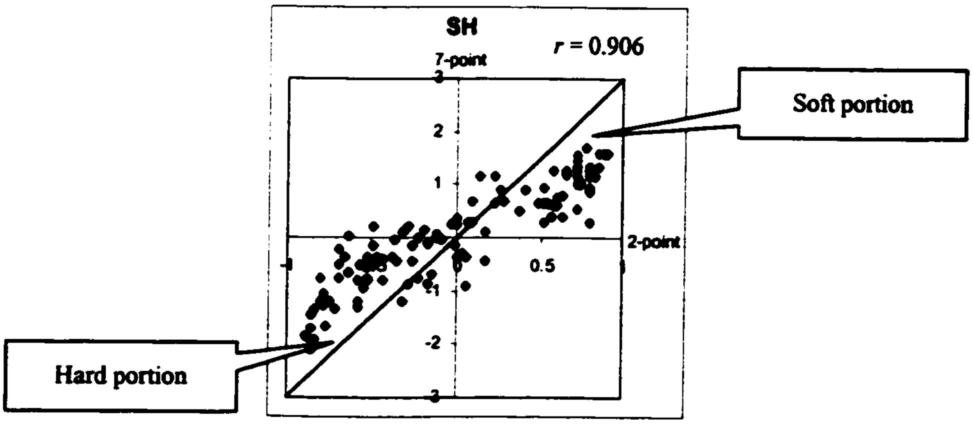

Figure 6.41 Correlation of 7-point and 2-point visual assessment methods of Soft-Hard colour emotion, *SH*

The correlation coefficient between the 2-point and 7-point methods of 'soft-hard' colour emotion was found to be 0.906. Figure 6.41 indicates that the same observation was found as most of the other pairs since the range of 'soft-hard' assessment was found to be wider in the 2-point method than that in the 7-point method. In the 'soft' portion, the same colour was assessed to be much 'softer' in the 2-point method than that in the 7-point method, while in the 'hard' portion, a much 'harder' impression was induced to the subjects in the 2-point method than the 7-point method for the same colour.

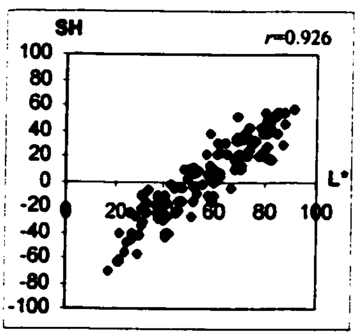

Figure 6.42 Correlation of Soft-Hard colour emotion, SH, with lightness, L^*, in 7-point method

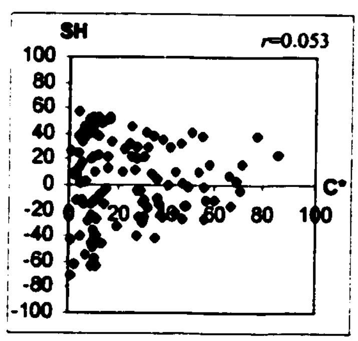

Figure 6.43 Correlation of Soft-Hard colour emotion, SH, with chroma, C^*, in 7-point method

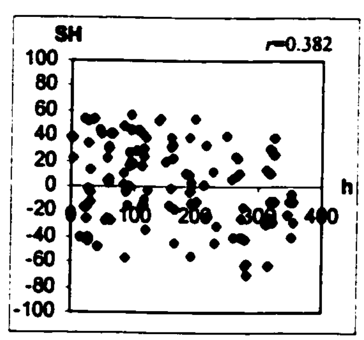

Figure 6.44 Correlation of Soft-Hard colour emotion, SH, with hue, h^o, in 7-point method

Similar correlations of 'soft-hard' colour emotion with the three colorimetric attributes were found between the 2-point and 7-point methods. A very good correlation with lightness was observed in both methods, as shown in Figures 3.32 and 6.42 for the 2-point method and 7-point method respectively. Figure 6.43 shows the correlation of 'soft-hard' colour emotion with chroma in the 7-point method and also illustrates similar plots to the 2-point method, as shown in Figure 3.33. A scattered plot was obtained for the correlation with hue using both methods, as shown in Figure 3.34 for the 2-point method and Figure 6.44 for the 7-point method.

Strong-Weak Colour Emotion

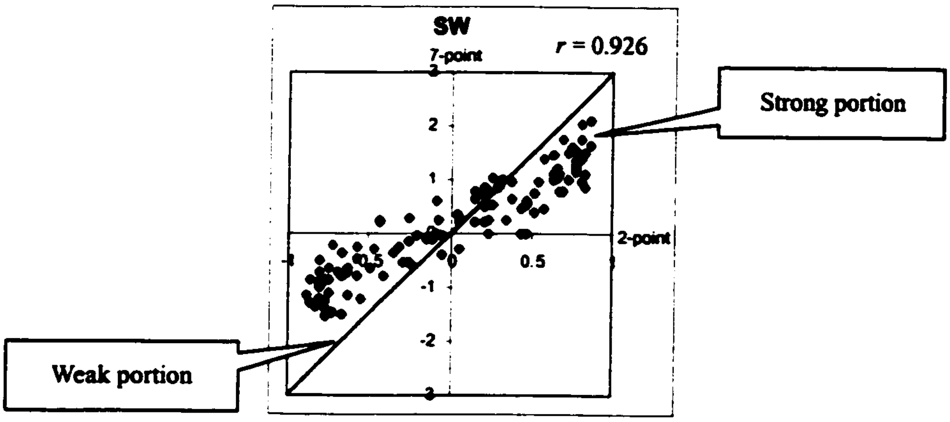

Figure 6.45 Correlation of 7-point and 2-point visual assessment methods of Strong-Weak colour emotion, *SW*

The correlation coefficient, *r*, between the 2-point and 7-point methods of 'strong-weak' colour emotion was found to be 0.926. In Figure 6.45, the range of 'strong-weak' assessment was also found to be wider in the 2-point method than that in the 7-point method as was the case for most of the other pairs. In the 'strong' portion, the same colour was assessed to be much 'stronger' in the case of the 2-point method than that of the 7-point method; while in the 'weak' portion, a much 'weaker' impression was found in the 2-point method than the 7-point method for the same colour.

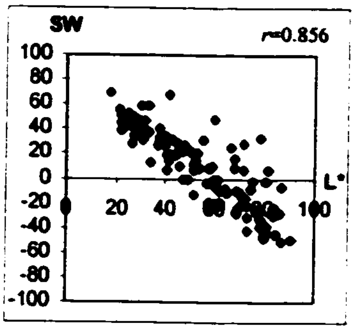

Figure 6.46 Correlation of Strong-Weak colour emotion, SW, with lightness, L^*, in 7-point method

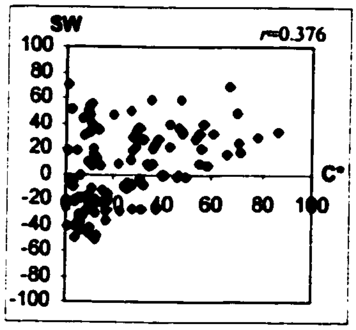

Figure 6.47 Correlation of Strong-Weak colour emotion, SW, with chroma, C^*, in 7-point method

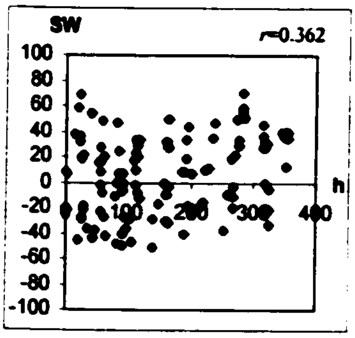

Figure 6.48 Correlation of Strong-Weak colour emotion, SW, with hue, h^o, in 7-point method

The same finding of the correlation of 'strong-weak' colour emotion and lightness was found between the 2-point method (Figure 3.35) and 7-point method (Figure 6.46). In both methods, a 'strong' feeling was evoked in the subjects when perceiving a colour with low lightness whereas a 'weak' feeling was evoked for the colour with high lightness. In addition, some colours, which were expected to be 'weak' in the high lightness region, gave a 'strong' impression to the subjects in the case of both methods, and this unexpected result may be attributed to the chroma effect since these were high chromatic colours. As the chroma of colour increased, so a 'stronger' emotion was induced in the case of both methods, as shown in Figures 3.36 and 6.47 for the 2- and 7-point methods respectively. The same phenomenon was also observed in that a variety of 'strong' and 'weak' emotion was induced for the colours with low chroma. When comparing the influence of hue on 'strong-weak' colour emotion for these two methods, no significant correlation was found, which may be seen in the scattered plots in Figure 3.37 for the 2-point method and Figure 6.48 for the 7-point method.

6.4 Conclusions

Good correlations were found in most of the colour emotion pairs between the 2-point and 7-point methods. Similar influences of the colorimetric attributes on the colour emotions were observed in the 7-point method as in the 2-point method. Since there were more divisions of each colour emotion pair for each colour sample in the 7-point method, that means more choices of colour emotion point were provided and thus it was less easily to select the extremes, it was found for all colour emotion pairs that the ranges of colour emotion assessment were narrower than those of the 2-point method. For example, those colours assessed as very 'deep' in the 'deep-pale' colour emotion assessment in the 2-point method was evaluated to have a lower level of 'deep' in the 7-point method, whereas those 'pale' impression colours in the 2-point method were assessed to evoke a lower level of 'pale' using the 7-point method.

The correlation coefficient of the 'distinct-vague' colour emotion pair was found to be comparatively small between the 2-point and the 7-point methods. The influence of colorimetric attributes to this colour emotion pair was observed to be quite different. In the 2-point method, the dominant colorimetric attributes affecting the 'distinct-vague' colour emotion were found to be both the lightness and chroma. However, in the 7-point method an obvious influence of chroma on this colour emotion was found, and it may be seen from Figure 6.35 that an almost directly proportional relationship was indicated between the 'distinct-vague' colour emotion and chroma, but no significant correlation was observed with lightness of colour (Figure 6.34). In addition, the lowest correlation coefficient between the two assessment methods was found in the case of 'transparent-turbid' pair. As was the case for the 'distinct-vague' colour emotion pair, although lightness and chroma influences were found in the 'transparent-turbid' pair in the 2-point method, no correlation was found with lightness in the 7-point method (Figure 6.38) whereas a more significant correlation was observed with chroma (Figure 6.39). The correlation coefficients of the 2-point and 7-point visual assessment methods of all the colour emotion pairs were shown in Table 6.2.

Table 6.2

The correlation coefficients of the two assessment methods

Colour Emotion Pair	Correlation Coefficient, *r*, of 2-point and 7-point Visual Assessment Methods
Warm-Cool	0.866
Light-Dark	0.901
Deep-Pale	0.945
Heavy-Light	0.953
Vivid-Sombre	0.919
Gaudy-Plain	0.940
Striking-Subdued	0.931
Dynamic-Passive	0.929
Distinct-Vague	0.816
Transparent-Turbid	0.794
Soft-Hard	0.906
Strong-Weak	0.926

It is recommended to carry out the 7-point assessment method for further analysis because the subjects can select a grade which has the best representation of their emotion during the perception of the colour sample from the colour emotion scale with more divisions. Moreover, it was suggested to derive mathematical models for correlating the colour emotions with the standard colorimetric attributes using the visual assessment results obtained from the 7-point method in the future work, because the assessment method may affect the dominant parameter of or the degree of influence of colorimetric attribute on colour emotion.

APPLICATION OF COLOUR EMOTIONS

7.1 Objectives

- To derive colour planners of colour emotions for representing the quantitative correlation of colour emotions and standard colour specifications.
- To introduce a colour emotion display system so that the designers can visualize and select colours for their products according to the colour emotions of the general public using this computer program.

7.2 Methodology

7.2.1 Derivation of colour planners

The colour planners showing the relationship of colour emotions and colour specifications were then created according to the derived mathematical models. There were four planners for each colour emotion pair and each planner was used to represent one hue, i.e., red (hue-angle=0^0), yellow (hue-angle=90^0), green (hue-angle=180^0) and blue (hue-angle=270^0). In each colour planner, the correlation of lightness and chroma to each colour emotion pair was illustrated and the relationships between them were clearly presented. The iso-emotion lines were plotted in those graphes.

7.2.2 Colour Emotion Display System

After the derivation of colour planners, a colour emotion display system in the computer was built to illustrate the correlation of the colour coordinates and colour emotions as well as visualise this correlation using the monitor. The colour planners show the iso-emotion lines while the colour emotion display system gives the visualization of colour and its emotion to designers or colour users so that they can select colours on the display and find out the corresponding colour emotions of the selected colours. The colour emotion display system was derived by means of C++ programming.

7.3 Results and Discussions

7.3.1 Colour Planner

Since the hue influence was not obvious in many colour emotion pairs, and the similarity for the methodology, not all of the colour planners of all the four hues for each colour emotion word pair are illustrated in this chapter. Only the colour planners of red hue (hue-angle=0^0) are used for discussion. However, since a comparatively significant influence of hue observed in the 'warm-cool' colour emotion pair, four colour planners including the red, yellow, green and blue hues are illustrated for comparison and discussion.

In the colour planners, if the iso-emotion lines are almost vertical, it indicates that the corresponding colour emotion is mainly influenced by chroma of colour. Hence, any change in lightness will only cause a slight change in colour emotion. On the other hand, if the iso-emotion lines in the colour planners are nearly horizontal, it indicates that the corresponding colour emotion is mainly influenced by lightness of colour, and change of chroma will not have a significant impact on the colour emotion. The inclined iso-emotion lines in some figures suggest that the corresponding colour emotion is influenced by both chroma and lightness of colour, and any change in chroma or lightness or both of them will induce a significant change in colour emotion.

7.3.1.1 Chroma dependent colour emotions

Warm-Cool Colour Emotion

Of the three colour specifications, chroma of colour was found to be the dominant parameter in 'warm-cool' colour emotion and hue was also observed to have an influence on it, whereas no significant correlation was found between lightness of colour and 'warm-cool' colour emotion. As the chroma of colour increased, an impression approaching 'warm' was experienced by the subjects. According to the findings, 'warmer' colour emotions were experienced by the subjects when perceiving red and yellow colours, while 'cooler' emotions were experienced when perceiving green and blue colours. The colour planners showing the 'warm-cool' colour emotions for red, yellow, green and blue colours are illustrated in Figures 7.1 to 7.4 respectively.

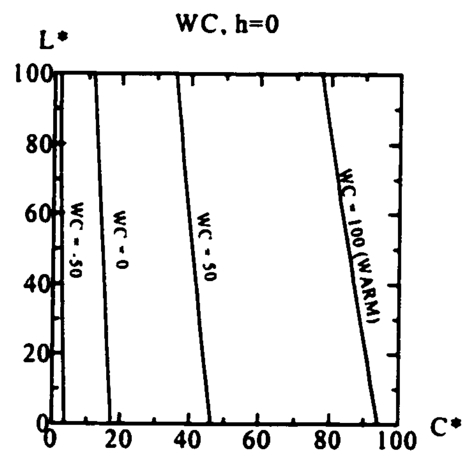

Figure 7.1 Colour planner for 'warm-cool' colour emotion at $h=0^0$

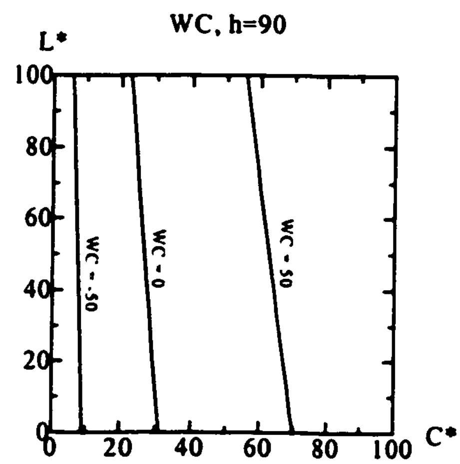

Figure 7.2 Colour planner for 'warm-cool' colour emotion at $h=90^0$

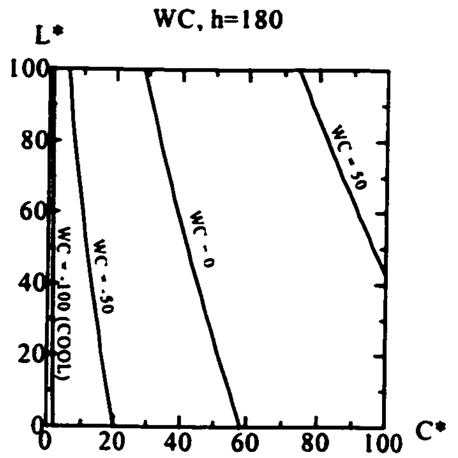

Figure 7.3 Colour planner for 'warm-cool' colour emotion at h=180^0

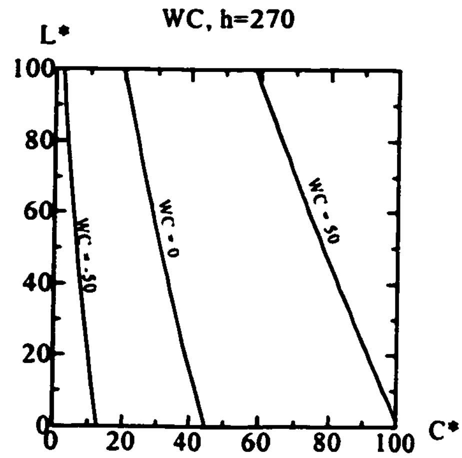

Figure 7.4 Colour planner for 'warm-cool' colour emotion at h=270^0

Figure 7.1 illustrates that a 'warm' colour emotion, WC=100, was given to the subjects when C^* was between 80 and 95 and hue angle=0^0, i.e., red colours, irrespective of the lightness of the colour. However, at the same range of chroma for yellow colours, hue angle=90^0 (Figure 7.2), the 'warm-cool' colour emotion tended to be a lower level of 'warm' with WC less than 100 but larger than 50; while for green colours, hue angle=180^0 (Figure 7.3), the colour emotion tends to be a much lower level of 'warm' with WC equaled to around 50. In Figure 7.3, it may be seen that a 'cool' colour emotion, WC=–100, was obtained at C^* around 2, representing that for those green colours with low chroma, they gave 'cool' impression to the subjects during perception. The induced emotion for those yellow and blue colours at the same chroma, C^*=2, was not as 'cool' as green colours and their WC values were smaller than –50, as shown in Figures 7.2 and

7.4 respectively; whereas for the red colours at $C^*=2$, the induced emotion was much less 'cooler', with *WC* being around −50. Apart from these, the influence of lightness in green and blue colours was observed to be greater than that of the red and yellow colours (Figures 7.1 to 7.4). For example, Figure 7.4 shows that a rather 'warm' impression, $WC=50$, was experienced during the perception of blue colours at $L^*=70$ and $C^*=70$ or $L^*=20$ and $C^*=90$, so that either changing the lightness or chroma of colour gave similar 'warm-cool' emotion to the subjects. From the colour planners of the 'warm-cool' colour emotion, it can be concluded that colours of higher chroma tended to evoke 'warmer' emotion in the subjects, and red colours evoked 'warmer' emotion than green colours, even if they were of the same chroma.

Vivid-Sombre, Gaudy-Plain, Striking-Subdued and Dynamic-Passive Colour Emotions

Chroma of colour was also found to be the dominant parameter influencing the selection of 'vivid-sombre', 'gaudy-plain', 'striking-subdued' and 'dynamic-passive' colour emotions as 'warm-cool' colour emotion. Since the hue influence was not significant in these pairs, unlike the 'warm-cool' colour emotion, only the colour planners at hue-angle=0^0 are provided in Figures 7.5 to 7.8 respectively.

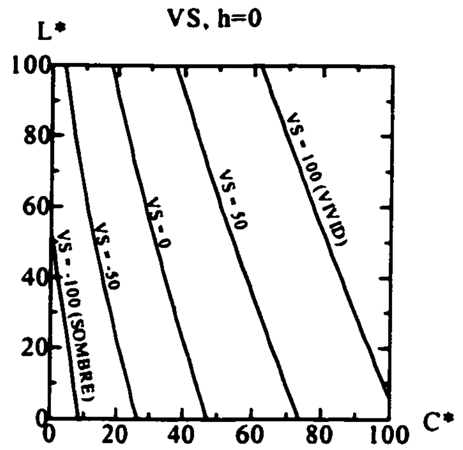

Figure 7.5 Colour planner for 'vivid-sombre' colour emotion of at h=0^0

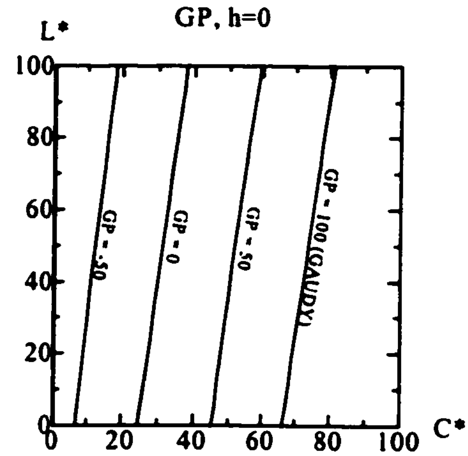

Figure 7.6 Colour planner for 'gaudy-plain' colour emotion at h=0^0

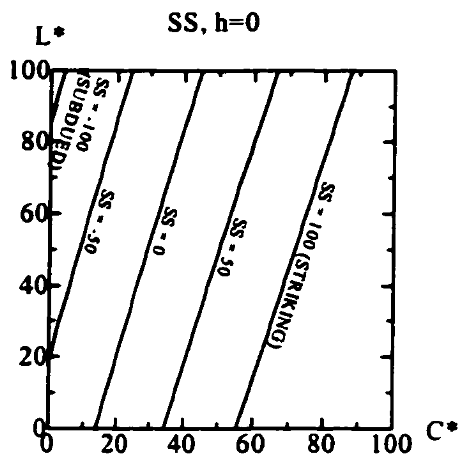

Figure 7.7 Colour planner for 'striking-subdued' colour emotion at h=0^0

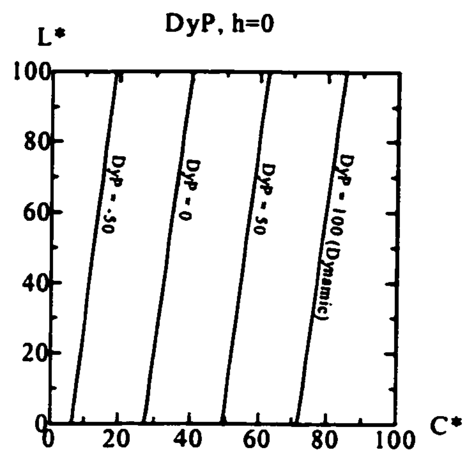

Figure 7.8 Colour planner for 'dynamic-passive' colour emotion at h=0^0

Figures 7.5 to 7.8 show that, although these four colour emotion pairs were chroma dependent, the 'vivid-sombre' and 'striking-subdued' pairs were influenced by lightness to larger extents than the 'gaudy-plain' and 'dynamic-passive' pairs, because the inclinations of the iso-emotion lines in Figures 7.5 and 7.7 are larger than those in Figures 7.6 and 7.8. From the colour planners, it may be seen that for the same chroma, as the lightness of colour increased, the induced impression in the minds of the subjects was more 'vivid', 'plain', 'subdued' and 'passive'.

Figure 7.5 illustrates that as the chroma increased, the 'vivid-sombre' colour emotion given to the subjects tended to be more 'vivid'. In the case of the red colours with C^* larger than 70 and high lightness, i.e., L^* was around 100, or C^* around 100 and L^* larger than 10, the impression to the subjects was very 'vivid', i.e., VS=100. Conversely, when the subjects viewed the colours with very low chroma, C^*<10, and rather low lightness, L^*<50, a very 'sombre' impression, i.e., VS=-100, was given to them.

