

The Colour-Emotion Association

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Abstract. It is suggested that there might be an association between colour and emotion. Most of previous research in this field did not investigate this topic from different perspectives (e.g., interpersonal, subjective). Therefore, this paper reviews several recent studies on the colour-emotion association to demonstrate how their results can specify and deepen the understanding about colour-emotion association. Studies on the subjective feeling of colour found that the effects of colour stimuli are not only determined by hue, but also by a combination of effects from the three dimensions of colour: hue, lightness, and saturation. Other studies explored the relationship between colour and expressive emotion through facial colour to analyse the association in social interaction. They identified the effects of facial colour on emotion interpretation, the recognition of facial emotions, and emoticons (emoji). Additionally, they compared the effects of facial colour with the background colour. Finally, some studies attempted to identify the mechanisms of colour-emotion associations. The mapping between the representational dimensions of colour and emotion revealed colour temperature as a mediator, with cultural and personal differences as secondary associations. Machine learning classifiers also quantified the influence of cultural differences on this relationship. It was suggested that different cultures can share common colour-emotion associations to some extent. Plus, there are specific associations related to each culture. Future studies could advance their research design by controlling colour stimuli in the three dimensions, applying different methods to assess emotional responses, and constructing experimental settings closer to real life. This paper can provide some guidance for future research to examine colour-emotion associations more systematically. It can also give some suggestions to the design of emotion related curriculum at school.

Keywords: Colour-emotion association; Culture difference; Facial coloration.

1. Introduction

One can think of perceived colour as the physical properties of an object reflecting part of the spectrum, which is then received by the photoreceptor cells of the human eye. These signals were projected into the brain for colour recognition. They can represent a huge range of colours that differ in three basic dimensions: hue (i.e., the term used to label colours, such as blue), luminance/lightness (i.e., the intensity of light reflected by an object to the eye) and chromaticity (i.e., also known as chroma, indicating the intensity of a hue, which can be changed by adding white, black and, grey) [1]. Colour contains information that is beneficial to human survival. For example, it can help people hunt for food by distinguishing between red ripe fruit and green leaves in the background. The study of colour allows different perspectives to be taken: colour properties in physics, colour processing in neuroscience, and colour terminology in linguistics. However, the human perception of colour goes beyond the simple reception of physical stimuli and the physiological action of neurons. For example, the illusion of colour constancy allows people to perceive the colour of an object that remains the same regardless of changes in illumination [1]. As changes in illumination change the reflected light to activate neurons differently, people can ignore this effect and recognize that the colours are constant. This illusion reveals the underlying psychological processes in colour perception.

Emotions are psychological states that represent the feelings people derive from their experiences and influence human behaviour [2]. Human emotions can be divided into three different components: physiological, subjective, and expressive [2]. Emotions represent the physiological response of humans to the outside world. For example, when people see tigers, they usually feel fear. As a result,

they tend to avoid approaching them. This adaptive behaviour to the challenges and dangers encountered in the environment is an evolutionary gift of humans [2]. Expressive emotions also play a crucial role in human social life, providing additional cues to the physical and psychological state of humans. It helps to construct effective interpersonal communication [3]. It is common to observe the collaborative influence of colour and emotion on people's behaviour. For example, in marketing design, the colours of product packaging are carefully designed to ensure that customers feel positive emotions about the product and elicit the desire to purchase. This has led people to consider the possible links between colour and emotion.

