



Effects of colour towards underwear choice based on electroencephalography (EEG)

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ABSTRACT

The purpose of this paper is to investigate whether colours as stimuli can affect underwear choice based on consumers' EEG recording as biological response to elicit preferences towards underwear products. The study employs applications of neuroscience methods to analyse the physiological choice process. Twenty underwear buyers were asked to evaluate several underwear colours (red, white, blue, brown, grey and black) by using wireless EEG headset with 6 channels to collect EEG signals from participants' frontal, temporal and occipital brain areas that can give us a measure to estimate consumers' choice. The result indicated there was a clear and significant change ($p < 0.05$) of EEG brain waves activities of right and left hemisphere in the frontal (F3 and F4), temporal (T7 and T8), and occipital (O1 and O2) brain areas when participants indicated their preferred colour. Additionally, based on the results female consumer prefers underwear which has red colour while male consumer prefers white colour. This research would essentially contribute in enriching marketing research method by using more advanced experimental designs rather than traditional marketing research methods.

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CHINESE ABSTRACT

本文的目的是研究作为刺激因素的色彩是否会影响基于消费者 EEG 记录(作为生物反应引起的内衣产品偏好)的内衣选择。该研究采用神经科学方法来分析生理选择过程。请 20 位内衣购买者使用 6 通道无线 EEG 头戴式设备评估几种内衣颜色(红色、白色、蓝色、棕色、灰色和黑色),并收集参与者额叶、颞叶和枕叶脑区的 EEG 信号,为我们提供估计消费者选择的量度。结果表明,在参与者指示其喜欢的颜色时,额叶(F3 和 F4)、颞叶(T7 和 T8)和枕叶(O1 和 O2)脑区左右半球的 EEG 脑电波活动出现明显而显著的变化 ($p < 0.05$)。此外,根据研究结果,女性消费者更喜欢红色内衣,而男性消费者更喜欢白色内衣。这项研究将使用更先进的实验设计,而非传统的营销研究方法,在本质上有有助于丰富营销研究方法。

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1. Introduction

Consumer choice towards the product is one of the fundamental units of consumer behaviour analysis. It is hard to identify consumer choice towards underwear products because underwear market is characterized by the variety of categories and types; also, there is very limited research about consumer rationales and decision when choosing underwear product (Hale and Hodges 2013). Underwear currently become a rapidly growing and sizeable product category in the apparel market, align with the population growth rate and changing attitudes (Askin, 2004; Capelaci, 2006; Hume and Michael, 2013). Thus the research in this product category area is very required to meet consumer needs, help marketers reach their

target markets to be more efficient, and guide the marketing strategy process of underwear product.

Based on previous research, colour is one of the main intrinsic cues that are considered when consumers choose underwear product (NPD Fashion World, 2015). Colour as product attribute plays a significant role in affecting consumers' visual perceptions. It can arouse the visual system and can increase visual attention, influencing the interactions between individuals and objects. According to Berger and Fitzsimons (2008), colour is probably the most visible element in the product that can affect product accessibility, even in noisy real-world consumer environments, also plays a very crucial role when consumers evaluate the product quality.

To investigate the effect of colour towards underwear choice, many researchers start to use consumer neuroscience, the emerging interdisciplinary field of marketing, which combines psychology, neuroscience, and economics to study how the brain is physiologically affected by marketing stimuli (Lee et al., 2007). It can link

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consumer choices to marketing research (Camerer et al., 2004; Pirouz, 2007; Plassmann et al., 2012). The human brain activity as a biological response of consumers that happened during evaluation of products cannot be manipulated because the subconscious process involves multiple areas of the brain. With such characteristics, it can provide marketers with information that is not obtainable by using conventional marketing research methods (Ariely and Berns, 2010), because in fact when conducting marketing research, most of the people cannot fully explain what they want or do not want to reveal their preferences when explicitly asked. Human behaviour mostly is driven by processes operating below the level of conscious awareness (Calvert and Brammer, 2012). In such cases, the effectiveness of the marketing strategies can be evaluated by monitoring consumers' brain activity. It will provide evidence of how product cues related to sensory inputs (visual) can influence consumer's choice and offer the hope of characterizing decision process in consumers (Astolfi et al., 2009; Ohme et al., 2009).