The colour planner in Figure 7.6 for the 'gaudy-plain' colour emotion shows that increasing chroma tended to give a more 'gaudy' impression to the subjects.

The red colours with C^* larger than 65 and low lightness, i.e., L^* was around 0, or C^* around 80, irrespective of the lightness value, gave a totally 'gaudy' impression, i.e., GP=100, to the subjects. However, no totally 'plain' impression was received by the subjects, even when they perceived very low chromatic red colours, as shown in the planner.

The colour planner in Figure 7.7 illustrates that, as the chroma increased, so a more 'striking' impression was given to the subjects. For those red colours with C^* larger than 55 and low lightness or C^* larger than 90 and any lightness value, a very 'striking' impression, i.e., SS=100, was the result. Conversely, when the subjects perceived the low chromatic colours, i.e., $C^*<5$, with high lightness, i.e., $L^*>85$, a very 'subdued' impression, i.e., SS=-100, was given to them.

The colour planner in Figure 7.8 for the 'dynamic-passive' colour emotion shows that a more 'passive' impression was obtained when the chroma was increased. The red colours with C^* larger than 70 and low lightness, or C^* larger than 80 and any lightness value, gave a totally 'dynamic' impression, i.e., DyP=100, to the subjects. However, no totally 'passive' impression was observed even when they perceived very low chromatic red colours.

7.3.1.2 Lightness dependent colour emotions

Deep-Pale, Heavy-Light, Soft-Hard and Strong-Weak Colour Emotions

Lightness of colour was found to be the dominant parameter in 'deep-pale', 'heavy-light', 'soft-hard' and 'strong-weak' colour emotions whereas the influence of hue was insignificant. However, chroma was found to slightly affect the selection of the 'strong-weak' colour emotion while no such observation was made in the case of other pairs. The colour planners for these four colour emotion pairs are shown in Figures 7.9 to 7.12.

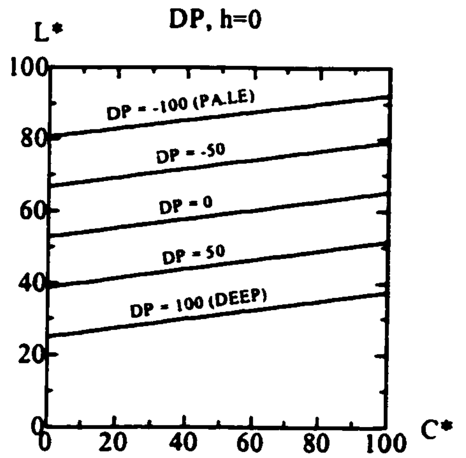

Figure 7.9 Colour planner for 'deep-pale' colour emotion of at h=0^0

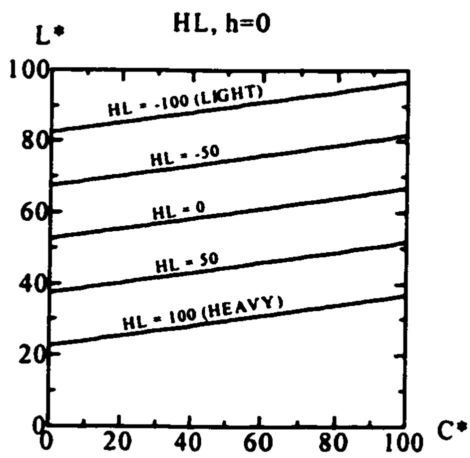

Figure 7.10 Colour planner for 'heavy-light' colour emotion at h=0^0

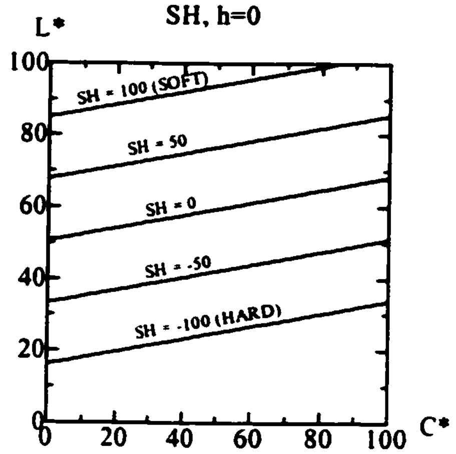

Figure 7.11 Colour planner for 'soft-hard' colour emotion at h=0°

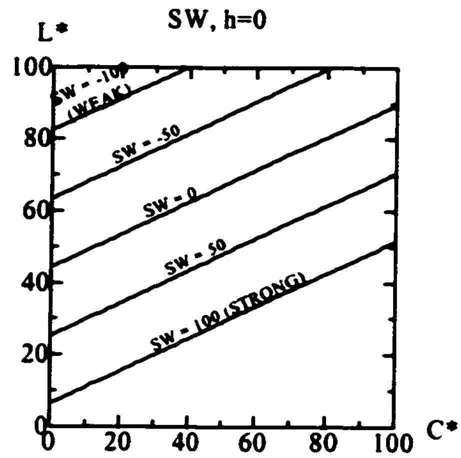

Figure 7.12 Colour planner for 'strong-weak' colour emotion at h=0°

Of the four colour planners shown in Figures 7.9 to 7.12, although most of the iso-lines were more or less lain horizontally which suggested these colour emotion pairs were mainly lightness dependent, the influence of chroma on the 'strong-weak' colour emotion was the most obvious one since the inclinations of the iso-emotion lines in Figure 7.12 were the largest. From the colour planners, it may be seen that for the same lightness value, increasing the chroma of colour induced a 'deeper', 'heavier', 'harder' and 'stronger' impression in the minds of the subjects, and the increment of 'strong' impression was the largest.

As shown in Figures 7.8 and 7.9, the colour planners for 'deep-pale' and 'heavy-light' colour emotions were very similar to one another, irrespective of the inclinations of the iso-emotion lines and the intervals between lines. These two colour emotion pairs were highly dependent on lightness of colour. The red colours with low lightness, i.e., L^* was round 25, and with any choma values or with L^* around 40 but very high chroma, i.e., C^* was around 100, they gave the subjects 'deep' and 'heavy' impressions. As the lightness increased, so the induced impressions became 'paler' and 'lighter'. Perfectly 'pale' and 'light' impressions were perceived by the subjects when they viewed colours with L^* larger than 80 and low chroma or L^* larger than 95 and any chroma.

The 'soft-hard' colour planner shown in Figure 7.11 was similar to the colour planners of 'deep-pale' and 'heavy-light' colour emotions (Figures 7.9 and 7.10), but it was slightly more dependent on chroma with a slightly larger inclination of the iso-emotion lines. The red colours with L^* less than around 20 gave a 'hard' impression to the subjects; whereas those with L^* larger than around 90 gave a 'soft' impression instead.

In the 'strong-weak' colour planner, it may be seen that those colours with very low lightness and low chroma or with L^* less than around 50 and even very high chroma induced a very 'strong' impression in the minds of the subjects

(Figure 7.12). A totally 'weak' impression was given to the subjects during the perception of high lightness, i.e., L^* larger than 80, and low to medium chroma, i.e., C^* less than 40. A comparatively larger chroma dependent feature of 'strong-weak' colour emotion than the other lightness dependent colour emotion pairs was shown in the 'strong-weak' colour planner. For example, when the subjects perceived a red colour with $L^*=50$, changing the chroma of colour caused the change of 'strong-weak' and 'deep-pale' colour emotions as shown in Table 7.1.

Table 7.1

'Strong-weak' and 'deep-pale' colour emotions for variation in chroma

Colour Planner	Hue and Lightness	Chroma	Colour Emotion
Strong-Weak (Figure 7.12)	$h=0^0$ $L^*=50$	$C^*=0$	$SW=-20$ slightly 'weak'
		$C^*=100$	$SW=100$ very 'strong'
Deep-Pale (Figure 7.9)		$C^*=0$	$DP=10$ slightly 'deep'
		$C^*=100$	$DP=50$ rather 'deep'

Table 7.1 illustrates that changing the chroma from 0 to 100 caused the 'strong-weak' colour emotion of the subjects to change from slightly 'weak' to very 'strong'; whereas the same extent of change in chroma caused the

'deep-pale' colour emotion of subjects to change from slightly 'deep' to rather 'deep' only. Hence, the same extent of change in chroma resulted in a larger change of colour emotion in the 'strong-weak' pair that which was more chroma dependent.

7.3.1.3 Lightness and chroma dependent colour emotions

Light-Dark, Distinct-Vague and Transparent-Turbid Colour Emotions

Both lightness and chroma of colour were found to be the dominant parameters in 'light-dark', 'distinct-vague' and 'transparent-turbid' colour emotions and none of them was found to be significantly influenced by hue. The colour planners for them are shown in Figures 7.13 to 7.15.

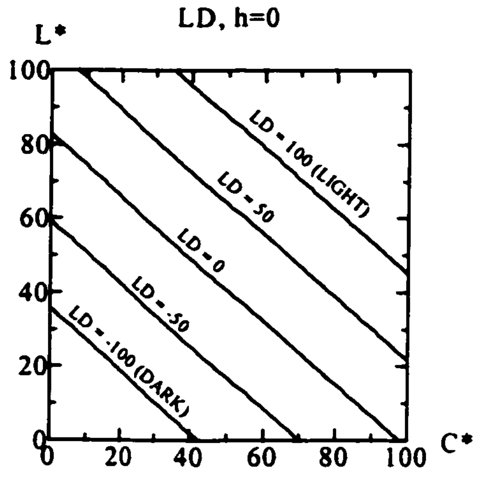

Figure 7.13 Colour planner for 'light-dark' colour emotion of at $h=0^0$

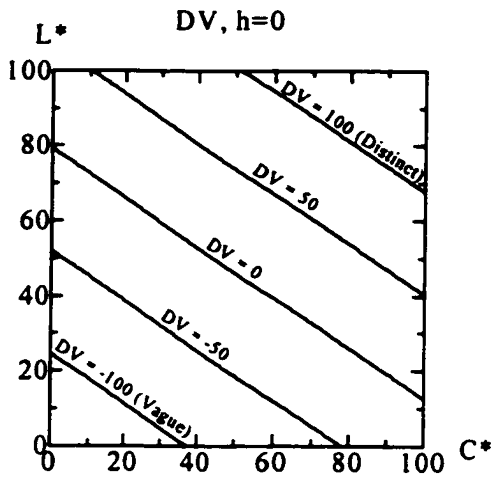

Figure 7.14 Colour planner for 'distinct-vague' colour emotion at $h=0^0$

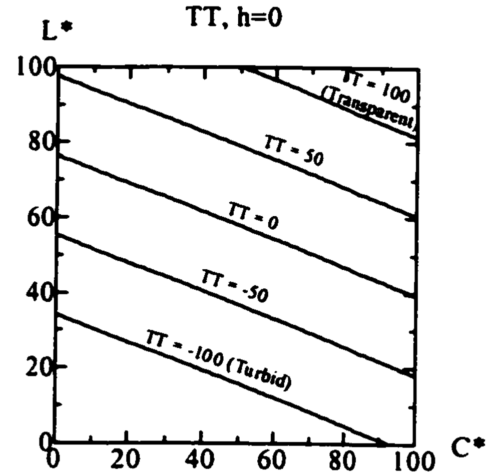

Figure 7.15 Colour planner for 'transparent-turbid' colour emotion at h=0°

The 'light-dark', 'distinct-vague' and 'transparent-turbid' colour planners in Figures 7.13 to 7.15 indicate that, when colours were of high lightness and high chroma, 'light', 'distinct' and 'transparent' impressions were given to the subjects; whereas those colours with low lightness and low chroma normally gave 'dark', 'vague' and 'turbid' impressions. Of these three colour planners, less chroma dependency was observed in the 'transparent-turbid' pair because a less distinct inclination of iso-emotion lines was obtained, indicating that a similar degree of change in chroma generally involved a less change in 'transparent-trubid' colour emotion.

7.3.1.4 Use of colour planners

The derivation of the colour planners can help the designers or colour users to understand the impression or emotion induced in the minds of the customers or general public during colour perception. After obtaining the colour specifications, $L*$, $C*$ and h^0, of a colour, he/she can check the corresponding colour emotions using the colour planners. A contrast colour emotion can be given to the customers or general public, depending on the decision of the designers or colour users, by changing either the lightness, or chroma, or both of a colour according to the colour planners.

For example, when a designer intends to use a colour with $L*$=40, $C*$=20 and h=0^0, he/she can check the target colour emotion to convey his/her idea to the customers using the colour planner. The colour planners for 'warm-cool', 'heavy-light' and 'transparent-turbid' colour emotions are cited as examples for representing the 'chroma dependent', 'lightness dependent' and 'lightness and chroma dependent' colour emotions which are shown in Figures 7.1, 7.10 and 7.15. If he/she desires to give a 'warm' impression to the product users, he/she can check that this colour is just slightly 'warm' only, with WC=10 (Figure 7.1). The induced colour emotion will be much 'warmer' when the chroma of colour is increased from 20 to 80. Moreover, for the 'heavy-light' colour emotion, the colour which is intended to be used by the designer will induce a rather 'heavy' impression, with HL=50 (Figure 7.10). If he/she desires to give a totally 'heavy' impression to the product users, he/she can select a colour with a lower lightness value, i.e., L^*=20, C^*=20 and h=0^0. In addition, the original colour chosen by the designer will induce a 'turbid' impression, with TT=–75, to the general public. If he/she would like to induce a 'neutral' emotion, i.e., neither 'transparent' nor 'turbid', this can be achieved by either increasing the L^* from 40 to 70 or increasing the L^* from 40 to 60 and the C^* from 20 to 60, since this colour emotion pair is both lightness and chroma dependent.

7.3.2 Colour Emotion Display System

The window display from the computer's monitor of the colour emotion display system is shown in Figure 7.16. This illustrates a bright red colour with L^*=41, C^*=91 and h=0^0 has been selected. As this colour emotion display system is derived from the colour emotion of the Hong Kong's subjects, the corresponding colour emotions are representative of Hong Kong people only.

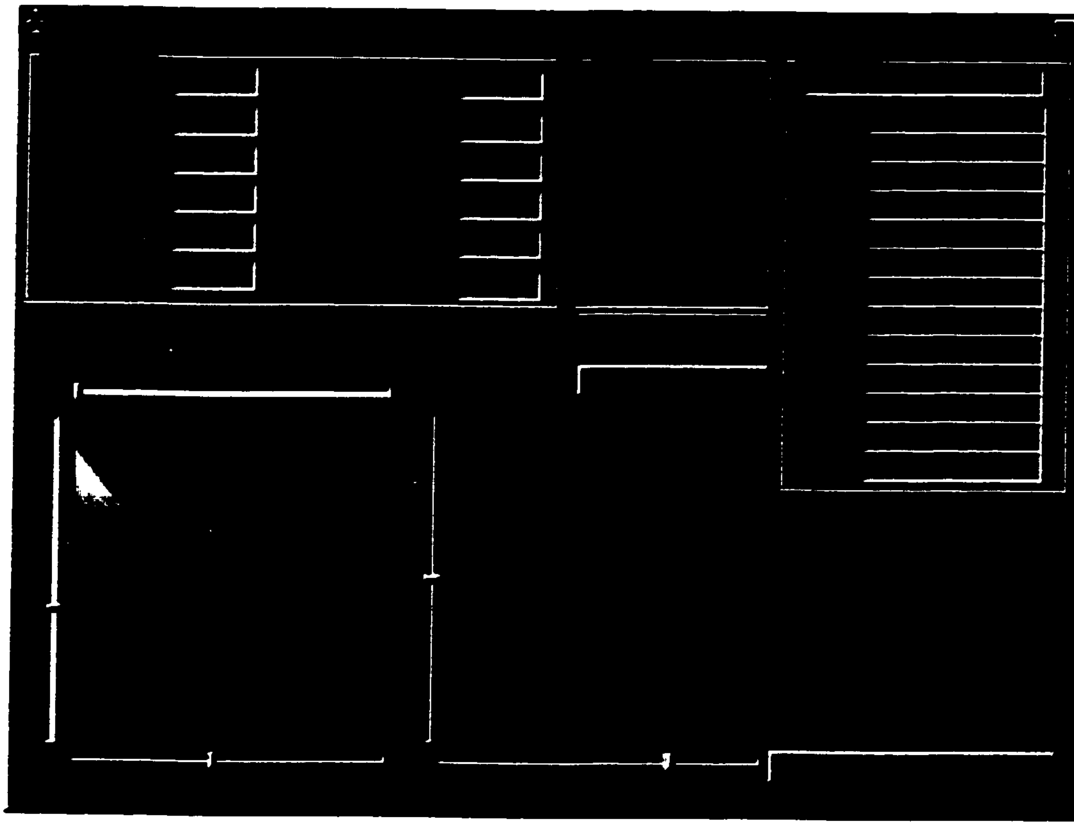

Figure 7.16 An example of display of the colour emotion display system

In the window display of the colour emotion display system shown in Figure 7.16, the colour specifications of the selected colour are illustrated in the right upper side of the display. The left upper part indicates the twelve colour emotion indices of the selected colour. Hence, if a designer or colour user intends to use this colour, he/she will know from the system that the impressions which will be given to the general public will be very 'warm' (*WC*=100), 'light' (*LD*=74.93), 'deep' (*DP*=83.31), 'heavy' (*HL*=81.84), very 'vivid' (*VS*=100), very 'gaudy'

(*GP*=100), very 'dynamic' (*DyPa*=100), quite 'distinct' (*DV*=40.35), just slightly 'turbid' (*TT*=-4.04, quite 'neutral'), rather 'hard' (*SH*=-74.21), very 'striking' (*SS*=100) and very 'strong' (*SW*=100). In the lower part of the display, there are three boxes indicating colours: the right side one is for placing the selected colours for comparison and reference, whereas the middle and left side ones show the colour gamut. The designer or colour user can adjust the movable bars of the left colour box to change colour. The top movable bar is for selecting hue, which has a selection from $h=0^0$ to 360^0, the left movable bar is for selecting lightness, which has a selection from $L^*=0$ to 100, and the bottom movable bar is for selecting chroma, which has a selection from $C^*=0$ to 200. After a colour has been chosen, the middle colour box will automatically show the corresponding colorimetric values a* and b* and its gamut. As a result, the designers or colour users can select colours to convey the target colour emotions easily using this colour emotion display system.

7.4 Conclusions

The colour planners for the twelve colour emotion pairs were developed to represent the correlation between the colour emotion and the colour specifications. The extent of change in each colour emotion pair caused by changing the lightness or chroma of a colour is clearly presented in the colour planners. Fashion, graphic, interior, web site or other designers can select suitable colours for inducing target colour emotions in the customers' or product-users' minds by means of the colour planners. In addition, the designers can enhance the functionality and increase the attractiveness of their designed products by selecting suitable colours. As colour emotions are directly correlated to standard colour specifications in the colour planner, this can avoid any possible misunderstanding between the designers or colour users and the colourists during their communication by using the numerical terms.

In order to assist the designers or colour users in selecting colours, a visualization of colours in the colour planner was achieved by establishing a colour emotion display system which provides a means for the designers or colour users to select colours from the monitor. The designers or colour users can select the target colours from the displayed colour gamut, and the system will automatically show the standard colour specifications and colour emotions of the selected colours. This is the most convenient way to show the correlation of colour emotions and standard colour specifications.

QUALITATIVE ANALYSIS OF COLOUR EMOTIONS OF DESIGNERS

8.1 Objectives

- To anaylse the colour emotions of designers --- Since one of the objectives of this study was to derive tools for designers to select suitable colours for their products, it was considered worthwhile to investigate the similarities and differences of colour emotions between designers and general public.

8.2 Methodology

8.2.1 Visual Assessment

8.2.1.1 Subjects, experimental conditions and questionnaire

The subjects representing the general public, experimental conditions and questionnaire in the visual assessment were the same as those used in Section 3.2.1.

When investigating the colour emotions of the designers, five designers with an average of about 10 years' experience in textile design were invited as the subjects for this visual assessment.

8.2.1.2 Colour samples

A total of 114 colour samples was used in this comparison. Those with the notation of Munsell hue '5' and neutral colours, i.e., the notations N1, N2, N4, N6, N8 and N9.5, were used for analysis.

8.2.2 Calculation of Colour Emotion Percentage

The method for calculating the colour emotion percentage was the same as the two-point method for quantifying colour emotions that was discussed in Chapter 3.2.2. For each colour sample, one colour emotion percentage was calculated for the general public while another one was calculated for the designers.

8.2.3 Definition of terms

Since there were seventy subjects representing the general public, the spread of opinions amongst subjects caused inevitable variations in feelings, emotions and subsequent 'ratings'; in other words, it was difficult to have 100% 'warm' or 100% 'cool' assessment from them. Hence, citing the 'warm-cool' colour emotion pair as an example, if the calculated colour emotion percentage was larger than 50% or smaller than –50% for the general public, the colour was assessed as 'warm' or 'cool' accordingly. However, the assessment results obtained from the five designers indicated that they had a consistently induced emotion in the case of some colours. Therefore, 100% 'warm' and 100% 'cool' colour emotions were obtained when all the designers assessed the colours as 'warm' and 'cool' respectively in the example of the 'warm-cool' colour emotion pair.

8.3 Results and Discussion

8.3.1 Chroma Dependent Colour Emotions

When investigating the influence of hue, lightness and chroma of colour on colour emotions, it was found that, irrespective of whether the visual assessment results were from the subjects representing the general public or the designers, their 'warm-cool', 'vivid-sombre', 'gaudy-plain', 'striking-subdued' and 'dynamic-passive' colour emotions were mainly determined by the chroma of colour.

8.3.1.1 Warm-cool colour emotion

The highly chromatic colours were generally assessed to be 'warm', whereas those of low chroma were assessed to be 'cool' by all the subjects in this study.

'Warm' Colours

Although a good correlation was found between 'warm-cool' colour emotion and chroma, a tendency to be influenced by hue of colour was observed in the 'warm' colour emotion. In this study, fifteen colour samples were calculated to be WC>50% as they were assessed to be 'warm' by the subjects representing the general public. The hue-angles of these 'warm' colours were 0^0 to 95^0 and 310^0 to 360^0, and they were all red and yellow colours. Of these fifteen 'warm' colours, twelve had chroma values larger than 40, and were considered as high chromatic colours in this study; and the remaining colours had medium chroma values, i.e., between 20 and 40, indicating that colours of higher chroma gave 'warmer' impression to the subjects.

Twenty-six colour samples were assessed to be very 'warm' by all designers involved in this study, i.e., 100% 'warm' was obtained. These colours were not only red and yellow colours as the assessments of the subjects representing general public, but also some greenish-yellow and green colours were considered as 'warm' colours by the designers. Their hue-angles ranged from 0^0 to 120^0 and 310^0 to 360^0, and one of them, colour sample 5BG4, with hue-angle equals to 185.19^0 was a pale green colour of high lightness, L^*=68.13, and medium chroma,

C^*=21.98. A correlation between 'warm-cool' colour emotion with chroma was also found in the designers' perception but it was less obvious than that found in the case of the general public. Of these twenty-six 100% 'warm' colours, twelve of them were of high chroma, i.e., C^*>40, eleven of them were of medium chroma, i.e., C^* between 20 and 40, and three of them were of low chroma, i.e., C^*<20.

Five colour samples were assessed as 'warm' by all designers in this study but they were considered as 'neutral', i.e., neither 'warm' nor 'cool', or 'cool' by the subjects representing the general public. The five colour samples were: 1) 5Y4—it is a greyish yellow colour of high lightness, L^*=77.51, medium chroma, C^*=27.91, and hue-angle of 97.90^0; 2) 5GY4—a pale green colour of high lightness, L^*=74.94, medium chroma, C^*=36.75, and hue-angle of 117.31^0; 3) 5GY10—a deeper green colour of medium lightness and chroma, L^*=45.87 and C^*=36.75, and hue-angle of 114.13^0; 4) 5BG4—a cyan colour of relatively high lightness, L^*=68.13, medium chroma, C^*=21.98, and hue-angle of 185.19^0; and 5) 5RP9—a dark brownish red colour of low lightness and chroma, L^*=26.99 and C^*=10.64, and hue-angle of 350.87^0. When comparing the 'warm' colour emotion between the general public and designers, it was found that no blue colour was regarded as 'warm' in both cases.

'Cool' Colours

Subjects representing general public assessed twenty-six colour samples with the result that their 'warm-cool' percentages were calculated to be smaller than –50% and these colours were considered to be 'cool'. These colours were distributed in all hue-angles but they all had very low chroma values, $C^*<15$. In other words, regardless of the hue of colour, if it was of low chroma, a 'cool' impression was normally given to the public.

Twenty-eight colour samples were assessed by all the designers in this study to be 'cool', i.e., a 100% 'cool' colour emotion was obtained for these colours. The hue-angles of these colours were mainly around 140^0 to 330^0, hence these were green, blue and purple colours. Twenty-two were of low chroma, $C^*<20$, whereas six were of medium chroma, C^* between 20 and 45.

When the differences of the perception of general public and designers of 'cool' colours were compared, it was found that almost all 100% 'cool' colours assessed by the designers were also considered to be 'cool' by the subjects representing general public, except in the case of two colour samples that induced neither a 'warm' nor a 'cool' emotion. These colour samples were 5PB5 and 5PB8, both of which were blue colours with similar hue-angles around 270^0. 5PB5 was of high lightness, L^*=65.34, and medium chroma, C^*=25.46, whereas 5PB8 was of lower lightness, L^*=50.00, and higher chroma, C^*=43.30.

8.3.1.2 Vivid-sombre colour emotion

Colours of high chroma were generally assessed to be 'vivid', whereas colours with low chroma were assessed to be 'sombre' by all subjects.

'Vivid' Colours

In the analysis of subjects representing the general public, the 'vivid-sombre' colour emotion percentages (*VS*) of twenty-six colour samples were calculated to be larger than 50%, indicating they were assessed as 'vivid' by them. Of these 'vivid' colours, twenty-two had chroma values larger than 40, which were considered to be high chromatic colours; and the chroma values of the other three colours were larger than 33, i.e., of medium chroma; however, one of these 'vivid' colours was very special in that it had low chroma, C^*=12.05. This low chromatic colour, which was pastel blue, had a high value of lightness, L^*=83.88, and its hue-angle was equal to 200.35^0.

The correlation of chroma of colour and 'vivid-sombre' colour emotion of the five designers was not as significant as that of the subjects representing the general public. In this study, thirty-seven colour samples were assessed as very 'vivid' by all designers, i.e., VS=100% was obtained. Twenty-two had high chroma values, i.e., $C^*>40$, while eleven had medium chroma values, i.e., $20<C^*<40$. Although higher chroma colours were expected to be 'vivid', the remaining five colours assessed to be 'vivid' by all designers in this study were of low chroma, i.e., $C^*<20$. These colours were of high lightness, i.e., $L^*>70$, and had different hues.

Four colour samples were assessed as 'vivid' by all designers in this study but they were considered to be 'neutral', i.e., neither 'vivid' nor 'sombre', or 'sombre' by the subjects representing the general public. The four colour samples were: 1) 5BG2—a pale greenish blue colour of high lightness, L^*=84.36, low chroma, C^*=12.14, and hue-angle of 161.28^0; 2) 5Y2—a pale yellow colour of high lightness, L^*=87.04, medium chroma, C^*=25.77, and hue-angle of 94.35^0; 3) 5Y10—a yellowish brown colour of medium lightness, L^*=49.77, quite high chroma, C^*=46.74, and hue-angle of 84.52^0; and 4) 5P7—a purple colour of relatively low lightness, L^*=39.75, medium chroma, C^*=30.08, and hue-angle of 314.88^0.

'Sombre' Colours

For those results obtained from the subjects representing general public, there were forty-three colour samples that their 'vivid-sombre' percentages were calculated to be smaller than –50% and these colours were considered to be 'sombre'. These colours were distributed in all hue-angles and all lightness values but they all had low chroma values, C^*<16. This indicated that, irrespective of the hue or lightness of colour, if it had low chroma, a 'sombre' impression was normally given to the subjects.

When the colour emotions of designers towards the 'sombre' colours were evaluated, it was found that twenty-three colour samples were assessed as 'sombre' by all designers, i.e., VS=-100% colour emotion was obtained for these colours. All these colours had low chroma, C^*<15, but different values of lightness and hue-angle.

When the differences of the perception of general public and designers towards 'cool' colours were compared, all 100% 'sombre' colours assessed by the designers were also considered as 'sombre' by the subjects representing the general public. Hence, it may be concluded that the general public and designers had same perception towards 'sombre' colours.

8.3.1.3 Gaudy-plain colour emotion

'Gaudy' impressions were probably given to the subjects in the case of the high chromatic colours while 'plain' impressions were given in the perception of low chromatic colours.

'Gaudy' Colours

The 'gaudy-plain' colour emotion percentage (*GP*) of eighteen colour samples were calculated to be larger than 50% in the assessments by the subjects representing the general public, indicating that these colour samples were assessed to be 'gaudy' by them. All of these 'gaudy' colours had chroma values larger than 40, which were classified as high chromatic colours. Hence, it may be concluded that the 'gaudy' colour emotion of subjects representing general public was highly correlated to chroma of colour.

In this study, twenty-five colour samples were assessed to be very 'gaudy' by all designers, i.e., GP=100% was obtained. Twenty had high chroma values, i.e., $C^*>40$, while five had medium chroma values with $C^*>27.3$. As a result, the correlation of 'gaudy-plain' colour emotion with chroma for designers is not was significant as that for general subjects.

A similar perception of 'gaudy' colours was found in the case of both the general subjects and designers, as only one colour sample was assessed to be 'gaudy' by all designers yet it was assessed to be 'plain' by subjects representing general public. This exceptional colour sample was a yellowish brown colour of medium lightness, L^*=49.77, rather high chroma, C^*=46.74, and hue-angle of 84.52^0.

'Plain' Colours

The results obtained from the subjects representing general public were that forty-six colour samples had 'gaudy-plain' percentages calculated to be smaller than –50%, and these colours were considered as 'plain'. These colours were distributed in all hue-angles and all lightness values but most had low chroma values. Forty-two had low chroma values, i.e., $C^*<20$, while four had medium chroma values, C^*<33, but high lightness.

Forty-nine colour samples were assessed to be 'plain' by all designers, i.e., GP=-100%, and most of these were of low chroma. Forty-seven colours were of low chroma, C^*<20, whereas two colours had slightly higher chroma, i.e., C^*<31. Hence, low chromatic colours were normally assessed to be 'plain', regardless of the hue and lightness. .

The 'plain' colour emotions of designers and general subjects were very similar in this study. The colours assessed to be 100% 'plain' by the designers were also considered to be 'plain' by the general subjects.

8.3.1.4 Striking-subdued colour emotion

The colours of high chroma were normally assessed as 'striking', whereas the colours of low chroma were assessed as 'subdued' by all subjects.

'Striking' Colours

In the analysis of subjects representing the general public, the 'striking-subdued' colour emotion percentages (SS) of twenty-two colour samples were calculated to be larger than 50%, which demonstrates that they were assessed to be 'striking'. Nineteen had chroma values larger than 40, which were considered to be high chromatic colours; the chroma values of the other three colours were larger than 28, i.e., of medium chroma, and they were of low lightness, $L^*<38$. Therefore, lightness had a slight influence on the 'striking-subdued' colour emotion of the general subjects.

In this study, twenty-eight colour samples were assessed as very 'striking' by all designers, i.e., SS=100% was obtained. Twenty-one had high chroma values, i.e., $C^*>40$, while eleven had medium chroma values, i.e., $C^*>28$. These medium chroma colours were of different lightness and hue. Therefore, lightness had less influence on the 'striking-subdued' colour emotion of the designers.

Only one colour sample was assessed as 'striking' by all designers but it was considered to be slightly 'subdued' by the subjects representing the general public in this study. This colour sample was a grass green colour of hue-angle 114.13^0, and of medium lightness and chroma, $L^*=45.87$ and $C^*=36.75$. From the findings, it may be seen that the 'striking' colour emotion of designers and general subjects was very alike.

'Subdued' Colours

Results obtained from the subjects representing the general public show that thirty-nine colour samples had 'striking-subdued' percentages calculated as smaller than −50%, hence they were considered to be 'subdued'. Thirty-five of the colours had low chroma values, $C^*<20$, and for the remainders, $C^*<33$, i.e., medium chroma. These medium chromatic colours were all of high lightness. In other words, the lightness of the colour was also found to have an influence on the 'striking-subdued' colour emotion of the general subjects since colours of higher lightness evoked more 'subdued' impression in them.

When the colour emotions of designers were evaluated for the 'subdued' colours, thirty-nine colour samples were assessed as 'subdued' by all designers, i.e., SS=-100% colour emotion was obtained for these colours. Thirty-seven of the colours were of low chroma, $C^*<20$, and the remaining two colours were of medium chroma, i.e., $C^*<31$, but the degree of lightness was different. Hence, no significant correlation with lightness was found in the 'striking-subdued' colour emotion of designers.

When the differences of the perception of general public and designers towards 'subdued' colours were compared, it was found that only one deep sky blue colour was assessed to be 100% 'subdued' by the designers yet it was considered to be a slightly 'striking' colour by the general subjects. All the other 'subdued' colours were found to give very similar perception to the general subjects and the designers.

8.3.1.5 Dynamic-passive colour emotion

Those colours of high chroma were generally assessed to be 'dynamic', whereas those of low chroma were assessed to be 'passive' by all subjects. In addition, a slight influence was caused by hue as no 'dynamic' impression was given to the subjects during the perception of the greenish and bluish colours.

'Dynamic' Colours

For the subjects representing the general public, the 'dynamic-passive' colour emotion percentages (*DyPa*) of fourteen colour samples were calculated to be larger than 50%, indicating that they were assessed as 'dynamic' by them. All of these 'dynamic' colours had chroma values larger than 40, which were considered to be high chromatic colours. Almost all of them are red and yellow colours, with hue-angles smaller than 118^0 or larger than 319^0, except one which was a brilliant blue colour with hue-angle equaled to 276.46^0. Hence, not only did chroma of colour have influence on the 'dynamic' impression, but also hue.

In this study, nineteen colour samples were assessed as very 'dynamic' by all designers, i.e., $DyPa$=100% was obtained. Sixteen had high chroma values, i.e., $C^*>40$, while three had medium chroma values with $C^*>30.0$. These 'dynamic' colours were all red and yellow colours with hue-angles smaller than 118^0 and larger than 316^0. As a result, although chroma of colour was the dominant parameter of the 'dynamic' colour emotion, hue had a slightly effect on it in the case of the designers.

Two colour samples were assessed as 'dynamic' by all designers in this study but they were considered to be either 'neutral', i.e., neither 'dynamic' nor 'passive', or 'passive' by the subjects representing the general public. The two colour samples were: 1) 5RP7---a reddish purple colour of low lightness, L^*=39.83, medium chroma, C^*=30.10, and hue-angle of 353.84^0; and 2) 5GY10---a grass green colour of medium lightness and chroma, L^*=45.87 and C^*=36.75, and hue-angle of 114.13^0.

'Passive' Colours

Results obtained from the subjects representing general public, indicating fifty colour samples had 'dynamic-passive' percentages calculated smaller than –50% and these colours were considered to be 'passive'. These colours were distributed in all hue-angles, but most had low chroma values. Forty-seven had low chroma values, i.e., $C^*<20$, while the remaining three colours had medium chroma values, $C^*<28$, but high lightness.

Forty-eight colour samples were assessed to be 'passive' by all designers, i.e., $DyPa$=-100%, and most of them had low chroma values but they were of different hues. Forty-four colours were of low chroma, $C^*<20$, whereas four colours were of medium chroma, i.e., $C^*<36$, and these four colours were of low to medium lightness. The finding was slightly different from that for the general subjects because colours of lower lightness were assessed as more 'passive' by the designers.

The 'passive' colour emotions of designers and general subjects were very close to each other in this study. Colours assessed to be 100% 'passive' by the designers were also considered to be 'passive' by the general subjects.

8.3.2 Lightness Dependent Colour Emotions

The 'deep-pale', 'heavy-light', 'soft-hard' and 'strong-weak' colour emotions of subjects representing the general public and designers in this study were found to be mainly influenced by the lightness of colour.

8.3.2.1 Deep-pale colour emotion

Colours of low lightness induced 'deep' emotion in the subjects' minds; whereas colours of high lightness resulted in a 'pale' impression being given to the subjects.

'Deep' Colours

Forty colour samples having 'deep-pale' percentages for the subjects representing the general public were calculated as larger than 50% and these colours were considered as 'deep'. The lightness of these 'deep' colours ranged from 17 to 47.21, which were low to medium lightness values.

Although a good correlation was found between lightness and 'deep-pale' colour emotion of designers, the trend was not as obvious as that obtained from the general public. Forty-two samples were assessed as 'deep' by all designers and the lightness ranged from 17 to 60.03. The one with high lightness value, L^*=60.03, but which was still assessed to be 'deep' by the designers, had a very low chroma value, C^*=3.04. This was the only sample assessed to be 'deep' by all designers, i.e., DP=100%, but it was considered to be a 'pale' colour by the general public. This was a greyish purple colour. In the case of the other 'deep' colours, the general subjects and the designers had similar perceptions.

'Pale' Colours

A colour sample 5Y1 was assessed to be 'pale' by all subjects, including those representing the general public and designers, with DP=-100% in both cases. This was a very light yellow colour of high lightness, L^*=80.66, low chroma, C^*=13.16, and hue-angle of 84.66^0.

Colours assessed as 'pale' by the general subjects, with DP smaller than –50%, had high lightness values range from 58.31 to 91.30. The findings in the case of the designers were similar to those for the general public: thirty-six colour samples were assessed to be 'pale' by all designers and these colours had high lightness values of 64.95 to 91.30; all these 100% 'pale' colours were also assessed as 'pale' to different extents by the general public. Hence, the 'deep-pale' colour emotion result for both designers and the general public was found to be very similar, and the 'pale' impression towards colours was highly dependent on the lightness value.

8.3.2.2 Heavy-light colour emotion

A 'heavy' impression was given to the subjects when they viewed colours of low lightness; whereas 'pale' impression was induced when perceiving colours of high lightness.

'Heavy' Colours

The 'heavy-light' percentages of thirty-four colour samples were found to be larger than 50%, indicating that these colours were assessed as 'heavy' by the general public. Twenty-nine had low lightness values, i.e., $L^*<40$, and the remaining five had slightly higher lightness values, all of them at $L^*<43$. However, the correlation of 'heavy' perception with lightness of the designers was not as significant as that of the general subjects. Fifty-one colour samples were assessed by all designers as 'heavy', i.e., HL=100%. Thirty of them had low lightness values, i.e., $L^*<40$, while the other twenty-one were of medium lightness, i.e., L^* between 40 and 70.

Of all the colour samples, four colours were considered as 'heavy' colours by all designers but they were assessed as 'light' colours by the general subjects. The four colour samples were 5GY3, 5P3, 5P5 and N6. Three of them were almost neutral grey colours of medium lightness, i.e., L^*=59-61, very low chroma, i.e., $C^*<9$, and different hue-angles. However, 5P5 was not a grey colour but a pale purple colour of medium lightness, L^*=61.55, rather high chroma, C^*=41.00, and hue-angle of 319.21^0, and the deviation of 'heavy-light' colour emotion between designers and general subjects was found to be the largest in the case of this colour. While all the designers assessed this pale purple colour as 'heavy', the 'heavy-light' colour emotion percentage of the general subjects was calculated to be –54.29% for this colour, representing a rather 'light' impression.

'Light' Colours

Three colour samples were assessed to be 'light' by all subjects, including those representing the general public and designers, with HL=-100% in both cases. All of them were neutral grey colours of high lightness, $L^*>80$, and very low chroma, $C^*<6$. Hence, it may be briefly concluded that those neutral colours of high lightness gave a 'light' impression to all subjects, but the high lightness colours in different hues did not necessarily give a 'light' impression to all subjects, because each subject had his/her own preference towards hue of colour in this selection of colour emotion.

Thirty-nine colours were assessed as 'light', with *HL* smaller than -50%, by the general subjects. Thirty-two had high lightness values, i.e., $L^*>70$, and the other seven colours had rather high lightness values, $L^*>58$. They had different chroma values and different hue-angles. The findings for the designers were similar to those for the general public since thirty colour samples were assessed to be 'light' by all designers and twenty-five of them had high lightness values, i.e., $L^*>70$, while the others were of rather high lightness, $L^*>64$.

The induced 'light' impression given by the colour samples to both the designers and general subjects were very similar. Those assessed as 'light' by all designers were also considered as 'light', but to different degree, by the general subjects.

8.3.2.3 Soft-hard colour emotion

Those colours of high lightness were normally assessed as 'soft' while those colours of low lightness were assessed as 'hard' by all subjects.

'Soft' Colours

In the analyswas of subjects representing the general public, the 'soft-hard' colour emotion percentages (*SH*) of thirty-eight colour samples were calculated to be larger than 50%, representing that they were assessed to be 'soft' by them. Thirty-one had lightness values larger than 70, which were considered to be high lightness colours; and the lightness values of the other seven colours were larger than 58, i.e., of quite high lightness. Although these 'soft' colours were of rather high lightness, they had different hue and chroma. In other words, the influence of hue and chroma was found to be insignificant for the 'soft-hard' colour emotion.

In this study, thirty colour samples were assessed as being very 'soft' by all designers, i.e., SH=100% was obtained. Twenty-three had high lightness values, i.e., L^*>70, and the remaining colour samples also had quite high lightness values that all were larger than 60. Almost all of these very 'soft' colour samples (twenty-eight of them) considered by the designers were also assessed as 'soft' colours with SH>50% by the general subjects, and the remaining two colours were assessed as quite 'soft', with SH=25.72% and 48.57%, by them. Hence, it may be concluded that the 'soft' impression of colours of the general subjects and the designers were similar.

'Hard' Colours

Results obtained from the subjects representing the general public showed that thirty colour samples had 'soft-hard' percentages calculated to be smaller than –50%, hence they were classified as 'hard'. Twenty-five of them had low lightness values, L^*<40, and the remainders had medium lightness values with L^*<50.

When the colour emotions of designers towards the 'hard' colours were evaluated, thirty-two colour samples were assessed as 'hard' by all designers, i.e., SH=-100% colour emotion was obtained for these colours. Eighteen of the colours were of low lightness, L^*<40, and the remaining two colours were of medium lightness, i.e., L^* between 40 and 67. The correlation of lightness of colour and 'soft-hard' colour emotion in the case of the designers was not as significant as that of the general subjects.

When the perceptions of general public and designers regarding 'hard' colours were compared, only one purple colour was assessed as 100% 'hard' by the designers, whereas it was considered to be slightly 'soft' by the general subjects. This colour was of medium lightness and high chroma. All the other 'hard' colours were found to give similar perceptions to the general subjects and the designers.

8.3.2.4 Strong-weak colour emotion

Colours of low lightness were assessed as 'strong', whereas those of high lightness were generally assessed as 'weak' by all subjects. However, in the case of the rather high lightness colours of high chroma, a 'strong' impression was given to all subjects instead. Therefore, chroma was found to have a slight influence on the 'strong-weak' colour emotion, especially in the case of colours of high chroma.

'Strong' Colours

For the subjects representing the general public, the 'strong-weak' colour emotion percentages (*SW*) of thirty-three colour samples were calculated to be larger than 50%, indicating that they were assessed to be 'strong' by them. Twenty-eight of these 'strong' colours had lightness values smaller than 40, which were considered to be low lightness, and the lightness of the other five colours ranged from 41 to 67, which were medium lightness. All the 'strong' colours of medium lightness had high chroma values, i.e., C^*>40.

In this study, thirty-one colour samples were assessed to be very 'strong' by all designers, i.e., SW=100% was obtained. Sixteen of them had low lightness values, i.e., L^*<40, and fourteen had medium lightness values with L^* ranging from 40 to 70 whereas one exceptional colour had a high lightness value, L^* being equal to 72.37. Almost all of the medium lightness 'strong' colours were of medium to high chroma, i.e., C^*>20. The high lightness colour assessed as 'strong' was a green colour with a very high chroma value, C^*=77.75. Hence, while lightness of colour was the dominant parameter, chroma was found to have limited influence on the 'strong' impression of the subjects.

Only one colour sample was found to give an adverse impression to the general subjects when the colours giving 'strong' impression were compared to the designers. This was a pale purple colour of medium lightness, L^*=61.55, and high chroma, C^*=41.00. It was found that a slight 'weak' impression, SW=-8.57%, was given to the general subjects during the visual assessment.

'Weak' Colours

Results obtained from the subjects representing the general public showed that thirty-one colour samples had 'strong-weak' percentages calculated to be smaller than –50% and these colours were considered to be 'weak'. Twenty-eight had high lightness values, i.e., $L^*>70$, while the remaining three colours had medium lightness values with L^* ranging from 58 to 70. These medium lightness 'weak' colours had low chroma values, $C^*<17$.

Twenty-seven colour samples were assessed as 'weak' by all designers, i.e., $SW=-100\%$, and most of them had high lightness values but in different hues. Twenty-three colours were of high lightness, i.e., $L^*>70$, whereas four colours were of medium lightness, $L^*>61$. These medium lightness 'weak' colours had low chroma values with $C^*<22$. Hence, both the general subjects and the designers gained a 'weak' impression for those colours of high lightness or those of medium lightness but rather low chroma.

The 'weak' colour emotions of the designers and general subjects were very close to each other in this study. Colours assessed as 100% 'weak' by the designers were also considered to be 'weak' by the general subjects.

8.3.3 Lightness and Chroma Dependent Colour Emotions

In this study, the 'light-dark', 'distinct-vague' and 'transparent-turbid' colour emotions of subjects representing the general public and designers were found to be influenced by both lightness and chroma of colour.

8.3.3.1 Light-dark colour emotion

Colours of high lightness or high chroma were assessed as 'light' perception by the subjects, whereas a 'dark' impression was obtained for colours of low lightness or low chroma.

'Light' Colours

Results obtained from the subjects representing the general public showed that thirty-two colour samples had 'light-dark' percentages (*LD*) which were calculated to be larger than 50%, and these colours were considered to be 'light'. All these colours had lightness values larger than 30 but they were with a large variety of chroma values. The colours with lightness values between 30 and 40 had high chroma values, which were larger than 45. Those with low chroma values, i.e., less than 10, had very large lightness values, which were larger than 80. Hence, colours of either high lightness or high chroma gave 'light' impressions to the subjects in this study.

During the investigation of the 'light-dark' colour emotion of designers, it was found that thirty-nine colour samples were assessed to be 'light' by all designers. Of these colours, thirty-eight had lightness values larger than 30 whereas the remaining one had a lower lightness value, L^*=28.89, but a high chroma value, C^*=46.68. Some of these 'light' colours were of very low chroma, C^*<10, but high lightness, L^*>80, which were the same as the general public.

Most of the 'light' colours assessed by all designers were found to induce the same 'light' impression in the minds of the general subjects but to different extents. However, there were three colour samples assessed by all designers as 'light', but 'dark' or 'neutral' impressions were given to the general public. These three colour samples were: 1) 5YR4—a pale brown colour of high lightness, L^*=64.95, and medium chroma, C^*=27.79; 2) 5YR10—a brownish red colour of medium lightness, L^*=39.92, and medium chroma, C^*=38.43; and 3) 5RP11—a deep purplish red colour of medium lightness, L^*=30.51 and high chroma, C^*=43.51.