The primary goal of this research is to detect the changes in the electroencephalogram (EEG) recording (changes in the brain signals), which areas of the brain react towards colour presentation in underwear products. Previous research (Kenning and Plassmann, 2008; Kushaba et al., 2013) did not provide information about the process of preference formation/choice based on colour, especially in underwear product. This research sets out to address the research gap by examining what colour can attract consumers when choosing underwear and is therefore significant in two ways. First, it focuses on underwear, an under-studied product category in fashion. Second, it applies a neuroscience application to explore the choice process by the fact that underwear is an intimate apparel that is very private for most of the people. They might feel uncomfortable and not reveal "what they feel" and "what are their preferences" towards underwear product. Thus the neuroscience application method is more suitable to know the underwear consumer choice because we can get the hidden thought of consumers.

2. Literature review

2.1. Consumer choice and visual sensory system

Consumer choice is the process of determining what options are available, and then choosing the most preferred one by referring to some consistent criteria and mostly influenced by the sensory aspects of a product (Alpert et al., 2006; Bloch et al., 2003; Bone and Jantrania, 1992; Hagtveldt and Patrick, 2008; Morrin and Ratneshwar, 2000; Peck and Childers, 2003). It found that these sensory experiences are more detailed and enable individuals to be confident about their choice (Schifferstein and Cleiren, 2006).

The most powerful human senses is visual sensory, and it is also the most seductive because it enables consumers to experience beauty only by looking at the product item, and this clearly plays a significant role in the evaluation of products' quality. It will affect subsequent willingness to accept a product (Fiore, 2000). By knowing the human visual system, we can discover changes and differences when consumers see the product and the visual system probably the most significant to the aesthetical experience that derived from products.

Affecting consumer's visual sensory by visual stimuli is the effective way to obtain an individual's attention. Research on visual stimuli in consumer behaviour has predominantly focused on visual aesthetic experience (Bloch et al., 2003; Desmet and Hekkert, 2007). Visual aesthetic experience refers to emotions and feelings derived from non-instrumental qualities of a product (Hirschman and Holbrook, 1982). These visual responses based on product cues, such as colour can lead to influence consumer choice by differentiating from competitors in a chaotic market. (Gutjar et al., 2014).

Many researcher and marketers try to rationalize it and try to imply the pattern of consumer choice precisely by the vast range of alternative models. Nowadays, there is certainly room for improvement; the electroencephalogram (EEG), which is one of the consumer neural activity measurements, has been found to predict consumer's choice. In this research, we focused on a specific cue, "colour" in underwear product, exposed towards consumers.

2.2. Colour

Colour is one of the product attributes that play an important role in affecting consumers' visual perceptions. Visual perception since the first encounter with products will affect subsequent willingness to accept a product. Colours can increase visual attention that leads to an aesthetic evaluation of the products. The visual attention to the product had a strong association and affected consumer willingness to choose (Fiore, 2000). This statement was supported by Leatrice Eiseman research, in Peng (2009), that found colour can dominate the attention of consumers and cause their emotional reactions. Besides, the study suggests that colour not only shows the performance of products but also pass itself rational and emotional influence.

Within the context of consumer choice and decision making, colour has been defined as an extrinsic cue and is probably the strongest and most visible element of any clothing product. Previous studies (Albers, 1963; Banks and Fraser, 2004; Birren, 1978; Bourgoes, 1997) have pointed out that colour is the most powerful product attribute for consumers. Colour preference influences judgements of consumers and plays an important role to stimulate consumption (Kao, 2009), because it can give a significant effect on consumers' emotions and plays a vital role when consumers evaluate the product's quality. Colour stimuli that carry positive meaning produce approach responses, whereas those that give a negative meaning produce avoidance responses (Berger and Fitzsimons, 2008). Colours can help differentiate a product and influence product evaluations (Gorn et al., 1997; Macklin, 1996) and also sell products.

Different colours have a different influence on people. When consumers see colours, they attach meanings, feelings, and symbolism to them. Researchers have found many similarities between consumers' associations with colours. Marketers use the knowledge of how consumers respond to colour to help clearly communicate a product's message and attributes. This knowledge is also used to differentiate a product from competitors, hopefully resulting in a purchase.

There are some colour associations. Brighter colours (e.g., white, pink, red, yellow, blue) elicit more positive reactions (e.g., happy, excited, relaxation) than darker colours (e.g., brown, black). One of the clothing products that have a variety of colour is underwear. Underwear with the same types is often sold in a different colour or different packaging colour. However, there is no colour preference research on underwear product that has been studied and this remains unknown. It raised a question on whether colours can influence consumers' choice and whether they showed colour preference on underwear products.

2.3. Human brain

The human brain is the command centre for the human nervous system. It receives input from the sensory organs and sends output to the muscles. The human brain is divided into two hemispheres, left and right. The cerebral cortex brain area is split into four sections, which are known as lobes. The frontal lobe, parietal lobe, occipital lobe, and temporal lobe have been associated with different functions (Allen et al., 2002). One way to address whether colours as stimuli can influence underwear choice based on consumers' brain response is to record from multiple brain regions simultaneously

while subjects perform decision tasks (Lee et al., 2007). In this research, we will focus on frontal lobe that can draw consumer choice process. The frontal lobe is located at the front of the brain and associated with reasoning, motor skills, higher level cognition, and decision process (Plaus, 1993). This area of the brain receives information from various lobes of the brain, organize and utilizes the information to choose a course of action, to summon drive to execute the action, and remain attentive and resist distraction (Kosslyn and Koenig, 1994).

2.4. Electroencephalography (EEG)

Electroencephalography (EEG) is a popular research tool among scientists for evaluating somatosensory responses towards stimuli. It can also be used to get consumer's deeper reactions to various marketing stimuli (Ariely and Berns, 2010; Ohme et al., 2009; Wilson et al., 2008; Zurawicki, 2010). The current marketing research has employed EEG data to understand consumers' responses towards various forms of advertising (Morrin and Ratneshwar, 2000; Ohme et al., 2009; Vecchiato et al., 2011) as well as their taste preferences (McClure et al., 2004; Plassmann et al., 2008). The general assumption is that human brain activity can provide marketers with information not obtainable via conventional marketing research methods (e.g., interviews, questionnaires, focus groups) (Ariely and Berns, 2010). It is mainly driven by the fact that people cannot fully explain their preferences when explicitly asked in the level of conscious awareness (Calvert and Brammer, 2012).

The EEG records are seen as an indicator of consumer's real response because there are several activations in particular regions in the brain that may suggest the consumer's unfiltered response (Davidson, 1992). The EEG records are seen as an indicator of consumer's real response because there are several activations in particular regions in the brain that may suggest the consumer's unfiltered response (Davidson, 1992). In addition, by using EEG it is possible to gather immediate feedback to presented stimuli as fluctuations in brain signal frequencies to learn more about emotion, judgement, and attention (Davidson, 1992; Fugate, 2007; Vecchiato et al., 2011). EEG also provides a richer context to understand consumer behaviour and it links consumer choices and decision-making to marketing research (Plassmann et al., 2008).

Over 70 published studies have now examined the relationship between emotion or emotion-related constructs and asymmetries in electroencephalographic (EEG) activity in the frontal cortex. A review of these studies suggests that asymmetries in frontal EEG activity respond to emotional stimuli and changes in emotional state (Coan and Allen, 2003). Explanations of the research have suggested that relatively greater left frontal activity is associated with positive affect emotion, and that relatively greater right frontal activity correlated with negative affect emotion (Davidson, 1998).

Frequency and amplitude are the characteristics of the recorded EEG patterns. The frequency range is usually from 1–80 Hz (divided into alpha bands, beta band and more), with amplitudes of 10 to 100 microvolts. The frequency divided into distinct groups frequency ranges into particular states of mind. The main spectral bands of Delta (0–4 Hz), Theta (3–7 Hz), Alpha (8–12 Hz), Beta (13–30 Hz), and Gamma (30–40 Hz) were observed to examine consumers' cognitive or affective processes in response to marketing stimuli (Aurup, 2011; Bourdaud et al., 2008; Custidio, 2010; Kawasaki and Yamaguchi, 2012; Kushaba et al., 2013; Mostafa, 2012; Ohme et al., 2009). However in this research we use Beta waves activity that related to an active state of mind, most prominent in the frontal cortex and over other areas during intense mental activity (Jasper, 1958).

Based on the preceding discussion, an interesting question has emerged, forming the objectives of this study to investigate whether

colours as stimuli can affect underwear choice based on consumers' EEG recording as a biological response to elicit their preference towards underwear products.

RQ1: How does colour influence consumer's choice of underwear products?

RQ2: Will consumers differ in their choice towards different underwear colours?

Furthermore, it has been noted in the literature that colour can influence consumers on product considerations and evaluations (Gorn et al., 1997; Macklin, 1996). As such, it is of great interest to determine if consumers will show differing choice towards different colour products. The following hypotheses were proposed:

H1. Underwear colour stimulus can modulate the neural activities in frontal brain area.