'Dark' Colours

Colours of low lightness or low chroma were assessed as 'dark' colours by the subjects representing general public and designers. Thirty-six colour samples were assessed as 'dark', with *LD* smaller than –50%, by the general subjects. The lightness of these colours ranged from 17 to 63, and for those with medium lightness values, i.e., $L^*>40$, they were generally with low chroma values, i.e., $C^*<20$. These findings were similar to those obtained from the designers: twenty-three colour samples were assessed as 'dark' colours by them, and those of high lightness were with very low chroma values.

When the differences between the designers and general public regarding 'dark' perception were evaluated, it was found that all 'dark' colours assessed by designers were also considered to be 'dark' by the general public but to different extents. Therefore, it may be concluded that the designers and general public had very similar perceptions towards 'dark' colours.

8.3.3.2 Distinct-vague colour emotion

'Distinct' impression was induced in the subjects' minds during the perception of colours of high lightness or high chroma; while 'vague' impression was induced when those colours of low lightness or low chroma were perceiving.

'Distinct' Colours

The 'distinct-vague' percentages of twenty-nine colour samples were found to be larger than 50%, indicating that these colours were assessed as 'distinct' by the general public. Fourteen had high chroma values, i.e., $C^*>40$, and their lightness values deviated from 37 to 83. The other fifteen 'distinct' colours had low to medium chroma values, i.e., $C^*<40$, and they had rather high lightness values that all of them were larger than 65. Hence, colours of either high lightness or high chroma generally gave 'distinct' impression to the subjects.

The 'distinct-vague' colour emotion of designers was studied, the correlation of it with lightness was found to be less significant than with chroma. It was found that twenty-eight colour samples were assessed to be 'distinct' by all designers. Twenty-one had high chroma values, i.e., $C^*>40$, and the other seven 'distinct' colours had medium chroma values, of $C^*>28$. They were all with different lightness values and hue-angles, and hence the influence of lightness on 'distinct-vague' colour emotion of the designers was not as obvious as that of the general subjects.

Of all the colour samples, three colours were considered to be 'distinct' colours by all designers, but they were assessed as 'vague' colours by the general subjects. These colour samples were: 1) 5GY10—a grassy green colour of medium lightness and chroma, L^*=45.87 and C^*=36.75, and hue-angle of 114.13^0; 2) 5YR11—a deep orange colour of medium lightness, L^*=51.31, high chroma, C^*=55.86, and hue-angle of 62.21^0; and 3) 5P7—a purple colour of quite medium lightness, L^*=39.75, medium chroma, C^*=30.08, and hue-angle of 314.88^0. All of the colours were assessed as quite 'vague', with DV ranging from -8% to -20%, by the general subjects.

'Vague' Colours

The 'vague' colour emotion of the subjects representing the general public was found to be more chroma dependent than the 'distinct' colour emotion. Twenty colours were assessed as 'vague', with DV smaller than -50%, by the general subjects. All of them were of low chroma, i.e., C^*<20, but had a wide range of lightness, that L^* ranging from 21 to 63.

As was the case for the 'distinct' colours, the correlation of 'vague' colour emotion of the designers with lightness was found to be less significant than with chroma. Sixteen colour samples were assessed as 'vague' by all designers with DV=–100%. Fifteen had low chroma values, i.e., C^*<20, and they had a variety of lightness values. The remaining one sample was a brownish yellow colour of rather high chroma, C^*=40.43, and medium lightness, L^*=60.26.

Since the 'vague' impression of both the general subjects and designers was found to have a higher correlation with chroma than with lightness, the evoked 'vague' impression in them was very similar. Those colours assessed as 'vague' by all designers were also considered to be 'vague', but to different degree, by the general subjects.

8.3.3.3 Transparent-turbid colour emotion

Colours of high lightness or high chroma were assessed as 'transparent' by the subjects, whereas a 'turbid' impression was obtained for colours of low lightness or low chroma.

'Transparent' Colours

The 'transparent-turbid' percentages of twenty-one colour samples were found to be larger than 50%, indicating that these colours were assessed as 'transparent' by the general public. Seventeen had high lightness values, i.e., $L^*>70$, and the remaining four had medium lightness values, $L^*>50$. The high lightness 'transparent' colours had a wide range of chroma values, whereas most of the medium lightness ones had high chroma values. As a result, the correlation of 'transparent' colours with lightness was found to be more significant than that with chroma for the perception of the general subjects.

When the 'transparent-turbid' colour emotion of the designers was evaluated, twenty-three colour samples were assessed as 'transparent' by all designers. Twelve had low to medium lightness values, i.e., $L^*<70$, and almost all of these colours had high chroma values. Eleven of these 'transparent' colours had high lightness values, i.e., $L^*>70$, but they had a wide range of chroma values, from 3 to 87. Hence, colours of either high lightness or high chroma gave a 'transparent' perception to the designers.

Of all the colour samples, four colours were considered to be 'transparent' by all designers, but they gave either 'neutral' or 'turbid' colours to the general subjects. These colour samples were: 1) 5G11—a green colour of medium lightness, $L^*=43.22$, high chroma, $C^*=48.85$, and hue-angle of 161.56^0; 2)

5Y8—a golden yellow colour of medium lightness, L^*=66.83, high chroma, C^*=70.45, and hue-angle of 85.76^0; 3) 5YR11—a deep orange colour of medium lightness, L^*=51.31, high chroma, C^*=55.86, and hue-angle of 62.21^0; and 4) 5P11—a deep purple colour of low lightness, L^*=28.89, high chroma, C^*=46.68, and hue-angle of 316.24^0. All of these colours had high chroma values. The largest deviation between the designers and general subjects in 'transparent' impression of colour was found in the colour sample 5YR11, because the general subjects assessed it as a rather 'turbid' colour with TT=-37.14%.

'Turbid' Colours

Forty-two colour samples were assessed as 'turbid', with TT smaller than −50%, by the general subjects. All these 'turbid' colours had low to medium lightness values, L^*<63. However, they had a wide range of chroma values, from 1 to 47. Therefore, in the case of the general subjects, the correlation of the induced 'turbid' impression with lightness of colour was found to be more significant than that with chroma.

Eighteen colour samples were assessed as 'turbid' by all designers for the 'transparent-turbid' colour emotion. The lightness values of them ranged from 33 to 74. Two had low lightness and medium chroma values; thirteen were of medium lightness and had a deviation in chroma values; whereas three had high lightness and low chroma values. Colours either of low lightness or low chroma generally induced 'turbid' colour emotion in the minds of the designers.

The 'turbid' impression of the designers and general subjects towards the colour samples were found to be very close to each other. The colours assessed as 'turbid' by all designers were also considered to be 'trubid', but to different degree, by the general subjects.

8.4 Conclusions

Since the designers usually have received formal training or education about the meanings of colours, they expressed consistent colour emotion for certain colours in this analysis. For example, in the 'warm-cool' colour emotion pair, all designers in this study assessed some bluish and purplish colours as 'cool'; but in the analysis of the general subjects, some assessed these colours as 'cool' while some assessed them as 'warm'.

When comparing the colour emotions of general subjects and the designers, larger deviations were obtained for those purplish and reddish colours whereas closer colour emotions were found for those yellowish colours. The best correlated colour emotion pair between general subjects and designers was the 'deep-pale' pair, while less correlation was found in the 'warm-cool', 'light-dark', 'distinct-vague' and 'transparent-turbid' colour emotions. On the other hand, the general trends of the correlation of colour emotions with the standard colour specification of the designers were observed to be similar as those of the subjects representing the general public, hence, the dominant parameter(s) of their colour emotions were found to be similar.

CONCLUSIONS AND RECOMMENDATIONS

9.1 Conclusions

9.1.1 Quantitative Representation of Colour Emotion

The influence of each colorimetric attribute on each colour emotion pair was analysed in this study. The contribution of hue of colour to colour emotion was found to be less important than the other attributes. Nevertheless, a larger influence of hue was found to be in the 'warm-cool' colour emotion pair. According to the visual assessment results of Hong Kong subjects, lightness and chroma were found to be the dominant influential attributes in these twelve colour emotion pairs. It is conclusive that human colour emotions were mainly affected by either lightness or chroma, or both of them for those colour emotion pairs in this study.

Mathematical models have been derived to correlate the colour emotion pairs with the three colorimetric attributes, which are defined by CIE colorimetry. The quantitative correlations between colours and colour emotions were clearly illustrated in the models. These models are simpler and more easily-understanding than the models derived by the Japanese research group. By these models, the communication between the designers or other users of colour and the colourists can be facilitated and improved.

Moreover, the colour emotion pairs were categorized into different groups according to the most influential attribute(s) of colour. These groups are: 'Chroma Dependent Colour Emotions' which include 'warm-cool', 'vivid-sombre', 'gaudy-plain', 'striking-subdued' and 'dynamic-passive' colour emotion pairs; 'Lightness Dependent Colour Emotions' which include 'deep-pale', 'heavy-light', 'soft-hard' and 'strong-weak' colour emotion pairs; and 'Lightness and Chroma Dependent Colour Emotions' which include 'light-dark', 'distinct-vague' and 'transparent-turbid' colour emotion pairs.

9.1.2 Influence of Gender Effect on Colour Emotions

During the comparison of colour emotion between genders, generally good correlation in colour emotions between male and female subjects was found in this study. The best correlation was found in the 'deep-pale' colour emotion that very similar sensations were obtained by male and female subjects. New and interesting results were obtained in the 'warm-cool' and 'dynamic-passive' colour emotion pairs. Although they were both categorized as chroma dependent, which means chroma was found to be the dominant parameter influencing these emotion pairs, the hue influence on them was found to be more significant for the male subjects that red and yellow colours with high chroma were normally regarded as 'warm' and 'dynamic' whereas green and blue colours were considered as 'cool' and 'passive' colours by them. However, this sort of hue influence was not so obvious for the female subjects because some green and blue colours were assessed to be rather 'warm' and 'dynamic' by them.

9.1.3 Influence of Cultural and Geographical Factor on Colour Emotions

When analyzing the influence of cultural and geographical factor on the colour emotion, the best correlation of colour emotion pair between the subjects of two different regions was found in the 'heavy-light' pair between the Japanese and Hong Kong's subjects. The worst correlated colour emotion pair was found in the 'distinct-vague' pair between the Japanese and Hong Kong's subjects.

The best correlated colour emotion pairs in general, i.e., having good and average correlation between all the regions under this investigation, were found to be the 'heavy-light' and 'transparent-turbid' pairs. The correlation coefficients of 'heavy-light' colour emotion between all the Asians were all above 0.9, whereas no statistically significant difference between subjects of the three Asian regions was found in the 'transparent-turbid' pair and it showed good correlation in the colour emotion planners. Therefore, it may conclude that Japanese, Thai and Hong Kong Chinese have similar 'heavy-light' and 'transparent-turbid' impressions during colour perception. However, since no visual assessment data of 'heavy-light' and 'transparent-turbid' colour emotion pairs have been received from the United Kingdom, another pair was selected for possessing very good correlation between subjects from all regions, including the United Kingdom. This very good correlated pair was found to be the 'deep-pale' colour emotion pair that the correlation coefficients between all the regions were all larger than 0.8. The worst correlated colour emotion pair was found to be the 'distinct-vague' colour emotion pair because very poor correlation was obtained between the subjects of each of the other regions comparing with the Hong Kong's subjects. The reason of this might be due to a wrong translation of this colour emotion pair from English to Cantonese or due to a different interpretation of the meanings of this word pair by the Hong Kong subjects. Moreover, 'light-dark' colour emotion pair was found to be another pair which has a quite bad correlation between three asian regions and the United Kingdom. The correlations of this pair between all the three asian regions were found to be good with the correlation coefficients between any two regions were larger than 0.9; however, when comparing with the United Kingdom's results, the correlation coefficients were found to be much lower, which were between 0.5 to 0.7. The reason is that all Asians in this study considered that 'light-dark' colour emotion was influenced by both the lightness and chroma of colour, while the United Kingdom's subjects thought that lightness was the dominant parameter in this colour emotion pair.

When studying the correlation of all colour emotion pairs between any two regions, the best correlated regions was found to be Japan and Hong Kong. These two regions exhibit very good correlation in every colour emotion pair, except the 'distinct-vague' colour emotion pair. In addition, it was found that the correlation of colour emotion between the United Kingdom and Hong Kong was worse than those between any one of the other two asian regions and Hong Kong.

9.1.4 Influence of Assessment Methods

Good correlations were found in most of the colour emotion pairs between the 2-point and 7-point methods. Similar influences of the colorimetric attributes to the colour emotions were observed in the 7-point method as the 2-point method. As there were more divisions of each colour emotion pair, that means more selections of colour emotion point, for each colour sample in the 7-point method, it was found in all colour emotion pairs that the ranges of colour emotion assessment were narrower than those of the 2-point method. For example, those colours assessed to be very 'deep' in the 'deep-pale' colour emotion assessment in the 2-point method was evaluated to have a lower level of 'deep' in the 7-point method, whereas those 'pale' impression colours in the 2-point method were assessed to evoke a lower level of 'pale' using the 7-point method.

The correlation coefficient of the 'distinct-vague' colour emotion pair was found to be comparatively small between the 2-point and the 7-point methods. The influence of colorimetric attributes to this colour emotion pair was observed to be quite different. In the 2-point method, the dominant attributes affecting the 'distinct-vague' colour emotion were found to be both the lightness and chroma. However, in the 7-point method an obvious influence of chroma on this colour emotion was found — an almost directly proportional relationship was indicated between the 'distinct-vague' colour emotion and chroma, but no significant correlation was observed with lightness of colour. In addition, the lowest correlation coefficient between the two assessment methods was found in the case of 'transparent-turbid' pair. The findings were the same as the 'distinct-vague' colour emotion pair that although both lightness and chroma influences were found in the 'transparent-turbid' pair in the 2-point method, no correlation was found with lightness in the 7-point method whereas a more significant correlation was observed with chroma.

9.1.5 Application of Quantifying Colour Emotions

In this study, the colour planners for the twelve colour emotion pairs were developed to represent the correlation of the colour emotion and the colour specifications. The extent of change in each colour emotion pair caused by changing the lightness or chroma of a colour is clearly presented in the colour planners. Fashion, graphic, interior, web site or other designers can select suitable colours for inducing target colour emotions in the minds of customers or product-users by means of the colour planners. Moreover, the designers can enhance the functionality and increase the attractiveness of their designed products by selecting suitable colours. As colour emotions are directly correlated to standard colour specifications in the colour planner, this can avoid any possible misunderstanding between the designers or colour users and the colourists during their communication by using the numerical terms.

In order to assist the designers or colour users in selecting colours, a visualization of colours in the colour planner was achieved by establishing a colour emotion display system which is a computer program and provides a means for the designers or colour users to select colours from the monitor. The designers or colour users can select the target colours from the displayed colour gamut, and the system will automatically show the standard colour specifications and colour emotions of the selected colours. This is the most convenient way for showing the correlation of colour emotions and standard colour specifications.

9.1.6 Comparison of Colour Emotions of Designers and General Subjects

Since the designers usually have received formal training or education about the meanings of colours, they expressed consistent colour emotion for certain colours in this analysis. For example, in the 'warm-cool' colour emotion pair, all designers in this study assessed some bluish and purplish colours as 'cool'; but in the analysis of the general subjects, the assessment results were more varied that some assessed these colours as 'cool' while some assessed them as 'warm'.

When comparing the colour emotions of general subjects and the designers, larger deviations were obtained for those purplish and reddish colours whereas closer colour emotions were found for those yellowish colours. The best correlated colour emotion pair between general subjects and designers was the 'deep-pale' pair, while less correlation was found in the 'warm-cool', 'light-dark', 'distinct-vague' and 'transparent-turbid' colour emotions. On the other hand, the general trends showing the correlation of colour emotions with the standard colour specification of the designers were observed to be similar as those of the general subjects. Hence, the dominant influential colorimetric attribute(s) of their colour emotions were found to be similar.

9.2 Recommendations for Further Study

Since the colour samples used in the visual assessment in this study were very small, 1.0 cm x 1.5 cm, it is recommended to manufacture some larger samples for the analysis. It is a fact that increasing the size of the samples will alter the impression of the subjects towards the same colour. Therefore, it is valuable to compare the influence of size effect on the colour emotion, and larger colour samples can have better representations of the products because the major products in the market are not in so small size as the colour samples in this study.

The twelve colour emotion pairs in this study involved the fundamental and the lowest level of emotions of human beings, i.e., somewhat between perception and emotion. It is considered worthwhile to investigate some other colour emotion word pairs which involve higher level of emotion and deeper mechanism of human thoughts. For example, some word pairs involving the own preference of the subjects, such as 'like-dislike'; some word pairs involving the aesthetic feelings, such as 'beautiful-ugly' and 'elegant-inelegant'; and some word pairs involving the arouse status after perception, such as 'happy-sad' and 'excited-calm'.

It is important to invite more colour researchers from different regions or countries to carry out this quantitative evaluation of colour emotion because only four regions in this study are not enough for the comparison of the cultural effect on colour emotion. Globalization of this study will facilitate the evolution of quantifying colour emotions.

Since the 7-point assessment method provides more selections in divisions of each colour emotion pair, it is recommended to carry out further analysis of colour emotions using 7-point method, so that better indication and understanding of colour emotions of subjects can be obtained.

Last but not least, due to the limitation of time and availability of the designers, only 5 designers have been successfully invited to carry out the visual assessments in this study. It is suggested to obtain more colour emotion results from the designers in the future work, so that an in-depth analysis of colour emotion of the designers and comparison of their colour emotions with the ordinary subjects can be investigated.

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Appendix A

Subjects' Reliability and Target Number of Subjects (Sample Size)

The maximum error of estimate, E, of each pair of colour emotion words was calculated using the standard deviations obtained from the subjects' reliability. The method of root-mean-square error was used to analyse the reliability of the subjects. The deviation of an individual data of each subject from the mean value of each colour was studied. If the deviation of a specific subject is very large, this represents he/she always chose a different emotion word from the others, and he/she is not reliable enough in this visual assessment. The required number of subjects, n, was determined according to the reliability of the subjects.

$$n = \left(\frac{2.845 \times \sigma}{E}\right)^2$$

where 2.845 is the t-value of an 1-tail t-distribution with 99.5% confident interval and degree of freedom=20 (in the preliminary analysis), σ is the standard deviation between the individual data of a subject and the mean of all data of a colour and E is the maximum error of estimate of each pair of colour emotion words.

Table A-1 shows the standard deviation between the individual data of a subject and the means of all data of a colour. The upper limit for subject error was calculated by 1-tail t-distribution with 99.5% confident interval. From the t-distribution table, the t value was found to be 2.845 as the degree of freedom is 20.

Table A-1 The Standard Deviations between the Individual Data of a Subject and the Means of all Data of a Colour

	Colour Emotion Word Pairs											
	W-C	L-D	D-P	H-L	V-S	G-P	S-S	Dy-Pa	D-V	T-T	S-H	S-W
Mean of all Data of a Colour	0.8507	0.7485	0.6755	0.7358	0.7303	0.7179	0.7293	0.7457	0.8342	0.7890	0.7522	0.7647
Standard Deviation	0.1409	0.0941	0.1396	0.1290	0.1170	0.1001	0.0942	0.1449	0.1043	0.1223	0.1505	0.1611
Upper Limit for Subject Error	0.9382	0.8069	0.7621	0.8159	0.8029	0.7800	0.7878	0.8356	0.8990	0.8650	0.8456	0.8647

The required number of subjects to give a meaningful and representative investigation in this study was forecasted using the average of the maximum error of estimate of each word pair. These are all shown in Table A-2.

Table A-2 Target Number of Subjects

	Colour Emotion Word Pairs											
	W-C	L-D	D-P	H-L	V-S	G-P	S-S	Dy-Pa	D-V	T-T	S-H	S-W
Maximum Error of Estimate, E	0.0875	0.0584	0.0867	0.0801	0.0726	0.0621	0.0585	0.0900	0.0648	0.0759	0.0934	0.1000
Average of E	0.0775											
Target No. of Subjects	27	12	27	23	19	14	12	29	15	21	31	35

From the above table, the largest target number of subjects for archiving a meaningful analysis was found to be 35 in the strong-weak emotion pair. Therefore, if the results of more than 35 subjects were obtained in this study, the analysis would be sufficiently meaningful and representative for all emotion word pairs.

Appendix B

Notations of Colour Samples

5B1	5BG1	5G1	5GY1	5P1	5PB1	5R1	5RP1	5Y1	5YR1	N1
5B2	5BG2	5G2	5GY2	5P2	5PB2	5R2	5RP2	5Y2	5YR2	N2
5B3	5BG3	5G3	5GY3	5P3	5PB3	5R3	5RP3	5Y3	5YR3	N4
5B4	5BG4	5G4	5GY4	5P4	5PB4	5R4	5RP4	5Y4	5YR4	N6
5B6	5BG6	5G6	5GY5	5P5	5PB5	5R5	5RP5	5Y5	5YR5	N8
5B7	5BG7	5G7	5GY6	5P6	5PB6	5R6	5RP6	5Y6	5YR6	N9.5
5B9	5BG9	5G9	5GY7	5P7	5PB7	5R7	5RP7	5Y7	5YR7	
5B10	5BG10	5G10	5GY8	5P8	5PB8	5R8	5RP8	5Y8	5YR8	
10B1	5BG11	5G11	5GY9	5P9	5PB9	5R9	5RP9	5Y9	5YR9	
10B2	10BG1	10G1	5GY10	5P10	5PB10	5R10	5RP10	5Y10	5YR10	
10B3	10BG2	10G2	5GY11	5P11	5PB11	5R11	5RP11	10Y1	5YR11	
10B4	10BG3	10G3	5GY12	5P12	5PB12	5R12	5RP12	10Y2	5YR12	
10B5	10BG4	10G4	10GY1	10P1	10PB1	10R1	10RP1	10Y3	10YR1	
10B6	10BG6	10G6	10GY10	10P2	10PB2	10R2	10RP2	10Y4	10YR2	
10B7	10BG7	10G7	10GY11	10P3	10PB3	10R3	10RP3	10Y5	10YR3	
10B8	10BG9	10G9	10GY2	10P4	10PB4	10R4	10RP4	10Y6	10YR4	
10B9	10BG10	10G10	10GY3	10P5	10PB5	10R5	10RP5	10Y7	10YR5	
10B10		10G11	10GY4	10P6	10PB6	10R6	10RP6	10Y8	10YR6	
			10GY6	10P7	10PB7	10R7	10RP7	10Y9	10YR7	
			10GY7	10P8	10PB8	10R8	10RP8	10Y10	10YR8	
			10GY9	10P9	10PB9	10R9	10RP9		10YR9	
				10P10	10PB10	10R10	10RP10		10YR10	
				10P11	10PB11	10R11	10RP11			
				10P12	10PB12	10R12	10RP12			

Appendix C

Colorimetric Attributes of Colour Samples

(in the ascending order of hue-angles)

Colour Sample	L^*	a	b	C^*	$h°$	X	Y	Z
5RP8	58.373	54.997	0.365	54.998	0.38	41.444	26.633	31.183
10P2	81.237	7.193	0.109	7.194	0.871	60.788	58.973	69.533
5RP5	72.3	34.738	2.054	34.799	3.384	56.094	44.408	50.305
5RP4	61.42	15.659	1.035	15.693	3.783	33.437	29.831	34.405
10RP11	36.388	45.399	4.671	45.639	5.875	15.749	9.371	9.311
10RP10	32.601	26.327	3.294	26.532	7.131	10.258	7.422	7.757
10RP7	48.957	25.983	3.692	26.244	8.088	22.405	17.679	18.789
10RP12	43.238	63.22	9.481	63.927	8.529	25.315	13.533	11.898
5R9	21.875	10.912	2.631	11.225	13.555	4.135	3.496	3.643
10RP5	65.952	36.221	8.926	37.305	13.844	46.21	35.58	34.441
10RP4	67.734	16.312	4.066	16.811	13.996	42.078	37.796	40.91
10RP8	56.442	47.25	13.265	49.077	15.681	36.279	24.648	20.691
10RP3	67.758	5.469	1.626	5.706	16.559	38.628	37.748	43.04
10RP6	47.05	7.965	2.469	8.338	17.221	17.181	16.134	17.769
5RP2	85.062	8.766	3.564	9.463	22.128	68.766	66.241	73.497
5R11	33.117	43.897	17.882	47.399	22.164	13.013	7.684	4.412
5R12	41.066	61.266	26.859	66.895	23.672	22.646	12.109	5.433
5R10	33.313	27.905	12.316	30.502	23.814	10.864	7.788	5.702
5R8	55.873	49.881	23.814	55.274	25.52	36.288	24.136	14.939
5R5	69.081	34.024	17.041	38.053	26.604	50.282	39.854	32.32
N4	40.449	0.904	0.456	1.012	26.747	11.432	11.541	13.433
5R6	42.008	10.359	5.283	11.628	27.019	13.826	12.55	12.587
10RP2	84.841	10.081	5.299	11.388	27.728	68.943	65.905	70.858
5R4	68.938	14.765	7.797	16.697	27.838	43.282	39.484	39.445
5R3	70.486	3.274	1.834	3.753	29.264	41.717	41.473	47.227
5R7	47.208	25.815	14.587	29.651	29.469	20.74	16.367	12.477

5RP3	57.716	4.298	2.535	4.99	30.535	26.192	25.699	28.591
10R9	25.917	7.395	4.788	8.809	32.922	5.208	4.737	4.548
10P1	79.622	2.529	1.709	3.052	34.053	55.929	56.04	64.147
5R2	79.549	13.408	9.44	16.398	35.148	60.219	56.139	55.432
10R7	52.45	22.076	16.627	27.637	36.986	24.879	20.716	15.388
10R10	30.762	24.523	20.952	32.254	40.51	9	6.631	3.137
5YR9	24.948	7.611	6.712	10.147	41.407	4.884	4.429	3.858
10R6	47.553	10.345	9.227	13.862	41.731	17.998	16.549	14.962
10R4	65.939	21.29	19.552	28.906	42.563	41.023	35.534	26.692
10R11	40.55	40.997	37.823	55.779	42.694	17.941	11.76	3.14
10RP1	83.094	4.026	3.891	5.599	44.024	62.803	62.397	68.714
5RP1	80.898	4.133	4.039	5.778	44.343	58.792	58.342	63.95
10R12	50.288	56.421	55.245	78.965	44.397	31.138	18.988	3.038
10R8	59.425	45.471	44.53	63.644	44.401	39.572	27.947	9.293
10R5	70.466	28.863	30.514	42.002	46.593	50.483	41.795	24.661
5R1	79.06	3.503	3.89	5.235	47.99	55.323	55.113	60.529
10PB1	77.598	0.692	0.883	1.121	51.9	51.791	52.53	61.087
10R1	79.165	5.549	7.098	9.01	51.981	56.276	55.301	57.161
10R3	70.89	4.063	5.2	6.599	51.993	42.516	42.076	44.682
5YR6	41.643	6.869	9.151	11.442	53.105	13.039	12.336	10.862
10R2	84.674	9.837	13.152	16.424	53.205	68.388	65.581	61.053
5YR7	57.564	20.271	29.811	36.05	55.786	29.933	25.75	13.496
5YR3	69.739	5.396	8.151	9.775	56.495	41.281	40.455	40.279
5YR10	39.916	20.553	32.471	38.429	57.668	13.928	11.342	3.854
5YR5	75.866	24.328	39.257	46.184	58.213	57.845	50.123	24.982
5YR12	52.434	34.45	56.389	66.08	58.577	27.774	20.855	3.44
5YR8	59.95	36.088	59.444	69.541	58.738	37.323	28.417	5.367
5YR4	64.953	14.039	23.977	27.785	59.65	37.317	34.199	22.83
5YR11	51.311	26.043	49.416	55.858	62.21	24.571	19.811	4.353
5YR2	78.213	14.539	28.211	31.737	62.735	58.081	53.903	35.739
5YR1	73.623	3.886	9.186	9.974	67.072	46.52	46.212	45.366
10YR6	50.264	4.826	11.557	12.524	67.337	19.161	18.69	16.003
10YR9	25.781	3.549	8.673	9.371	67.745	4.842	4.697	3.76
10YR7	54.112	14.099	42.038	44.339	71.46	24.622	22.295	7.212
10YR3	59.727	2.645	8.9	9.285	73.45	27.893	27.866	26.618
10YR10	41.167	6.805	28.092	28.905	76.382	12.648	12.059	5.155

10YR5	78.143	12.432	56.032	57.394	77.49	56.853	53.785	17.564
10YR1	78.602	1.796	9.414	9.584	79.199	53.793	54.297	53.634
10YR4	64.947	5.181	28.038	28.513	79.532	34.615	34.127	20.458
10YR2	86.072	3.216	20.237	20.491	80.971	68.019	68.257	55.763
10YR8	76.024	13.082	85.397	86.393	81.291	53.36	50.279	5.657
5Y3	70.522	1.396	10.23	10.325	82.229	41.064	41.546	39.632
5Y10	49.765	4.464	46.523	46.737	84.519	18.55	18.334	4.371
5Y1	80.656	1.224	13.102	13.159	84.661	57.079	57.923	53.442
5Y9	29.469	0.787	10.12	10.151	85.552	5.958	6.043	4.702
5Y8	66.831	5.203	70.258	70.45	85.764	36.88	36.616	5.517
5Y6	51.588	0.345	14.638	14.642	88.649	19.407	19.822	15.619
5PB1	80.599	-0.02	0.449	0.45	92.592	56.63	57.756	67.711
5Y7	60.264	-1.862	40.383	40.425	92.64	27.119	28.545	11.006
5Y5	82.251	-3.671	58.109	58.225	93.615	57.424	60.844	19.975
5Y2	87.037	-1.954	25.699	25.773	94.348	67.472	70.115	51.658
N9.5	91.304	-0.323	3.942	3.955	94.689	77.396	79.159	87.659
5Y4	77.51	-2.383	27.803	27.905	94.899	50.176	52.435	34.963
10Y8	82.175	-13.238	86.48	87.487	98.703	53.356	60.459	8.049
10Y7	67.871	-7.446	43.822	44.45	99.643	34.492	37.807	14.905
N8	80.681	-0.923	5.355	5.434	99.774	56.338	57.91	62.035
10Y1	76.98	-2.027	11.118	11.301	100.335	49.622	51.52	49.018
10Y5	83.171	-13.598	63.734	65.168	102.043	54.971	62.405	17.78
10Y10	42.261	-7.251	32.575	33.372	102.549	11.283	12.67	4.567
10Y9	26.236	-2.006	8.694	8.923	102.994	4.563	4.836	3.893
10Y4	70.407	-7.553	31.648	32.537	103.422	37.834	41.327	23.661
10Y6	39.932	-2.997	12.398	12.755	103.59	10.55	11.219	8.716
10Y2	88.664	-7.057	26.522	27.445	104.9	68.316	73.428	53.584
5GY2	86.494	-6.106	21.792	22.631	105.652	64.556	68.95	54.642
10Y3	62.685	-1.821	5.946	6.219	107.03	30.085	31.22	32.208
5GY1	80.58	-2.972	9.368	9.828	107.601	55.273	57.724	57.187
5GY11	68.342	-26.596	65.926	71.088	111.97	29.613	38.208	7.158
5GY5	81.027	-20.342	46.054	50.347	113.831	48.921	58.341	25.967
5GY10	45.87	-15.021	33.536	36.746	114.128	12.371	15.141	5.687
5GY8	78.844	-37.314	77.499	86.014	115.71	39.62	54.171	9.006
5GY3	59.302	-3.83	7.948	8.822	115.728	25.844	27.349	26.746
5GY7	53.678	-16.225	32.455	36.285	116.561	17.815	21.623	9.81

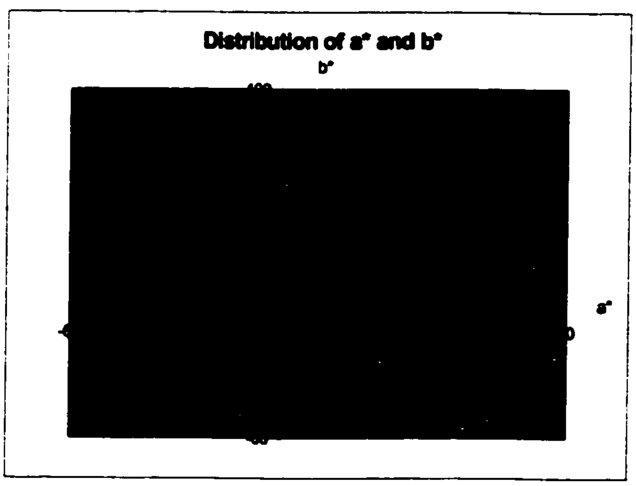
5GY4	74.939	-14.877	28.811	32.425	117.309	41.756	48.166	30.673
5GY12	72.366	-36.906	68.434	77.752	118.338	31.457	43.797	8.406
5GY9	31.04	-4.835	8.38	9.675	119.985	6.064	6.671	5.679
5GY6	51.668	-7.628	12.698	14.813	120.993	17.904	19.838	16.522
10GY2	86.838	-11.945	11.844	16.822	135.243	62.757	69.56	66.681
10GY6	47.061	-9.82	8.581	13.041	138.851	14.064	16.036	14.761
10GY3	67.038	-5.789	5.02	7.663	139.067	34.222	36.653	38.95
10GY7	61.572	-32.078	27.365	42.164	139.534	21.461	29.699	17.514
5G1	83.444	-6.348	5.24	8.231	140.463	59.009	62.951	67.794
10B1	81.877	-1.428	1.156	1.838	141.007	58.313	60.063	69.54
10GY4	71.513	-20.924	16.302	26.525	142.076	35.304	42.777	35.774
5G2	86.962	-9.834	7.548	12.397	142.495	63.989	69.828	72.387
10GY1	81.048	-6.386	4.69	7.923	143.708	54.782	58.505	63.525
10GY11	53.712	-47.605	34.382	58.723	144.162	12.509	21.394	9.097
10GY10	39.377	-26.641	19.105	32.783	144.354	7.41	10.792	6.484
10GY9	24.074	-7.712	4.947	9.162	147.319	3.516	4.111	3.889
10BG1	75.998	-2.316	1.298	2.655	150.725	48.068	49.868	57.505
5G3	73.306	-8.174	4.383	9.275	151.797	41.917	45.568	49.424
10G1	81.371	-8.487	3.932	9.354	155.145	54.503	59.061	65.05
10G3	72.322	-5.311	2.414	5.834	155.556	41.495	44.083	49.708
5G6	47.067	-5.338	2.075	5.727	158.762	14.852	16.041	17.923
5G4	69.461	-23.216	7.968	24.546	161.057	32.167	39.794	39.799
5BG2	84.361	-11.494	3.896	12.137	161.277	58.51	64.637	71.345
5G11	43.22	-46.336	15.454	48.845	161.556	7.081	13.117	9.429
10G6	47.214	-4.944	1.604	5.197	162.022	15.031	16.164	18.304
5BG1	73.611	-4.968	1.33	5.143	165.008	43.5	46.041	53.026
5G7	56.838	-29.949	7.986	30.995	165.068	17.928	24.543	23.839
5G9	26.924	-8.54	2.084	8.791	166.289	4.31	5.049	5.489
5G10	36.675	-31.426	7.559	32.322	166.475	5.84	9.254	8.422
10G2	80.817	-20.22	4.598	20.736	167.188	49.049	57.921	62.971
10G4	71.354	-23.467	3.842	23.78	170.702	34.476	42.489	46.506
10G7	62.295	-32.479	4.506	32.79	172.102	22.205	30.522	32.575
10G9	24.801	-12.085	1.596	12.19	172.477	3.441	4.325	4.761
10G10G	34.471	-26.135	2.616	26.265	174.285	5.489	8.149	8.804
10G11	50.984	-41.552	3.782	41.723	174.799	11.809	19.038	20.363
5BG4	68.129	-21.893	-1.99	21.983	185.194	31.058	37.934	46.828

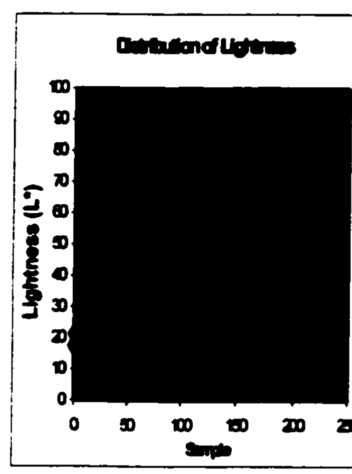
5B1	80.694	-3.507	-0.594	3.557	189.618	55.385	57.85	69.084
5BG7	53.761	-33.24	-6.017	33.781	190.261	15.044	21.534	29.584
5BG11	44.565	-27.519	-5.991	28.164	192.281	10.024	14.091	19.788
10BG2	80.239	-17.448	-4.159	17.937	193.407	49.283	56.895	72.58
10BG4	71.989	-21.352	-5.133	21.961	193.518	36.028	43.409	56.868
5BG10	37.374	-29.056	-7.101	29.911	193.733	6.402	9.603	14.263
5BG3	62.704	-6.311	-1.612	6.513	194.327	28.988	31.17	38.238
5BG9	23.709	-6.665	-1.783	6.899	194.981	3.5	3.996	5.126
10BG6	44.194	-7.722	-2.617	8.153	198.72	12.562	13.913	17.776
5B2	83.876	-11.296	-4.19	12.048	200.351	57.868	63.672	81.04
5BG6	40.974	-9.881	-4.132	10.71	202.696	10.284	11.797	15.789
10BG3	59.531	-3.403	-1.658	3.785	205.973	26.257	27.582	33.857
10BG7	51.871	-27.593	-13.774	30.839	206.527	14.69	19.849	32.938
10BG10	38.569	-24.808	-12.882	27.953	207.442	7.374	10.282	17.975
10BG9	27.168	-7.37	-4.612	8.694	212.036	4.497	5.126	7.304
5B3	60.011	-3.456	-2.318	4.161	213.853	26.762	28.171	35.085
5B4	71.358	-13.525	-10.791	17.302	218.586	37.665	42.539	62.035
5B6	45.669	-6.55	-5.794	8.745	221.498	13.723	14.977	20.843
5B7	51.772	-17.719	-20.809	27.331	229.585	16.379	19.808	38.503
5B9	27.218	-7.757	-10.756	13.262	234.202	4.5	5.141	9.137
10B2	79.374	-6.323	-8.8	10.836	234.302	52.166	55.467	76.79
5B10	31.719	-10.993	-16.459	19.792	236.262	5.857	6.911	14.185
10B3	66.246	-1.556	-2.334	2.805	236.309	34.56	35.609	44.246
10B5	70.248	-14.372	-21.866	26.167	236.684	36.107	40.896	73.347
10B4	66.052	-11.427	-18.387	21.649	238.14	31.673	35.23	60.395
10B7	54.216	-10.937	-21.268	23.916	242.785	19.665	22.064	42.567
10B6	44.134	-3.621	-8.042	8.819	245.761	13.164	13.901	20.623
10B8	54.437	-14.908	-34.51	37.593	246.636	19.207	22.229	56.042
5PB2	81.144	-1.877	-5.791	6.087	252.044	56.947	58.67	76.876
10B9	23.525	-2.462	-8.874	9.209	254.496	3.742	3.939	6.766
10B10	32.235	-4.912	-25.203	25.677	258.972	6.67	7.156	18.771
5PB3	62.092	-0.56	-2.989	3.041	259.393	29.836	30.49	38.547
5PB6	40.913	-0.533	-4.69	4.721	263.52	11.556	11.794	16.069
5PB4	62.131	-0.724	-12.281	12.302	266.627	29.934	30.505	46.997
N6	60.76	-0.045	-1.14	1.141	267.72	28.43	28.988	35.154
5PB5	65.343	-0.463	-25.454	25.458	268.958	34.025	34.405	67.355

5PB8	50.002	1.564	-43.271	43.299	272.069	18.841	18.341	57.566
5PB10	27.198	1.992	-27.468	27.54	274.148	5.341	5.147	15.689
5PB7	44.829	3.139	-30.322	30.484	275.91	14.899	14.384	36.661
5PB12	37.552	5.442	-48.059	48.366	276.461	10.713	9.795	41.117
5PB9	21.26	2.163	-10.752	10.967	281.374	3.415	3.309	6.254
5PB11	29.988	7.131	-34.935	35.655	281.536	6.979	6.219	22.146
N1	17.403	0.181	-0.756	0.778	283.475	2.353	2.388	2.936
N2	21.504	0.592	-2.295	2.37	284.46	3.358	3.381	4.441
10PB4	67.878	5.762	-13.857	15.007	292.579	39.084	37.817	58.841
10PB5	64.436	11.704	-27.936	30.289	292.732	36.543	33.368	68.59
10PB7	36.007	12.775	-25.764	28.758	296.374	10.622	9.024	22.846
10PB10	26.452	12.787	-23.147	26.444	298.917	6.003	4.914	13.293
10PB9	22.662	6.018	-10.362	11.983	300.144	4.081	3.706	6.776
10PB8	46.594	25.226	-40.991	48.131	301.608	20.59	15.774	49.186
10PB3	46.657	25.211	-40.913	48.057	301.642	20.642	15.822	49.213
1PB2	80.961	4.143	-6.466	7.679	302.648	59.143	58.406	77.379
10PB12	31.871	30.393	-47.036	56.001	302.869	10.76	7.079	32.497
10PB6	38.943	3.422	-5.149	6.182	303.612	10.927	10.634	14.752
10PB11	30.58	24.537	-36.494	43.976	303.915	9.212	6.519	23.735
5P4	58.324	10.994	-11.103	15.625	314.718	28.643	26.352	39.954
5P7	39.745	21.223	-21.309	30.075	314.884	14.17	11.156	24.105
5P9	21.97	6.446	-6.238	8.97	315.938	3.884	3.514	5.467
5P11	28.893	33.709	-32.286	46.677	316.235	9.405	5.86	19.718
5P10	26.501	21.289	-18.515	28.214	318.986	6.79	4.951	11.521
5P8	48.344	40.486	-35.083	53.572	319.09	25.682	17.238	46.437
5P5	61.548	31.044	-26.788	41.004	319.208	38.689	30.044	61.424
5P12	30.498	45.723	-39.332	60.313	319.297	12.015	6.542	25.578
5P6	37.896	5.772	-4.436	7.279	322.457	10.615	10.045	13.669
5P3	60.033	2.458	-1.78	3.035	324.089	28.275	28.168	34.681
5P1	73.582	3.135	-2.135	3.793	325.749	46.324	46.068	56.753
5P2	79.301	5.362	-3.58	6.447	326.274	56.587	55.492	69.978
10P7	39.086	24.487	-13.779	28.098	330.634	14.199	10.771	19.105
10P11	27.089	37.153	-20.734	42.547	330.835	8.815	5.194	12.847
10P12	33.429	56.822	-29.995	64.253	332.172	15.776	7.914	22.936
10P9	26.234	9.615	-4.768	10.732	333.624	5.554	4.84	6.916
10P10	27.071	23.061	-11.374	25.714	333.746	7.189	5.16	9.349

10P8	50.238	43.798	-21.278	48.693	334.088	28.31	18.816	37.061
10P4	67.726	12.932	-4.634	13.737	340.287	41.043	37.731	49.007
10P5	71.796	27.584	-8.946	28.998	342.031	52.6	43.537	61.12
5RP11	30.508	42.331	-10.072	43.513	346.616	11.361	6.559	10.972
10P6	41.268	4.098	-0.942	4.205	347.057	12.413	12.048	14.663
5RP10	31.249	30.205	-5.783	30.754	349.161	10.058	6.816	9.892
5RP6	33.94	12.567	-2.038	12.731	350.787	9.293	8.007	10.151
5RP9	26.989	10.502	-1.687	10.636	350.871	5.901	5.107	6.449
5RP7	39.827	29.93	-3.232	30.104	353.836	15.553	11.265	14.674
5RP12	37.583	56.397	-5.919	56.707	354.008	18.75	10.04	14.221
10P3	57.9	2.799	-0.2	2.806	355.909	26.055	25.87	30.741
10RP9	22.428	17.458	-0.374	17.462	358.771	4.81	3.657	4.393

The distribution of the colour samples in the CIE colour space was plotted and is shown in the graph below (using illuminant D_{65}).





Appendix D

Questionnaire

An example of the instruction page of the questionnaire using in the 2-point visual assessment method is shown in P. 335.

An example of the instruction page of the questionnaire using in the 7-point visual assessment method is shown in P. 336.

QUESTIONNAIRE (2-point Assessment Method)

Date: / /

Personal Information*

1. Name: 2. Sex: F / M 3. Age:

4. Place of Birth: 5. Nationality:

6. Your First Language:

(If you are Hong Kong Chinese and your first language is Cantonese, please go to No. 9.)

7. How many years have you lived in Hong Kong?

8. How many years have you received education in Hong Kong?

9. Course of Study:

Start time: End time:

Visual Experiment 視覺實驗

Instructions 指引

1) Please check and write down the colour number of the colour sample on the space provided.
請查閱並填上色辦上的號碼。

2) Use a grey mask provided to cover the sample.
利用灰罩覆蓋該色辦。

3) Observe the sample under D_{65} light.
於 D_{65} 燈光下觀評蓋該色辦。

4) Each opponent pair consists of two colour description words. Select one point that you consider as the most suitable to describe the sample colour.
請於每一對顏色形容詞中選擇最適合之形容詞形容該色辦的顏色。

e.g. Colour No.:

暖	冷
光	暗
深	淺
重	輕
鮮明	暗淡
俗艷	樸素
奪目	柔和
動	靜
清晰	模糊
通透	濁
柔軟	堅硬
強	弱

5) Repeat steps 1-4 until all the samples have been assessed.
重複部驟 1-4 直至完成評核所有色辦。

*Your personal information will be kept strictly confidential and it is used as reference only.

QUESTIONNAIRE (7-point Assessment Method)

Date: / /

Personal Information*

1. Name: 2. Sex: F / M 3. Age:

4. Place of Birth: 5. Nationality:

6. Your First Language:

(If you are Hong Kong Chinese and your first language is Cantonese, please go to No. 9.)

7. How many years have you lived in Hong Kong?

8. How many years have you received education in Hong Kong?

9. Course of Study:

Start time: End time:

Visual Experiment 視覺實驗

Instructions 指引

1) Please check and write down the colour number of the colour sample on the space provided. 請查閱並填上色辦上的號碼。

2) Use a grey mask provided to cover the sample. 利用灰罩覆蓋該色辦。

3) Observe the sample under D_{65} light. 於 D_{65} 燈光下觀評蓋該色辦。

4) There are 7 points for each opponent pair of colour description. Select one point that you consider as the most suitable to describe the sample colour. 每一對顏色形容詞分作 7 分。請選擇最適合之分數形容該色辦的顏色。

Point 分	**Suitability of Colour Description Word**	**該顏色形容詞的合適程度**
3	Most	最
2	Moderately	普通
1	Slightly	少許
0	Neutral (Neither is suitable in that pair)	中性(於該對內並無形容詞合適)

e.g.