H2. Colour can influence consumer's choice of underwear product.

3. Methodology

3.1. Participants

The participants for this research are underwear buyers and targeted towards both genders, male and female. They must meet the study criteria: have normal or corrected vision, not in the process of psychoactive medication, with neither a history of neurological nor psychiatric disturbances, right-handed as assessed by the Edinburgh Handedness Inventory, purchased underwear product during the past 2 months prior to the study and have monthly spending over 3 billion IDR that indicates their spending power is high and are appropriate sample for this research because they have the ability to purchase freely. In this experiment, judgemental sampling technique was conducted. The sample size for the test is 20 participants and consists of ten females and ten males.

3.2. Experiment instrument

The brainwave data collection process employed Emotiv EPOC, a high-resolution wireless EEG neuroheadset. It consists of 14 EEG channels that represent five brain part, coded by the electrode position and hemisphere position according to the International 10–20 system forming seven sets of symmetric channels as shown in Fig. 1. The experiment used several software programs, consists of: (1) OpenViBE 0.13.0 for creating data recording scenarios; (2) EPOC Panel control (Emotiv Software Development Kit) to ensure no data loss, a writable marker trace to ease single trial segmentation tasks, and real-time sensor contact display to ensure quality of measurements; and (3) Matlab R2009a which complemented with EEGLAB for data recording and data processing.

3.3. Experiment procedure

First, the baseline of participant brain wave was measured through Emotiv EPOC; in this process, participants closed their eyes while being measured. Then, several different colours (with the same style) of underwear photos (stimulus) were shown to the participants to know their neural responses (Fig. 2). The electrodes were placed on F3–F4 sites. Each stimulus is shown in 5s with 5s *inter-stimulus-interval* (ISI). This experiment will be repeated three times with the *inter-block interval* (IBI) 10–15 minutes. The sequence of underwear colour stimulus appearance can be seen in Table 1.

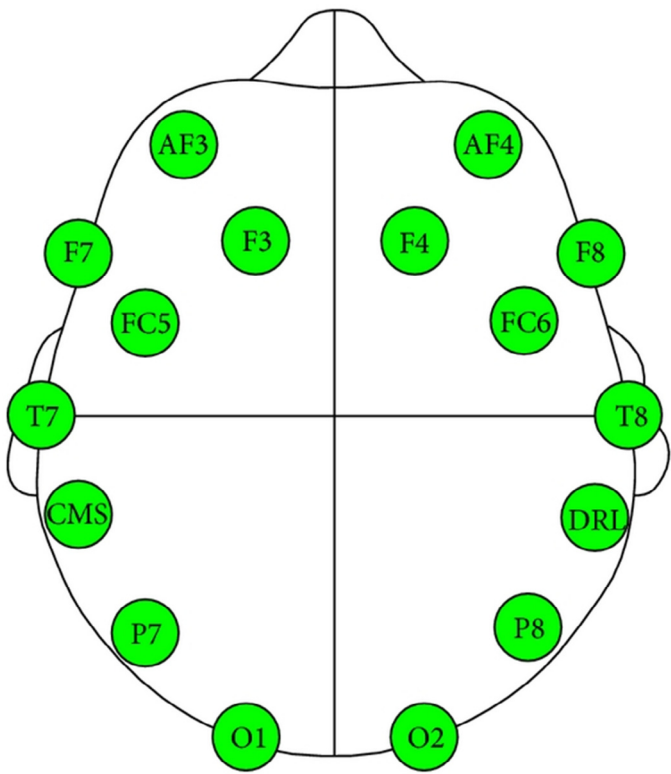


Fig. 1. Emotiv EPOCs electrode position.

3.4. Data processing and analysis

The raw data from Emotiv Epoc neuroheadset were being translated to numeric data in CSV file form. Then, the raw data were processed through several stages: (1) *Offset removal* is the noise waveform (waves with 0 frequency) filter (band-pass filter); (2) *Artefact removal* is filter for the artefacts waveform due to participant's muscle movement such as eye blinking or head movements; and (3) *Separation of beta wave* data from other brain waves with the filtering process using the filter beta waves (13–30 Hz).



Fig. 2. Underwear colour stimulus.

Table 1
The sequence of underwear colour stimulus appearance.