Colour No.:

暖	3	2	1	0	1	2	3	冷
光	3	2	1	0	1	2	3	暗
深	3	2	1	0	1	2	3	淺
重	3	2	1	0	1	2	3	輕
鮮明	3	2	1	0	1	2	3	暗淡
俗艷	3	2	1	0	1	2	3	樸素
奪目	3	2	1	0	1	2	3	柔和
動	3	2	1	0	1	2	3	靜
清晰	3	2	1	0	1	2	3	模糊
通透	3	2	1	0	1	2	3	濁
柔軟	3	2	1	0	1	2	3	堅硬
強	3	2	1	0	1	2	3	弱

5) Repeat steps 1-4 until all the samples have been assessed. 重複部驟 1-4 直至完成評核所有色辦。

*Your personal information will be kept strictly confidential and it is used as reference only.

Appendix E

Analysis of Visual Assessment Results by ANOVA Test

The significance of the results obtained from the visual assessment was investigated by ANOVA (Analysis of Variance). This is used as the preliminary analysis of the variations in the assessments of the colour samples with respect to each pair of colour emotion words. The results from 21 subjects were used for the preliminary analysis. *F-test* was applied to calculate the *F* value of the results. Each pair of colour emotion words has an individual calculated *F* value. *F* value is the ratio of the variation between the sample means, s_1^2, and the variation within the sample means, s_2^2.

i.e. $F = \dfrac{n \times s_1^2}{s_2^2}$

where n is the number of subjects, i.e. 21 in the preliminary analysis.

The variation between the sample means, s_1^2, is calculated by:

$$s_1^2 = \frac{\sum_{i=1}^{218} (x_i - \mu)^2}{a - 1}$$

where x is the mean of colour emotions of the 21 subjects of a specific colour, μ is the mean of replications over all colour samples, i.e. mean of x, and a is the total number of colour samples, i.e. 218.

The variation within the sample means, s_2^2, is calculated by:

$$s_2^2 = \frac{\sum_{i=1}^{218}\sum_{j=1}^{21}(y_j - x_i)^2}{a \times (n-1)}$$

where y is the emotion of a specific subject after perceiving a specific colour sample x is the mean of colour emotions of the 21 subjects of a specific colour, a is the total number of colour samples and n is the total number of subjects.

For each pair of colour emotion words, an individual ANOVA table was going to be constructed. A generalised one is shown below. (Table E-1)

Table E-1

An ANOVA table

Source of Variation	***Sum of Squares, SS***	***Degree of Freedom, d.f.***	***Mean Squares, MS***	***F Ratio***
Difference Between Means of Colour Samples	$SS_A = n\Sigma(x-\mu)^2$	$(a-1)$	$MS_A = SS_A/(a-1)$ $= ns_1^2$	$F = MS_A/MS_E$ $= ns_1^2/s_2^2$
Difference Between Individual Data and Means of Colour Samples	$SS_E = \Sigma\Sigma(y-x)^2$	$a(n-1)$	$MS_E = SS_E/a(n-1)$ $= s_2^2$	
Total	$SS = \Sigma\Sigma(y-\mu)^2$	$na-1$		

If the calculated F value is larger than the *F critical* value, which is found from the critical points table, the variation of colour emotions between colour samples is sufficiently significant for further analysis and creation of models. The ANOVA results of the preliminary analysis were summarised in the following table. (Table E-2)

Table E-2

The ANOVA table of colour emotion words

Colour Emotion	Calculated F Ratio	F_{crit} (from the F Critical Points Table)
Warm-Cool	6.09	$F_{0.01} = 1.00$ (when d.f. for numerator is 217 and d.f. for denominator is 4360)
Light-Dark	14.83	
Deep-Pale	22.01	
Heavy-Light	15.76	
Vivid-Sombre	16.07	
Gaudy-Plain	18.31	
Striking-Subdued	15.28	
Dynamic-Passive	8.82	
Distinct-Vague	8.12	
Transparent-Turbid	11.18	
Soft-Hard	13.48	
Strong-Weak	12.60	

Since all the calculated *F* values of the colour emotion words were larger than the *F critical* value, which is equal to 1.00 when the degree of freedom for numerator is 217 and the degree of freedom for denominator is 4360, the variations in colour emotions between colour samples were found to be sufficiently significant. As a result, it was valuable for further investigation on the quantitative relationship between the colour emotions and the colorimetric values.

Appendix F

Subdivided Graphs of Colour Emotion against L^* and C^*

Some of the subdivided graphs are shown and discussed in Chapter 3, and the other are shown here.