Block	
1	Run 1
	Run 2
	Run 3
	Run 4
	Run 5
2	Run 1
	Run 2
	Run 3
	Run 4
	Run 5
3	Run 1
	Run 2
	Run 3
	Run 4
	Run 5
Run	
Male sequence	
1	Black, White, Grey, Red, Blue
2	White, Grey, Red, Blue, Black
3	Grey, Red, Blue, Black, White
4	Red, Blue, Black, White, Grey
5	Blue, Black, White, Grey, Red
Run	
Female sequence	
1	Black, White, Brown, Red, Blue
2	White, Brown, Red, Blue, Black
3	Brown, Red, Blue, Black, White
4	Red, Blue, Black, White, Brown
5	Blue, Black, White, Brown, Red

4. Results and discussion

In this experiment, the beta brainwaves amplitudes of male and female participants were increased compared with baseline values after the underwear colour stimuli were given towards them as shown in Fig. 3 and Fig. 4. This results indicated underwear colour stimulus generally can modulate the activity of neurons in frontal brain area to become more active, which is due to the transient effects of underwear colour stimulus in the visual pathway as natural adaptations towards the environmental conditions (Vandewalle et al., 2007). Although there are some data that contradict our prediction of elicitation of stronger brain activity by colour, in female participant results the beta brainwaves in left frontal lobe (F4) were not increasing when red colour stimulus appeared. This fact was possibly caused by problems in stimulus information processing

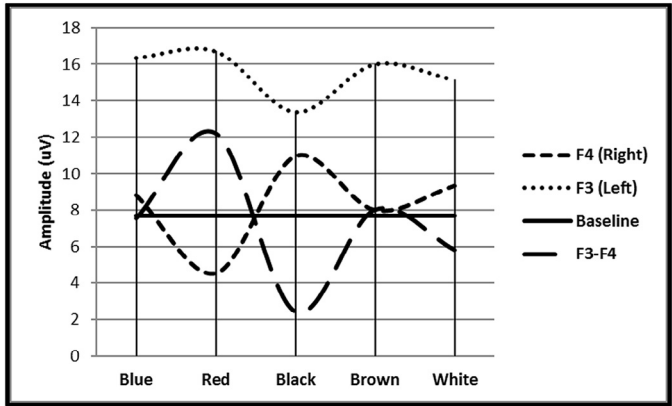


Fig. 3. The female consumer β frontal brain waves mean difference during underwear colour stimulus exposure.

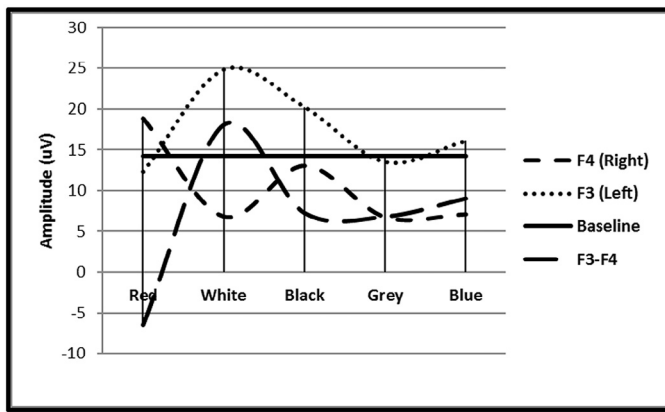


Fig. 4. The male consumer β frontal brain waves mean difference during underwear colour stimulus exposure.

system that happened because of too much eye and body movements as stated in the previous research (Christopher et al., 2012).

Each pair of electrodes from the left and the right hemispheres was analysed together in the frontal brain area that was studied. Data pooling of beta wave spectrum in channel F3 was compared with channel F4 (Frontal Lobes) to determine EEG asymmetry for the left hemispheres (F3) and right hemispheres (F4) as stated in Davidson (1992).

For results regarding female participants (Fig. 3), the amplitude value of frontal lobe in left hemisphere was higher than right hemisphere ($F3 > F4$). Based on paired sample t-test in each lobe, there was significant difference between amplitude activity in the left and right hemisphere, $F3-F4$, $t(8.25) = 6.331$, $p < 0.05$. This result shows female participants had positive emotion response towards all underwear colour stimuli when the stimuli were given. Based on previous research, larger activations in the left hemisphere are the indication of happiness, amusement, and positives emotions; however, greater activations in the right hemisphere indicated disgust and negative emotions (Davidson et al., 1990).