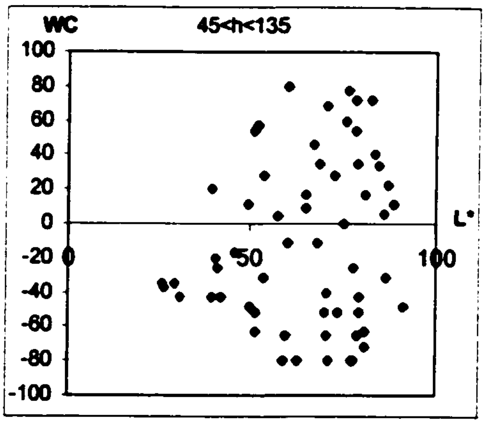


Figure AF1 Subdivided graph of *WC* against L^* of red colours

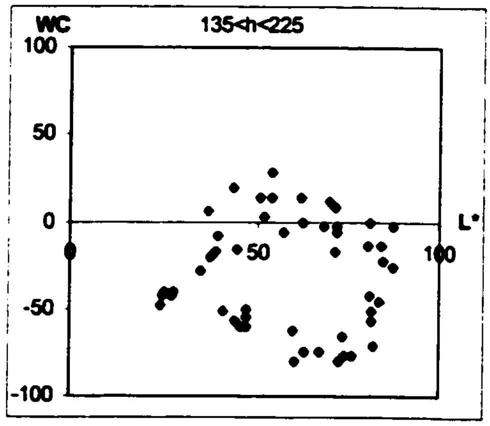


Figure AF2 Subdivided graph of *WC* against L^* of yellow colours

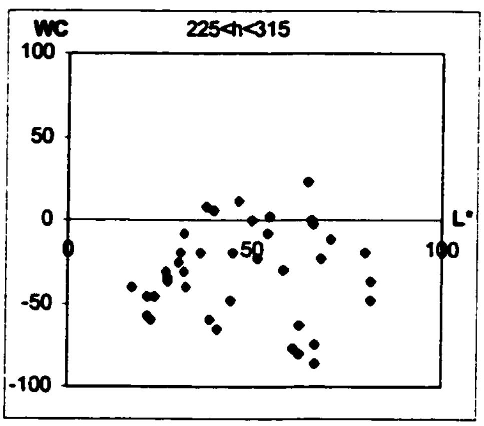


Figure AF3 Subdivided graph of *WC* against L^* of green colours

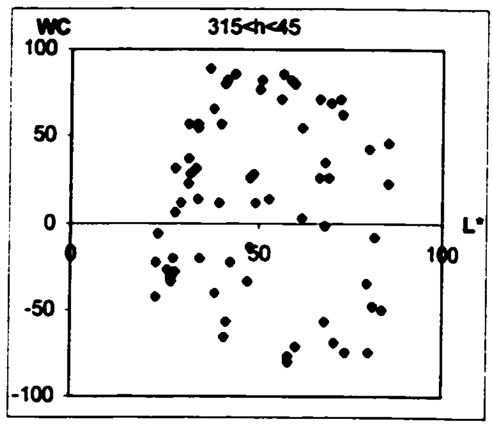


Figure AF4 Subdivided graph of *WC* against L^* of blue colours

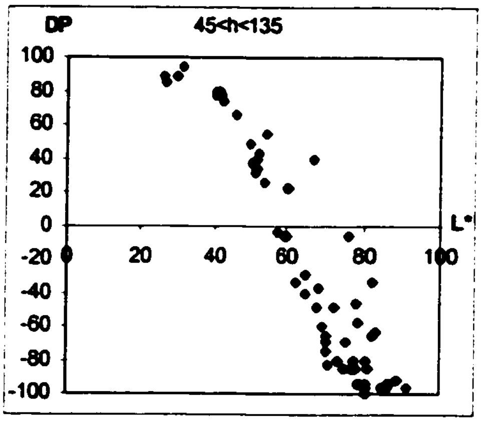


Figure AF5 Subdivided graph of *DP* against L^* of red colours

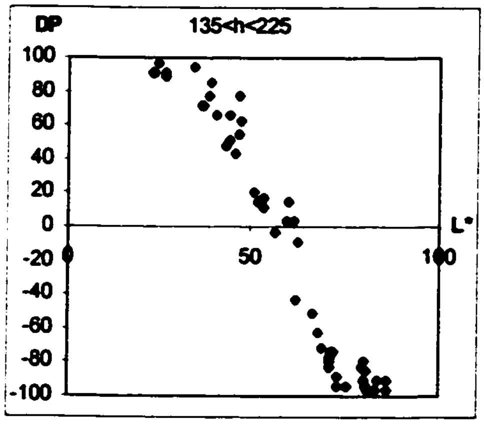


Figure AF6 Subdivided graph of *DP* against L^* of yellow colours

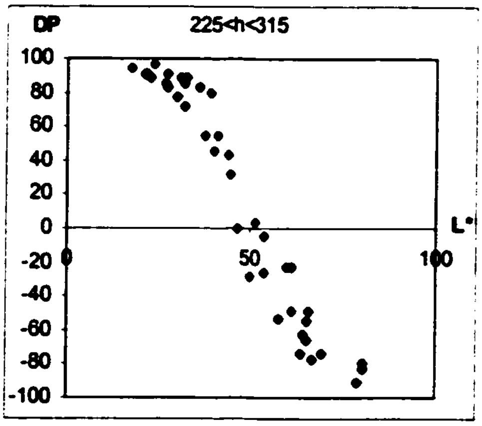


Figure AF7 Subdivided graph of *DP* against L^* of green colours

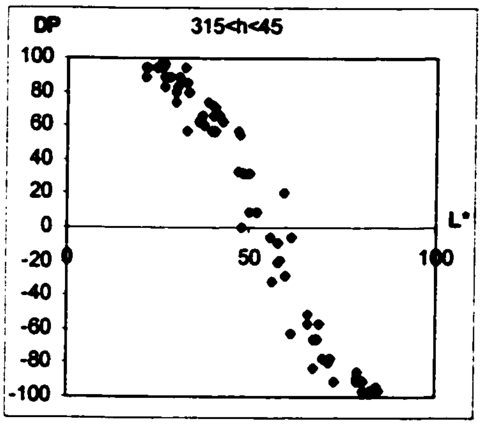


Figure AF8 Subdivided graph of *DP* against L^* of blue colours

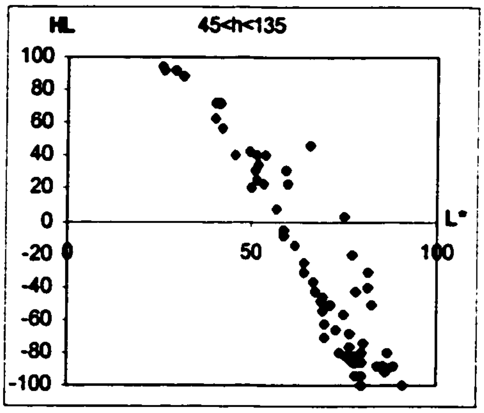


Figure AF9 Subdivided graph of *HL* against L^* of red colours

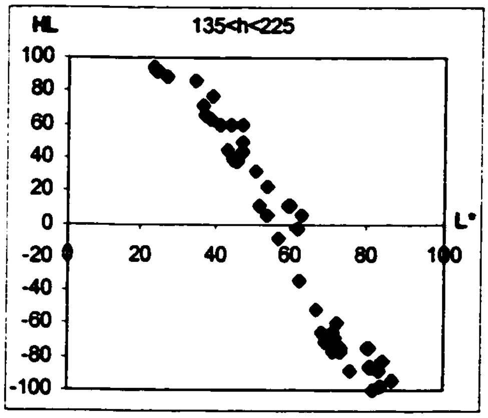


Figure AF10 Subdivided graph of *HL* against L^* of yellow colours

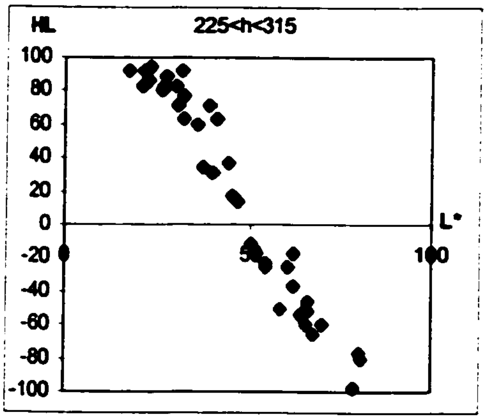


Figure AF11 Subdivided graph of *HL* against L^* of green colours

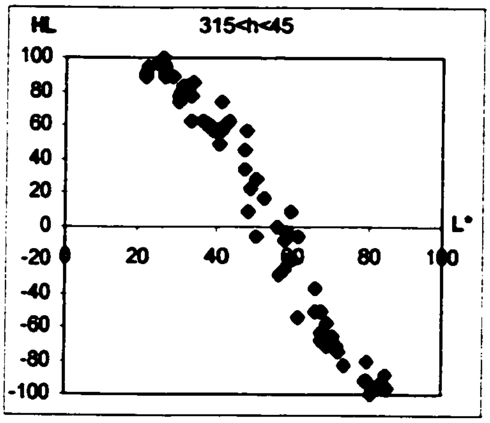


Figure AF12 Subdivided graph of *HL* against L^* of blue colours

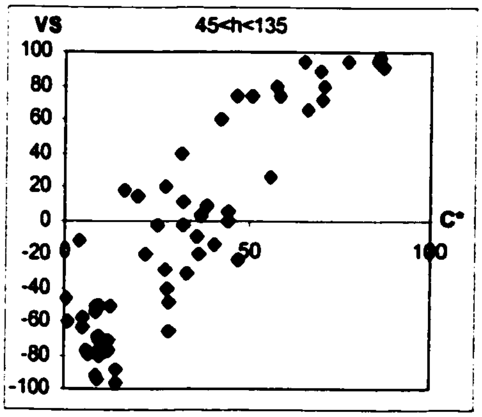


Figure AF13 Subdivided graph of *VS* against C^* of red colours

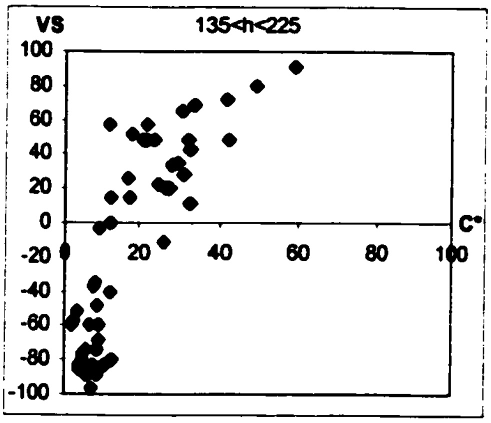


Figure AF14 Subdivided graph of *VS* against C^* of yellow colours

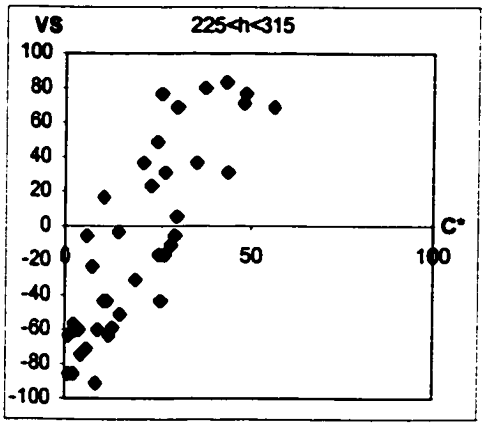


Figure AF15 Subdivided graph of *VS* against C^* of green colours

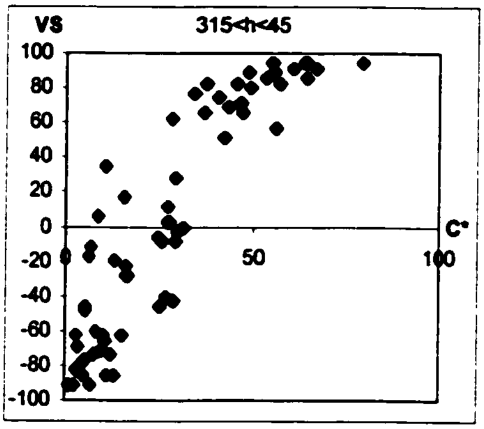


Figure AF16 Subdivided graph of *VS* against C^* of blue colours

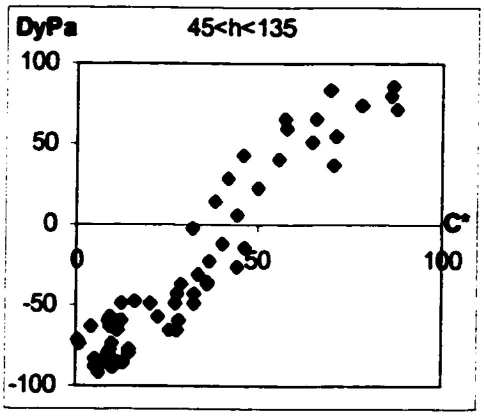


Figure AF17 Subdivided graph of *DyPa* against C^* of red colours

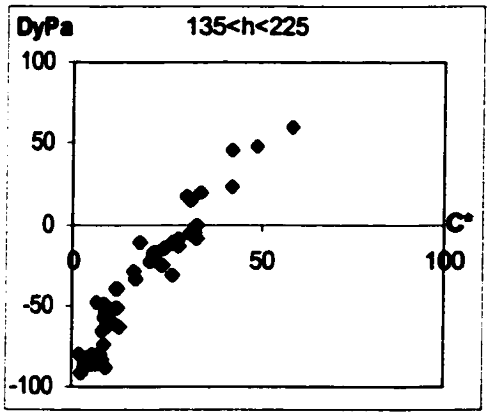


Figure AF18 Subdivided graph of *DyPa* against C^* of yellow colours

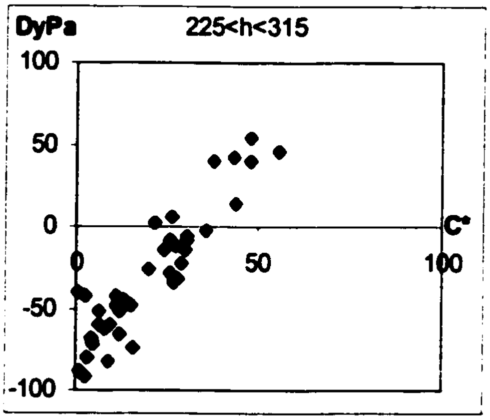


Figure AF19 Subdivided graph of *DyPa* against C^* of green colours

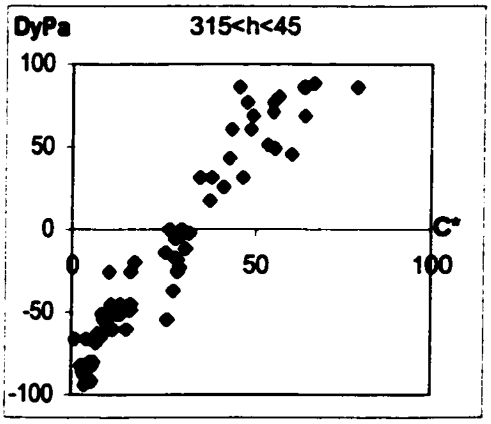


Figure AF20 Subdivided graph of *DyPa* against C^* of blue colours

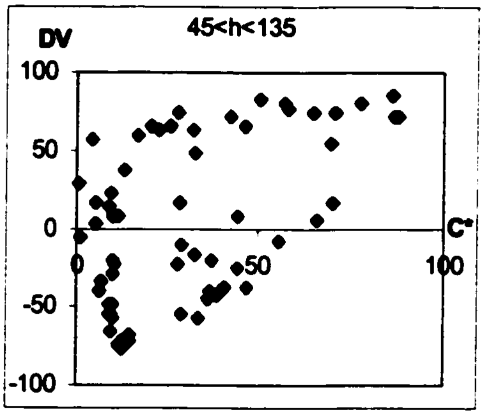


Figure AF21 Subdivided graph of *DV* against C^* of red colours

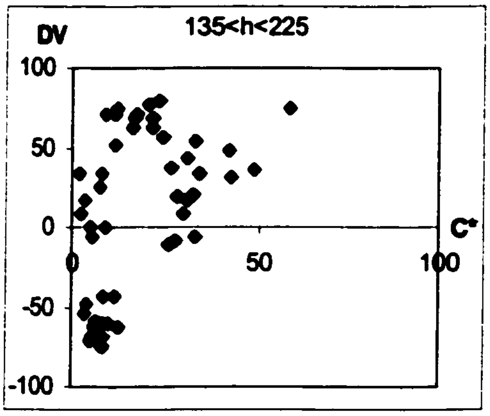


Figure AF22 Subdivided graph of *DV* against C^* of yellow colours

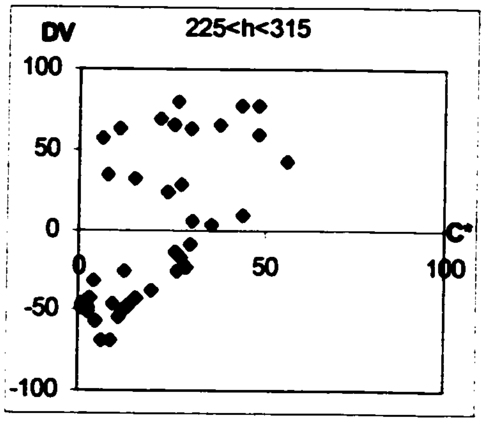


Figure AF23 Subdivided graph of DV against C^* of green colours

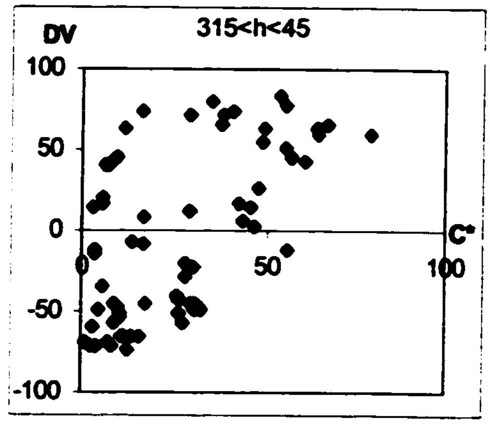


Figure AF24 Subdivided graph of DV against C^* of blue colours

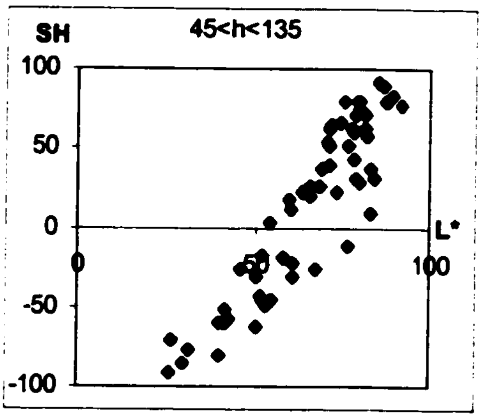


Figure AF25 Subdivided graph of SH against L^* of red colours

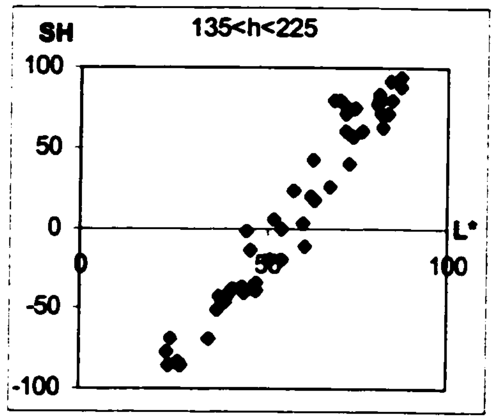


Figure AF26 Subdivided graph of SH against L^* of yellow colours

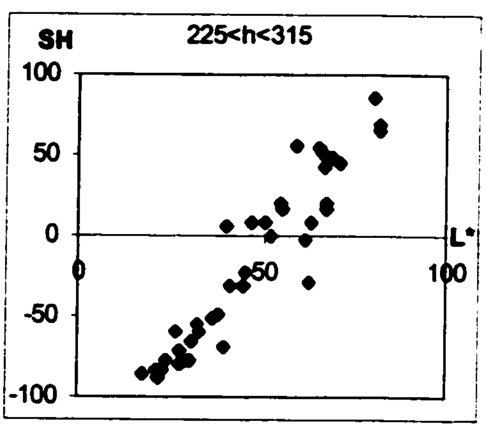


Figure AF27 Subdivided graph of SH against L^* of green colours

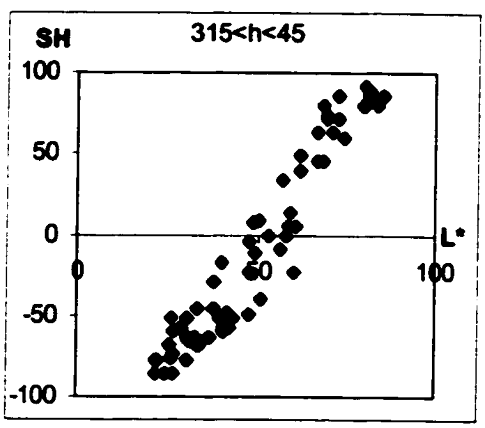


Figure AF28 Subdivided graph of SH against L^* of blue colours

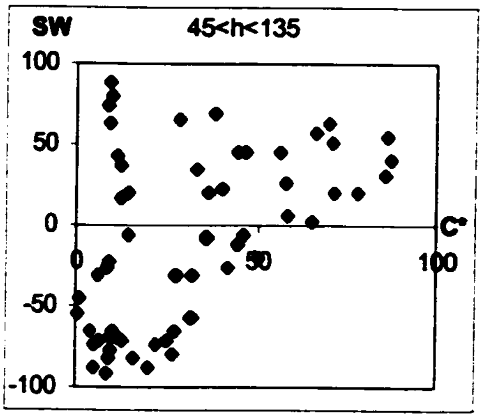


Figure AF29 Subdivided graph of *SW* against C^* of red colours

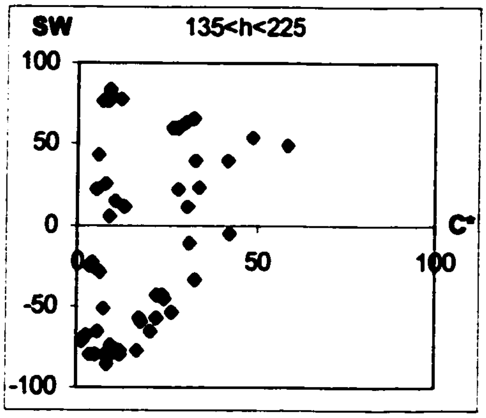


Figure AF30 Subdivided graph of *SW* against C^* of yellow colours

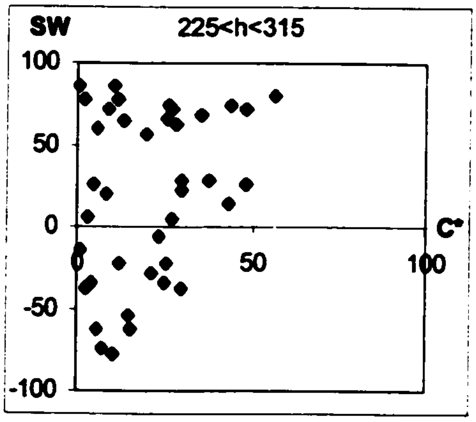


Figure AF31 Subdivided graph of *SW* against C^* of green colours

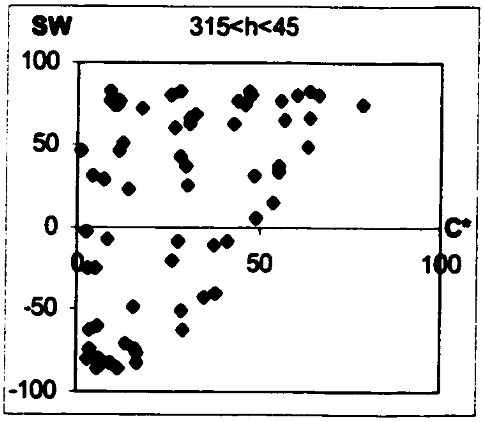


Figure AF32 Subdivided graph of *SW* against C^* of green colours

Appendix G

Reliability of Mathematical Models Derived by Method I

To determine whether the derived mathematical models are suitable to represent the colour emotions, the CIE colorimetric attributes were inserted to the models for calculating the corresponding emotion values of each colour emotion pair. The following figures illustrate the correlations between the colour emotion values obtained from the visual assessment and those calculated from the mathematical models where were derived by Method I (as shown in Chapter 3), and such relationships are shown by the solid lines. The dotted lines in these figures are the 45^0 line representing the exact equivalent in colour emotion values between them.

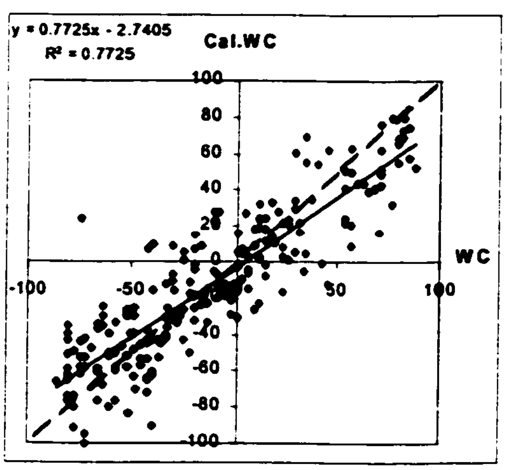


Figure AG1 The correlation of calculated warm-cool values and their corresponding visual assessment data.

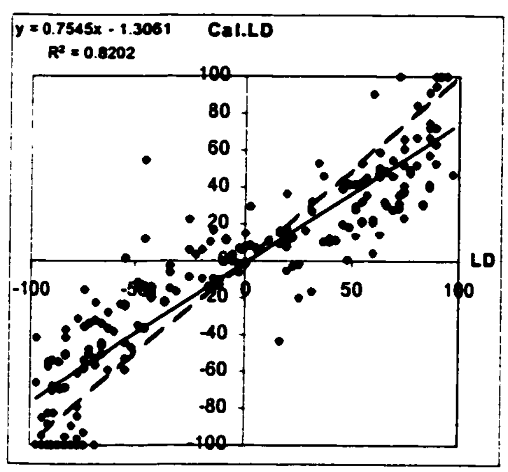


Figure AG2 The correlation of calculated light-dark values and their corresponding visual assessment data.

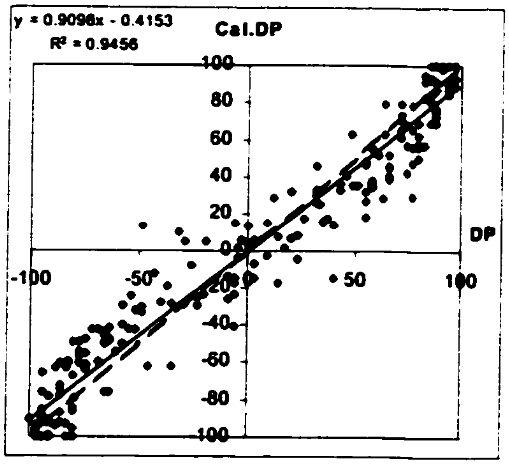


Figure AG3 The correlation of calculated deep-pak values and their corresponding visua assessment data.

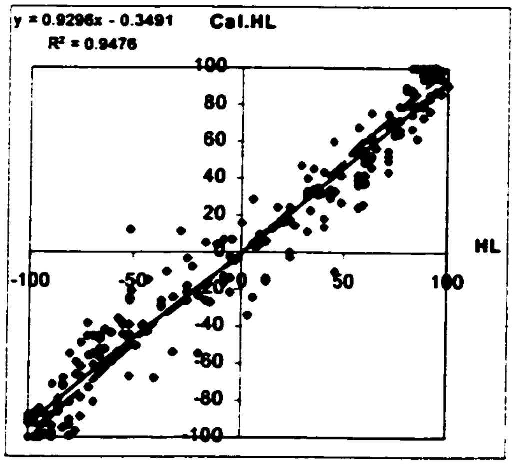


Figure AG4 The correlation of calculated heavy-light values and their corresponding visual assessment data.

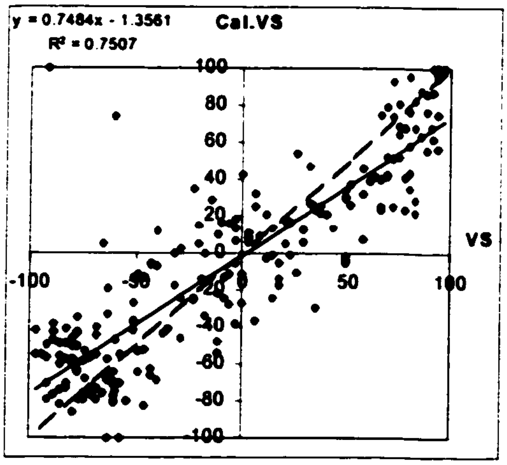


Figure AG5 The correlation of calculated vivid-sombre values and their corresponding visua assessment data.

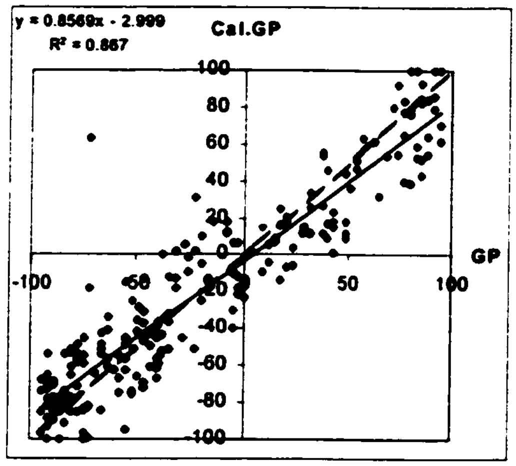


Figure AG6 The correlation of calculated gaudy-plain values and their corresponding visual assessment data.

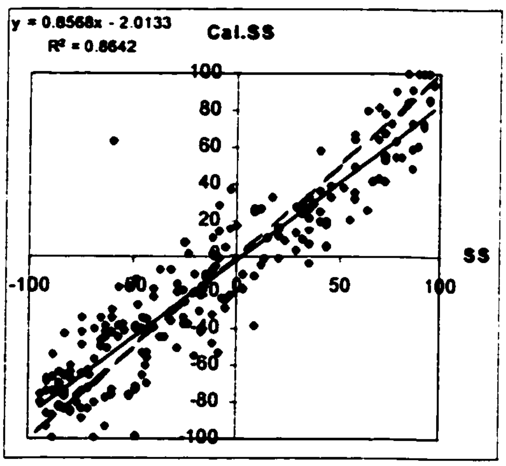


Figure AG7 The correlation of calculated striking-subdued values and their corresponding visual assessment data.

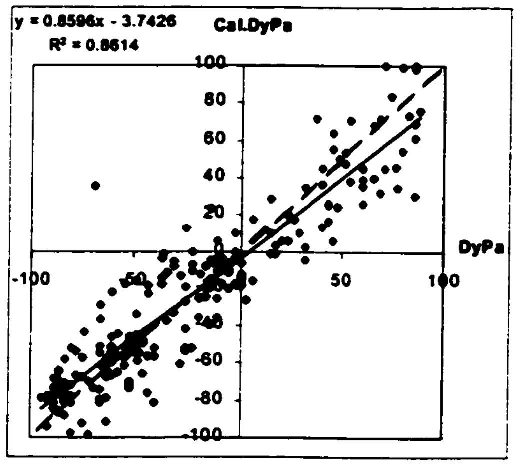


Figure AG8 The correlation of calculated dynamic-passive values and their corresponding visual assessment data.

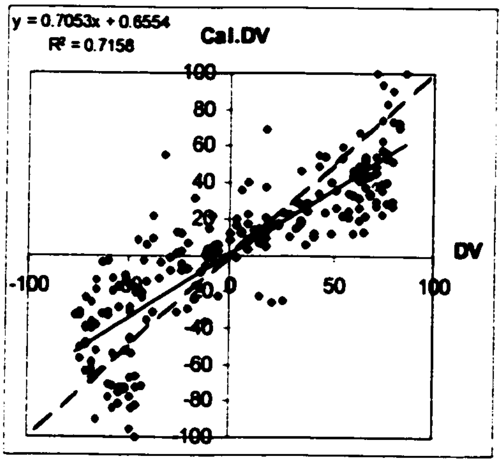


Figure AG9 The correlation of calculated distinct-vague values and their corresponding visual assessment data.

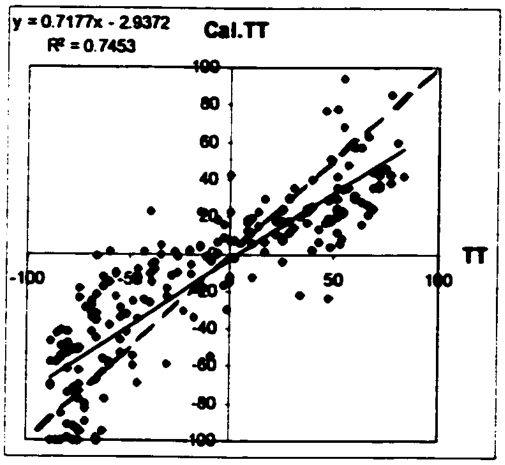


Figure AG10 The correlation of calculated transparent-turbid values and their corresponding visual assessment data.

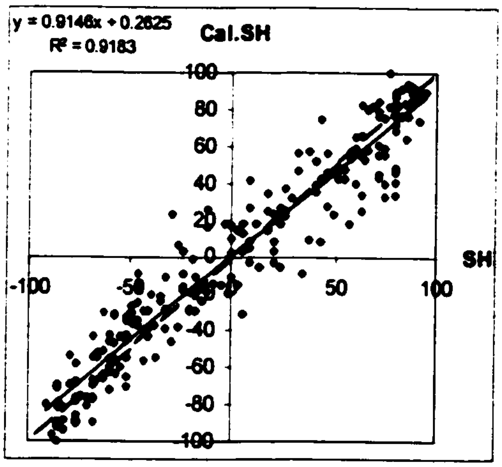


Figure AG11 The correlation of calculated soft-hard values and their corresponding visual assessment data.

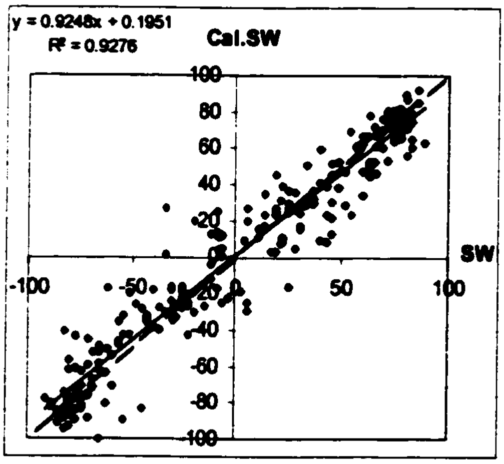


Figure AG12 The correlation of calculated strong-weak values and their corresponding visual assessment data.

Appendix H

Visual Assessment Results of Colour Emotion in the 2-point Method

	WC	LD	DP	HL	VS	GP	SS	DyPa	DV	TT	SH	SW
5B1	-0.429	0.200	-0.914	-0.857	-0.514	-0.829	-0.771	-0.857	0.171	0.229	0.829	-0.800
5B2	-0.143	0.629	-0.971	-0.971	0.571	-0.286	-0.286	-0.400	0.714	0.771	0.914	-0.800
5B3	-0.800	-0.771	0.143	0.114	-0.857	-0.829	-0.714	-0.857	-0.486	-0.743	-0.114	-0.229
5B4	-0.171	0.543	-0.829	-0.771	0.143	-0.200	-0.246	-0.343	0.686	0.686	0.714	-0.571
5B6	-0.600	-0.829	0.429	0.371	-0.886	-0.914	-0.743	-0.743	-0.743	-0.886	-0.143	0.057
5B7	-0.229	0.171	0.029	-0.171	0.314	0.143	0.200	-0.114	0.286	-0.057	0.000	0.043
5B9	-0.362	-0.884	0.913	0.884	-0.594	-0.362	-0.101	-0.449	-0.478	-0.623	-0.710	0.652
5B10	-0.314	-0.686	0.857	0.914	-0.314	-0.029	0.200	-0.257	-0.371	-0.629	-0.543	0.565
10B1	-0.714	0.257	-0.971	-1.000	-0.600	-0.914	-0.886	-0.800	0.343	0.343	0.629	-0.714
10B2	-0.200	0.514	-0.914	-0.971	0.171	-0.657	-0.429	-0.429	0.629	0.629	0.857	-0.771
10B3	-0.857	-0.571	-0.543	-0.457	-0.857	-0.943	-0.943	-0.914	-0.514	-0.600	0.171	-0.371
10B4	-0.029	0.514	-0.657	-0.600	0.371	-0.057	-0.143	0.029	0.686	0.478	0.429	-0.286
10B5	-0.114	0.886	-0.743	-0.600	0.771	0.229	0.200	0.057	0.800	0.714	0.457	-0.229
10B6	-0.486	-0.914	0.429	0.371	-0.914	-0.800	-0.657	-0.829	-0.686	-0.771	-0.314	0.200
10B7	-0.086	0.171	-0.043	-0.257	0.229	-0.257	-0.057	-0.143	0.229	-0.114	0.200	-0.057
10B8	0.029	0.657	-0.257	-0.229	0.800	0.514	0.514	0.400	0.657	0.371	0.171	0.286
10B9	-0.457	-0.914	0.971	0.943	-0.600	-0.543	0.029	-0.600	-0.457	-0.743	-0.771	0.714
10B10	-0.400	-0.600	0.886	0.771	-0.171	-0.029	0.086	-0.286	-0.143	-0.543	-0.600	0.657
5BG1	-0.771	-0.457	-0.943	-0.743	-0.800	-0.914	-0.914	-0.829	0.000	-0.143	0.743	-0.800
5BG2	-0.229	0.600	-0.914	-0.829	0.000	-0.571	-0.514	-0.514	0.514	0.514	0.800	-0.800
5BG3	-0.743	-0.743	-0.086	0.057	-0.886	-0.800	-0.886	-0.857	-0.629	-0.629	0.171	-0.286
5BG4	-0.029	0.486	-0.629	-0.657	0.486	-0.057	-0.114	-0.171	0.686	0.478	0.800	-0.429
5BG6	-0.514	-0.857	0.657	0.600	-0.829	-0.743	-0.400	-0.600	-0.600	-0.743	-0.371	0.143
5BG7	0.143	0.543	0.171	0.229	0.686	0.314	0.457	0.200	0.343	0.114	0.000	0.229
5BG9	-0.478	-0.826	0.913	0.942	-0.594	-0.391	-0.072	-0.478	-0.594	-0.739	-0.768	0.768
5BG10	-0.200	-0.029	0.714	0.657	0.343	0.400	0.571	0.171	0.086	-0.314	-0.429	0.629
5BG11	-0.159	-0.014	0.507	0.391	0.333	0.275	0.304	-0.130	0.188	-0.188	-0.014	0.217

10BG1	-0.771	-0.114	-0.943	-0.886	-0.571	-0.857	-0.914	-0.914	0.086	0.029	0.600	-0.686
10BG2	-0.143	0.857	-0.829	-0.743	0.514	0.000	-0.057	-0.114	0.714	0.743	0.771	-0.600
10BG3	-0.629	-0.686	0.029	0.114	-0.829	-0.886	-0.857	-0.886	-0.543	-0.686	0.029	-0.257
10BG4	-0.029	0.771	-0.743	-0.686	0.571	0.086	0.086	-0.200	0.629	0.571	0.743	-0.571
10BG6	-0.571	-0.886	0.657	0.600	-0.829	-0.771	-0.600	-0.829	-0.743	-0.829	-0.400	0.257
10BG7	0.029	0.514	0.143	0.114	0.657	0.429	0.629	0.143	0.429	-0.029	0.057	0.114
10BG9	-0.400	-0.743	0.886	0.886	-0.486	-0.371	-0.200	-0.486	-0.686	-0.829	-0.855	0.768
10BG10	-0.171	-0.114	0.771	0.629	0.200	0.314	0.371	-0.086	-0.086	-0.429	-0.457	0.600
5G1	-0.457	0.514	-0.971	-0.886	-0.343	-0.657	-0.800	-0.657	0.343	0.514	0.714	-0.857
5G2	-0.257	0.686	-0.914	-0.943	0.143	-0.514	-0.514	-0.514	0.743	0.829	0.886	-0.771
5G3	-0.657	-0.343	-0.886	-0.771	-0.686	-0.857	-0.829	-0.886	0.000	-0.057	0.571	-0.800
5G4	0.114	0.229	-0.714	-0.714	0.229	-0.343	-0.429	-0.143	0.571	0.514	0.800	-0.457
5G6	-0.600	-0.829	0.771	0.486	-0.886	-0.914	-0.714	-0.800	-0.686	-0.857	-0.343	0.429
5G7	-0.057	0.229	-0.029	-0.086	0.286	0.000	-0.200	-0.057	0.171	0.114	0.229	-0.114
5G9	-0.429	-0.943	0.914	0.886	-0.743	-0.486	-0.171	-0.571	-0.429	-0.771	-0.829	0.829
5G10	0.057	0.171	0.714	0.714	0.486	0.229	0.229	-0.057	0.200	-0.314	-0.514	0.657
5G11	0.188	0.478	0.478	0.449	0.797	0.652	0.681	0.478	0.362	-0.014	-0.362	0.536
10G1	-0.514	0.429	-0.857	-0.857	-0.029	-0.714	-0.686	-0.629	0.714	0.657	0.714	-0.739
10G2	0.000	0.714	-0.800	-0.743	0.486	-0.229	-0.086	-0.229	0.771	0.714	0.800	-0.657
10G3	-0.800	-0.343	-0.743	-0.600	-0.743	-0.886	-0.857	-0.857	-0.057	-0.200	0.400	-0.657
10G4	0.086	0.629	-0.771	-0.686	0.486	-0.057	0.086	-0.257	0.800	0.629	0.600	-0.429
10G6	-0.507	-0.855	0.623	0.594	-0.768	-0.884	-0.710	-0.826	-0.710	-0.884	-0.391	0.217
10G7	0.000	0.400	-0.429	-0.343	0.429	0.171	0.029	0.000	0.543	0.400	0.429	-0.343
10G9	-0.400	-0.800	0.971	0.914	-0.400	-0.400	-0.114	-0.400	-0.429	-0.743	-0.686	0.771
10G10	-0.286	-0.543	0.943	0.857	-0.114	-0.029	0.114	-0.114	-0.114	-0.457	-0.686	0.600
10G11	0.143	0.600	0.200	0.314	0.714	0.486	0.429	0.457	0.486	-0.029	-0.200	0.400
5GY1	-0.714	0.114	-0.943	-0.943	-0.514	-0.829	-0.829	-0.829	0.086	0.143	0.714	-0.771
5GY2	-0.314	0.686	-0.943	-0.914	-0.200	-0.657	-0.743	-0.571	0.629	0.571	0.800	-0.743
5GY3	-0.800	-0.629	-0.057	-0.057	-0.914	-0.914	-0.800	-0.829	-0.543	-0.686	0.171	-0.257
5GY4	0.000	0.457	-0.857	-0.800	0.114	-0.543	-0.514	-0.429	0.486	0.286	0.800	-0.571
5GY5	0.171	0.800	-0.857	-0.743	0.743	0.371	0.543	0.229	0.829	0.800	0.571	-0.200
5GY6	-0.629	-0.971	0.343	0.257	-0.971	-0.829	-0.829	-0.771	-0.714	-0.829	-0.171	-0.057
5GY7	-0.314	-0.543	0.257	0.229	-0.200	-0.314	-0.257	-0.371	-0.400	-0.629	0.029	-0.086
5GY8	0.343	0.943	-0.571	-0.429	0.943	0.800	0.829	0.800	0.857	0.771	0.286	0.314
5GY9	-0.429	-0.943	0.943	0.886	-0.714	-0.629	-0.457	-0.629	-0.486	-0.743	-0.771	0.629
5GY10	-0.171	-0.343	0.657	0.400	0.029	-0.057	-0.029	-0.229	-0.200	-0.657	-0.257	0.200
5GY11	0.343	0.886	-0.371	-0.429	0.800	0.800	0.714	0.543	0.743	0.571	0.371	0.200