Furthermore, the One-Way ANOVA test results showed there was a real difference between the beta waves amplitude value of each underwear colour stimulus in $F3-F4$, $p = 0.00 < 0.05$. The results indicate that female participants had different brainwave response towards each underwear colour stimulus. The amplitude value of the red colour stimulus was the highest among all colour stimuli while black colour was the lowest. Based on the results we can conclude that female participants were giving the highest response towards red colour and the lowest response towards the black colour. The result was supported by Bagchi and Cheema (2013) and Roberts et al., 2010, who stated that red colour is more likely to enhance the brain response of consumers, while black colour entailed eye-strain and tiredness.

For male participants (Fig. 4), the beta brainwaves amplitude frontal lobe value in left hemisphere was higher than right hemisphere ($F3 > F4$). Based on paired sample t-test, there was significant difference between amplitude activity in the left and right hemisphere, $F3-F4$, $t(16.404) = 9.552$, $p < 0.0$, that indicates male participants had a positive response towards all underwear colour stimuli given except for red colour stimulus ($F3 > F4$). These data showed that male participants had negative emotions response towards the red colour stimulus. Also, male participant data were analysed by using One-Way ANOVA test. The result shows there is a significant difference between beta waves amplitude of male participants of each underwear colour stimulus in $F3-F4$, $p = 0.00 < 0.05$, that indicates the male participant responds differently towards each underwear colour stimulus. The beta brainwaves amplitude value in white colour stimulus

is the highest than another underwear colour stimulus, while red colour is the lowest. Based on the results, the male participants give the lowest response towards the red colour stimulus and tend to give the highest response towards white colour. These results were different from previous research (Pryke, 2009) that had the high response towards chromatic colours rather than achromatic colour (white).

Conclusively, H1 which tested that underwear colour stimulus can modulate the neural activity in frontal brain area was accepted, because based on the results we can see that colour stimulus generally can modulate the activity of neurons in frontal brain area to become more active. H2 which tested the influence of colour to consumer's choice towards underwear product was also accepted. Based on the results we can see that overall, colour can influence consumers' emotion that leads to induce and drive them to be attracted and choose underwear, consumers have any favourable neural response to a particular underwear colour, and male underwear consumer has the highest response towards white colour while female towards red colour.

Gorn et al. (2004) and Valdez (1993) had shown that the positive response of consumers towards colour attributes can lead them in choosing the product. The positive and highest brain response results of female consumers towards red colour can induce and drive female participants to be attracted and to prefer red colour underwear, while male participants towards white colour.

5. Conclusion and implications

The findings indicated that colour has a positive influence and can affect consumers' choice of underwear products. Colour stimulus affecting consumer's choice was assessed in lobus frontal (F3 and F4), as it has noted in the literature that colour can influence consumers during product considerations and evaluations (Gorn et al., 1997; Macklin, 1996). Furthermore, consumers showed different choice towards different underwear colour. They give more favourable neural response to a particular underwear colour rather than others, such as male underwear consumer prefers white colour while female prefers red colour. This study can extend the consumer's choice theory even further. Combining it with neuroscience approach to fully explore the decision-making process from the perspective of underwear consumers' neural response (EEG) can give objective and honest information about the inner workings of the consumers' brains by analysing their biological response, which cannot be manipulated. The findings also will produce a framework for further research. It will enrich the knowledge, especially for underwear business in the academic area, and create a theory that is relevant to consumer behaviour area. As for practical contribution, this study provides information about design and presentation of products to optimize them to be as compatible as possible with consumer preferences because it is important to improve the way companies create and promote underwear products that are more interesting, attractive, and valuable for the consumer, and satisfy consumer needs. Therefore, underwear companies should be aware of this while doing product colour planning and choose carefully the dominant underwear colours that they will provide in their store so as to adjust them to their target consumers. They should also take into account the aesthetic and functional impact of those colours.

However, this paper is not without its limitations. First, the generalization cannot be made to other fields or sectors as the scope of the study covers only a single product category, underwear product. Second, the study only focuses on colour and neglects other product cues and other psychographic variables that can influence consumers' choice. Third, this research just focuses on young underwear shoppers. Lastly, the study only captured consumers' response and conduct in laboratory scale. This study does not necessarily translate into actual purchase intentions or consumption

behaviours, and for future research we can conduct field experiment in the store rather than in laboratory using eye tracker, so the consumer's choice prediction will be more accurate. Also, future studies should address this limitation by extending the framework of the study to incorporate the factor that can influence consumers' choice towards purchase intention of underwear product.

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