5GY12	0.286	0.886	-0.486	-0.514	0.943	0.743	0.771	0.743	0.800	0.657	0.229	0.200
10GY1	-0.571	0.200	-0.943	-0.857	-0.371	-0.857	-0.714	-0.800	0.257	0.257	0.800	-0.800
10GY2	-0.029	0.714	-0.971	-0.943	0.257	-0.429	-0.457	-0.286	0.629	0.714	0.943	-0.771
10GY3	-0.743	-0.686	-0.514	-0.514	-0.971	-0.857	-0.857	-0.829	-0.600	-0.571	0.257	-0.514
10GY4	-0.057	0.457	-0.800	-0.657	0.200	-0.057	-0.314	-0.314	0.371	0.257	0.743	-0.543
10GY6	-0.543	-0.914	0.543	0.429	-0.800	-0.771	-0.629	-0.629	-0.629	-0.800	-0.343	0.114
10GY7	0.143	0.314	0.029	-0.029	0.486	0.371	0.200	0.229	0.314	0.000	0.200	-0.057
10GY9	-0.429	-0.857	0.914	0.914	-0.600	-0.543	-0.229	-0.543	-0.600	-0.771	-0.857	0.800
10GY10	-0.086	-0.457	0.857	0.771	0.114	0.114	0.314	-0.086	-0.057	-0.543	-0.429	0.400
10GY11	0.286	0.743	0.114	0.057	0.914	0.829	0.857	0.600	0.743	0.486	-0.200	0.486
5Y1	-0.629	0.171	-1.000	-0.857	-0.514	-0.914	-0.914	-0.857	0.371	0.400	0.714	-0.714
5Y2	0.229	0.543	-0.943	-0.800	-0.029	-0.629	-0.600	-0.657	0.657	0.486	0.800	-0.714
5Y3	-0.657	-0.257	-0.743	-0.629	-0.771	-0.886	-0.886	-0.886	-0.229	-0.257	0.514	-0.657
5Y4	-0.257	0.200	-0.857	-0.771	-0.400	-0.514	-0.600	-0.657	0.171	0.286	0.600	-0.657
5Y5	0.714	0.943	-0.657	-0.400	0.743	0.400	0.457	0.600	0.771	0.543	0.371	0.057
5Y6	-0.514	-0.829	0.400	0.400	-0.886	-0.800	-0.743	-0.800	-0.686	-0.857	-0.457	0.200
5Y7	-0.114	-0.257	0.229	0.229	-0.143	-0.086	-0.086	-0.114	-0.371	-0.600	-0.229	0.229
5Y8	0.457	0.600	0.400	0.457	0.714	0.714	0.629	0.371	0.171	0.000	-0.257	0.514
5Y9	-0.343	-0.771	0.886	0.914	-0.686	-0.629	-0.314	-0.600	-0.571	-0.800	-0.857	0.800
5Y10	0.114	-0.457	0.486	0.429	-0.229	-0.229	-0.029	-0.143	-0.371	-0.743	-0.629	0.457
10Y1	-0.800	-0.200	-0.857	-0.829	-0.771	-0.886	-0.857	-0.857	0.086	0.143	0.629	-0.686
10Y2	0.114	0.629	-0.914	-0.886	0.200	-0.457	-0.400	-0.486	0.743	0.629	0.829	-0.800
10Y3	-0.800	-0.657	-0.343	-0.143	-0.771	-0.857	-0.857	-0.914	-0.400	-0.571	0.229	-0.304
10Y4	-0.400	0.029	-0.657	-0.457	-0.029	-0.343	-0.486	-0.486	-0.171	-0.057	0.400	-0.314
10Y5	0.400	0.714	-0.629	-0.514	0.943	0.629	0.714	0.514	0.743	0.457	0.314	0.029
10Y6	-0.429	-0.886	0.800	0.714	-0.714	-0.771	-0.629	-0.486	-0.714	-0.886	-0.600	0.371
10Y7	-0.114	0.371	-0.486	-0.371	0.000	-0.086	0.000	-0.257	0.086	-0.143	0.257	-0.114
10Y8	0.714	0.886	-0.343	-0.314	0.914	0.829	0.914	0.714	0.714	0.543	0.086	0.400
10Y9	-0.371	-0.886	0.857	0.914	-0.543	-0.800	-0.257	-0.600	-0.486	-0.771	-0.714	0.743
10Y10	-0.429	-0.629	0.743	0.571	-0.314	-0.371	-0.114	-0.314	-0.571	-0.800	-0.571	0.343
5YR1	-0.514	-0.343	-0.800	-0.657	-0.771	-0.914	-0.914	-0.886	-0.200	-0.343	0.657	-0.771
5YR2	0.543	0.629	-0.857	-0.829	0.400	-0.171	-0.257	-0.029	0.629	0.543	0.714	-0.571
5YR3	-0.514	-0.486	-0.600	-0.486	-0.800	-0.886	-0.829	-0.743	-0.286	-0.371	0.543	-0.686
5YR4	0.171	-0.086	-0.286	-0.257	-0.286	-0.314	-0.400	-0.429	-0.229	-0.343	0.257	-0.314
5YR5	0.600	0.857	-0.686	-0.571	0.743	0.429	0.429	0.429	0.657	0.514	0.514	-0.057
5YR6	-0.257	-0.886	0.771	0.714	-0.771	-0.657	-0.486	-0.657	-0.743	-0.743	-0.514	0.429
5YR7	0.043	-0.159	-0.043	0.072	-0.101	-0.275	-0.246	-0.362	-0.449	-0.565	-0.188	-0.072

5YR8	0.800	0.857	0.229	0.314	0.886	0.857	0.829	0.829	0.543	0.257	-0.314	0.629
5YR9	-0.275	-0.739	0.942	0.971	-0.710	-0.507	-0.176	-0.536	-0.478	-0.652	-0.855	0.739
5YR10	0.200	-0.371	0.771	0.629	0.086	0.171	0.343	0.143	-0.429	-0.743	-0.800	0.686
5YR11	0.543	0.314	0.314	0.314	0.257	0.371	0.400	0.400	-0.086	-0.371	-0.429	0.457
5YR12	0.571	0.343	0.429	0.343	0.657	0.771	0.686	0.657	0.057	-0.143	-0.486	0.571
10YR1	-0.657	-0.029	-0.943	-0.857	-0.686	-0.943	-0.857	-0.829	0.229	0.371	0.800	-0.826
10YR2	0.057	0.514	-0.971	-0.886	0.143	-0.543	-0.457	-0.486	0.657	0.686	0.886	-0.886
10YR3	-0.657	-0.714	-0.057	-0.086	-0.943	-0.943	-0.800	-0.771	-0.657	-0.714	0.114	-0.229
10YR4	0.086	-0.086	-0.400	-0.314	-0.657	-0.714	-0.571	-0.600	-0.101	-0.429	0.200	-0.314
10YR5	0.714	0.857	-0.457	-0.200	0.800	0.543	0.657	0.657	0.800	0.600	0.314	0.257
10YR6	-0.486	-0.714	0.371	0.200	-0.771	-0.743	-0.571	-0.600	-0.771	-0.800	-0.314	0.171
10YR7	0.286	-0.143	0.543	0.400	0.057	0.171	0.314	0.057	-0.257	-0.400	-0.457	0.457
10YR8	0.771	0.914	-0.057	0.029	0.971	0.800	0.886	0.857	0.714	0.514	-0.114	0.543
10YR9	-0.343	-0.829	0.886	0.943	-0.686	-0.543	-0.257	-0.571	-0.543	-0.886	-0.914	0.886
10YR10	-0.200	-0.829	0.800	0.714	-0.486	-0.257	-0.114	-0.371	-0.543	-0.829	-0.600	0.657
5R1	-0.429	-0.057	-0.943	-0.943	-0.629	-0.771	-0.743	-0.829	0.171	0.086	0.800	-0.886
5R2	0.429	0.543	-0.857	-0.800	0.171	-0.343	-0.429	-0.257	0.743	0.543	0.914	-0.743
5R3	-0.686	-0.429	-0.771	-0.657	-0.829	-0.886	-0.943	-0.886	-0.143	-0.257	0.629	-0.743
5R4	0.257	-0.057	-0.657	-0.714	-0.286	-0.457	-0.657	-0.457	0.086	0.029	0.714	-0.771
5R5	0.686	0.743	-0.571	-0.571	0.829	0.486	0.429	0.314	0.714	0.457	0.743	-0.400
5R6	-0.229	-0.971	0.657	0.600	-0.857	-0.657	-0.486	-0.600	-0.657	-0.886	-0.571	0.457
5R7	0.257	-0.686	0.571	0.457	-0.429	-0.200	-0.229	-0.229	-0.457	-0.800	-0.486	0.371
5R8	0.714	0.857	-0.057	0.000	0.886	0.686	0.714	0.714	0.514	0.171	-0.086	0.371
5R9	-0.229	-0.971	0.943	0.914	-0.657	-0.400	-0.057	-0.514	-0.657	-0.857	-0.771	0.771
5R10	0.143	-0.657	0.857	0.771	-0.086	0.029	0.343	-0.029	-0.486	-0.800	-0.686	0.623
5R11	0.571	0.257	0.857	0.829	0.657	0.857	0.771	0.771	0.257	-0.486	-0.686	0.800
5R12	0.826	0.826	0.710	0.739	0.913	0.913	0.971	0.884	0.652	0.478	-0.565	0.797
10R1	-0.514	0.000	-0.943	-0.857	-0.514	-0.829	-0.914	-0.800	0.143	0.086	0.743	-0.914
10R2	0.333	0.652	-0.971	-0.884	0.176	-0.382	-0.441	-0.471	0.594	0.681	0.913	-0.826
10R3	-0.797	-0.478	-0.826	-0.710	-0.797	-0.913	-0.884	-0.855	-0.333	-0.391	0.647	-0.710
10R4	0.257	0.000	-0.514	-0.371	0.029	-0.171	-0.286	-0.257	0.114	-0.200	0.457	-0.514
10R5	0.686	0.771	-0.686	-0.543	0.600	0.286	0.286	0.286	0.714	0.514	0.629	-0.257
10R6	-0.143	-0.829	0.543	0.571	-0.857	-0.771	-0.571	-0.457	-0.657	-0.829	-0.229	0.229
10R7	0.143	-0.429	0.086	0.171	-0.400	-0.457	-0.314	-0.371	-0.571	-0.686	0.000	-0.086
10R8	0.800	0.886	0.200	0.086	0.943	0.943	0.914	0.857	0.629	0.229	-0.229	0.486
10R9	-0.314	-0.857	0.971	0.971	-0.600	-0.571	-0.257	-0.514	-0.571	-0.829	-0.686	0.826
10R10	0.229	-0.543	0.829	0.800	0.000	0.114	0.400	-0.029	-0.486	-0.743	-0.771	0.686

10R11	0.800	0.371	0.714	0.571	0.571	0.829	0.714	0.486	-0.114	-0.543	-0.600	0.771
10R12	0.829	0.886	0.314	0.286	0.943	0.943	0.943	0.857	0.600	0.257	-0.400	0.743
5RP1	-0.486	0.057	-0.971	-1.000	-0.486	-0.857	-0.829	-0.914	0.171	0.286	0.857	-0.857
5RP2	0.229	0.543	-0.971	-0.971	0.057	-0.457	-0.600	-0.514	0.457	0.600	0.857	-0.829
5RP3	-0.800	-0.657	-0.086	-0.086	-0.857	-0.886	-0.800	-0.829	-0.486	-0.600	0.000	-0.257
5RP4	0.029	-0.429	-0.057	-0.057	-0.629	-0.543	-0.629	-0.600	-0.657	-0.657	0.486	-0.486
5RP5	0.629	0.857	-0.771	-0.743	0.771	0.429	0.343	0.314	0.800	0.657	0.714	-0.429
5RP6	-0.200	-0.914	0.800	0.857	-0.739	-0.486	-0.286	-0.514	-0.743	-0.743	-0.686	0.514
5RP7	0.571	-0.429	0.571	0.571	0.286	0.486	0.400	0.000	-0.229	-0.543	-0.171	0.257
5RP8	0.826	0.971	-0.188	-0.043	0.942	0.884	0.797	0.768	0.768	0.529	0.130	0.333
5RP9	-0.286	-0.857	0.971	0.943	-0.629	-0.371	-0.171	-0.257	-0.514	-0.800	-0.743	0.771
5RP10	0.286	-0.743	0.886	0.829	-0.029	0.200	0.343	-0.114	-0.457	-0.657	-0.657	0.657
5RP11	0.571	0.000	0.800	0.771	0.686	0.743	0.771	0.600	0.057	-0.314	-0.629	0.771
5RP12	0.657	0.800	0.657	0.600	0.829	0.886	0.943	0.800	0.457	-0.029	-0.457	0.652
10RP1	-0.500	0.200	-0.971	-0.943	-0.457	-0.743	-0.800	-0.800	0.200	0.371	0.800	-0.800
10RP2	0.457	0.743	-0.943	-0.886	0.343	-0.400	-0.486	-0.457	0.629	0.600	0.857	-0.857
10RP3	-0.571	-0.371	-0.657	-0.514	-0.771	-0.800	-0.714	-0.829	-0.343	-0.391	0.457	-0.600
10RP4	0.343	0.000	-0.657	-0.629	-0.229	-0.457	-0.343	-0.486	-0.086	-0.188	0.800	-0.829
10RP5	0.714	0.657	-0.571	-0.514	0.657	0.400	0.343	0.171	0.657	0.536	0.629	-0.114
10RP6	-0.333	-0.768	0.333	0.333	-0.739	-0.594	-0.623	-0.652	-0.710	-0.797	-0.043	-0.072
10RP7	0.114	-0.543	0.314	0.229	-0.457	-0.314	-0.371	-0.543	-0.429	-0.514	-0.114	-0.200
10RP8	0.857	0.714	-0.314	-0.286	0.800	0.771	0.714	0.686	0.629	0.257	0.343	0.057
10RP9	-0.057	-0.829	0.943	0.943	-0.286	-0.029	0.286	-0.200	-0.457	-0.714	-0.771	0.714
10RP10	0.314	-0.629	0.943	0.829	-0.086	0.200	0.429	0.000	-0.514	-0.714	-0.629	0.600
10RP11	0.886	0.314	0.629	0.629	0.829	0.800	0.857	0.857	0.143	-0.086	-0.629	0.743
10RP12	0.857	0.829	0.629	0.629	0.857	0.914	0.943	0.857	0.600	0.343	-0.514	0.829
5P1	-0.743	-0.171	-0.914	-0.829	-0.686	-0.857	-0.857	-0.943	-0.114	-0.086	0.600	-0.629
5P2	-0.343	0.057	-0.914	-0.914	-0.171	-0.571	-0.743	-0.800	0.400	0.429	0.800	-0.800
5P3	-0.714	-0.514	-0.286	-0.200	-0.829	-0.886	-0.829	-0.829	-0.600	-0.686	0.057	-0.257
5P4	-0.304	-0.478	-0.536	-0.507	-0.507	-0.478	-0.478	-0.739	-0.420	-0.478	0.565	-0.623
5P5	0.543	0.743	-0.629	-0.543	0.743	0.486	0.400	0.257	0.743	0.400	0.400	-0.086
5P6	-0.400	-0.943	0.600	0.600	-0.914	-0.743	-0.686	-0.629	-0.686	-0.771	-0.286	0.286
5P7	0.057	-0.429	0.457	0.314	-0.057	0.200	0.086	-0.143	-0.086	-0.400	0.057	0.229
5P8	0.286	0.857	0.000	0.086	0.857	0.800	0.857	0.514	0.829	0.314	0.072	0.143
5P9	-0.429	-0.743	0.886	0.886	-0.600	-0.429	-0.029	-0.543	-0.457	-0.657	-0.857	0.771
5P10	-0.200	-0.714	0.943	0.971	0.114	0.429	0.571	-0.171	-0.200	-0.600	-0.514	0.826
5P11	0.114	0.029	0.886	0.886	0.714	0.943	0.914	0.314	0.029	-0.143	-0.571	0.829

5P12	0.371	0.629	0.743	0.743	0.914	0.857	0.886	0.457	0.429	0.229	-0.514	0.797
10P1	-0.743	-0.029	-0.886	-0.914	-0.629	-0.829	-0.743	-0.857	0.143	0.286	0.800	-0.800
10P2	-0.086	0.400	-0.914	-0.971	-0.114	-0.514	-0.629	-0.686	0.400	0.486	0.886	-0.829
10P3	-0.771	-0.686	-0.200	-0.257	-0.914	-0.857	-0.771	-0.829	-0.714	-0.686	0.057	-0.029
10P4	-0.014	-0.101	-0.826	-0.681	-0.188	-0.391	-0.536	-0.507	-0.072	-0.275	0.797	-0.710
10P5	0.710	0.739	-0.797	-0.710	0.623	0.304	0.130	-0.188	0.710	0.768	0.855	-0.623
10P6	-0.571	-0.800	0.571	0.571	-0.800	-0.829	-0.686	-0.657	-0.714	-0.771	-0.478	0.314
10P7	0.114	-0.543	0.743	0.571	0.029	0.286	0.343	-0.057	-0.286	-0.514	-0.514	0.429
10P8	0.771	0.743	0.086	-0.057	0.886	0.886	0.886	0.600	0.543	0.171	0.086	0.314
10P9	-0.333	-0.739	0.971	1.000	-0.623	-0.420	-0.159	-0.594	-0.536	-0.768	-0.768	0.739
10P10	0.057	-0.743	0.886	0.914	-0.057	0.143	0.314	-0.143	-0.400	-0.743	-0.857	0.800
10P11	0.314	-0.200	0.829	0.886	0.514	0.857	0.686	0.429	0.171	-0.229	-0.600	0.629
10P12	0.543	0.800	0.571	0.629	0.943	0.914	0.943	0.686	0.629	0.000	-0.457	0.657
5PB1	-0.714	0.200	-0.800	-0.800	-0.457	-0.743	-0.686	-0.714	0.286	0.314	0.629	-0.543
5PB2	-0.371	0.486	-0.829	-0.800	-0.057	-0.457	-0.486	-0.514	0.571	0.543	0.657	-0.629
5PB3	-0.800	-0.486	-0.229	-0.171	-0.600	-0.743	-0.600	-0.800	-0.429	-0.486	-0.286	0.057
5PB4	-0.629	-0.257	-0.486	-0.371	-0.629	-0.629	-0.543	-0.657	-0.257	-0.457	0.086	-0.229
5PB5	0.000	0.571	-0.629	-0.514	0.486	-0.229	-0.086	-0.086	0.657	0.371	0.514	-0.343
5PB6	-0.657	-0.771	0.543	0.629	-0.743	-0.771	-0.657	-0.714	-0.571	-0.657	-0.314	0.257
5PB7	-0.200	-0.057	0.314	0.171	0.057	-0.143	0.114	-0.086	0.057	-0.286	-0.229	0.286
5PB8	0.000	0.743	-0.286	-0.114	0.829	0.543	0.714	0.429	0.771	0.514	0.086	0.143
5PB9	-0.457	-0.771	0.914	0.829	-0.429	-0.486	-0.143	-0.486	-0.543	-0.657	-0.829	0.857
5PB10	-0.343	-0.657	0.829	0.829	-0.171	-0.086	0.171	-0.314	-0.171	-0.486	-0.800	0.714
5PB11	-0.257	-0.314	0.771	0.829	0.371	0.314	0.571	-0.029	0.029	-0.171	-0.771	0.686
5PB12	0.086	0.743	0.543	0.343	0.771	0.771	0.743	0.543	0.594	0.429	-0.486	0.714
10PB1	-0.800	-0.143	-0.800	-0.686	-0.600	-0.714	-0.629	-0.743	-0.057	0.114	0.429	-0.457
1PB2	-0.486	0.286	-0.800	-0.771	-0.229	-0.400	-0.429	-0.629	0.343	0.514	0.686	-0.743
10PB3	-0.743	-0.457	-0.486	-0.514	-0.600	-0.714	-0.600	-0.686	-0.314	-0.400	0.200	-0.343
10PB4	-0.229	0.171	-0.771	-0.657	-0.029	-0.343	-0.457	-0.486	0.314	0.257	0.486	-0.543
10PB5	0.229	0.571	-0.743	-0.543	0.686	0.171	0.143	-0.057	0.629	0.629	0.543	-0.371
10PB6	-0.600	-0.771	0.800	0.714	-0.714	-0.686	-0.371	-0.600	-0.686	-0.771	-0.686	0.600
10PB7	-0.200	-0.543	0.829	0.600	-0.114	0.086	0.286	-0.229	-0.229	-0.457	-0.514	0.629
10PB8	0.114	0.686	0.000	0.143	0.714	0.571	0.571	0.400	0.771	0.371	0.086	0.257
10PB9	-0.600	-0.686	0.886	0.857	-0.429	-0.457	-0.114	-0.514	-0.514	-0.629	-0.829	0.771
10PB10	-0.314	-0.743	0.857	0.800	-0.429	-0.200	-0.086	-0.343	-0.257	-0.600	-0.600	0.743
10PB11	-0.200	-0.257	0.886	0.714	0.314	0.371	0.571	0.143	0.086	-0.314	-0.657	0.743
10PB12	-0.086	0.457	0.714	0.629	0.686	0.771	0.857	0.457	0.429	0.171	-0.543	0.800

N1	-0.400	-0.800	0.943	0.914	-0.629	-0.543	-0.200	-0.400	-0.457	-0.657	-0.857	0.857
N2	-0.571	-0.857	0.914	0.914	-0.571	-0.714	-0.114	-0.429	-0.486	-0.743	-0.886	0.771
N4	-0.657	-0.914	0.657	0.486	-0.914	-0.800	-0.743	-0.657	-0.686	-0.714	-0.571	0.457
N6	-0.771	-0.543	-0.229	-0.257	-0.857	-0.943	-0.714	-0.886	-0.486	-0.657	-0.029	-0.143
N8	-0.714	-0.229	-0.971	-1.000	-0.571	-0.914	-0.886	-0.886	0.029	0.086	0.714	-0.743
N9.5	-0.486	0.600	-0.971	-1.000	-0.114	-0.743	-0.486	-0.629	0.571	0.714	0.771	-0.657