The colour-emotion associations could be inferred intuitively from people's usage of colour terms to express emotions. For example, people often associate blue with negative emotions, such as sadness and cold, while red is often associated with positive emotions, such as activation and warmth. Based on conceptual metaphor theory, this use of colour terms may serve to concretize the meaning of abstract concepts, such as emotions [3]. However, these associations, summarized through people's subjective feelings, are low in reliability and further scientific evidence is needed to make them more convincing. Later, clinical observations of people's physiological responses to different colour stimuli provided further support for these intuitive associations. Colours, such as yellow and red, can increase the attraction of external objects and stimulate responses. In contrast, colours, such as green and blue, were found to make people calm and relaxed and focus more on internal sensations [4]. According to the Biopsychosocial Model of Challenge and Threat, emotions can be distinguished between approach and avoidance, which may elicit specific physiological response patterns [5]. For example, challenge (i.e., approach orientation) can stimulate blood flow, whereas threat (i.e., avoidance orientation) can constrain blood flow. However, these physiological results do not reflect the entire domain of colour-emotion associations, as human emotions can be represented not only from physiological responses, but also from people's subjective feelings and interpersonal expressions. Furthermore, there are other factors in colour-emotion association. Red can be associated with positive emotions in some cultures, but in other cultures, it may also be associated with negative emotions, such as anger. This phenomenon reminds scientists to further address the underlying patterns of colour-emotion associations and the influences involved with them, to clarify the mechanisms underlying these associations.

Therefore, current research builds on previous work by discussing different experimental methods, different measures of emotional response, and different testing contexts, to understand colour-emotion associations more closely. It included findings from different perspectives to deepen understanding of colour-emotion associations. The purpose of this review is to provide a summary of the current research state, by discussing the most recent research in colour-emotion associations. It can provide some suggestions for future psychological research in this area. In addition, it can provide some guidance to relevant emotion related education programs for children.

2. Revisiting the Intuitive Subjective Summary of Colour-Emotion Association

According to embodied cognition, colour processing can elicit physiological responses in humans and thus evoke emotional states. And further based on ecological value theory, people's feelings about colour are constructed from the range of reactions that they associate with the specific colour [6]. Thus, due to subjective feelings, people intuitively consider yellow to make them feel happy, while exposure to blue makes them feel sad. The colour-emotion associations are determined by hues. Since colour is not only characterised by hue, the intuitive claim of colour-emotion associations through hue may be inaccurate. The study by Schloss and his colleagues re-examined the link between yellow and happy, blue and sad by controlling for lightness and chroma [6]. They controlled for colour stimuli in two ways: statistically using a multivariate linear model to analyse previous ratings of colours in relation to emotion words, and colorimetrically using constant lightness and chromaticity to allow participants to judge the association of colours with emotion words. Their results showed that yellow hues were not happier than blue hues under statistical and colorimetric

control of colour. Therefore, they concluded that the idea that yellow was happier was due to the change in brightness of the colour stimuli, rather than their hue. Furthermore, they propose an explanation for why people construct this intuitive association. Yellow is the colour most likely to be associated with happiness because it maximises both brightness and chroma, while blue is most likely to be associated with sadness because it maximises both dark and achromatic. This study challenges the intuitive summary of the colour-emotion association and shows that by more detailed controls in colour stimuli, it is possible to find the factors that determine which colours are paired with which emotions.

As colour can vary in three dimensions, whether colour can influence mood in all three dimensions requires further research. The study by Wilms and Oberfeld analysed the effect of colour stimuli on emotion when there were independent controls on the three perceptual dimensions (hue, saturation and luminance) [7]. In the experiment, participants saw different colour lights, and the colour of the lights changed in three separate levels on each of these three dimensions. Their emotional responses were measured in two ways. One was self-report scales on two emotional dimensions (i.e., arousal and valence) and the other was the electrophysiological measure to record skin conductance (i.e., representing arousal) and heart rate (i.e., representing valence). From their results, they firstly found how the perceptual dimensions influence emotion. Emotional arousal became highest with saturated and bright colours as well as in red hues, while emotional valence was mainly influenced by saturation, becoming highest with more chroma. They also observed an interaction effect between colour dimensions on emotion, with brightness and hue affecting emotion only in high saturation conditions. The effects on physiological responses were all weaker than the ratings. The more saturated, brighter colours elicited stronger skin conductance, and heart rate accelerated with more chroma. These findings represent that the effects of colour stimuli on people's emotions are derived from each single dimension and there is an interrelationship between the effects of the dimensions. This in turn suggests that the effect of colour on mood is determined by a combination of the three perceptual dimensions.

3. The Effects of Colour on Facial Emotion Perception

3.1 The Unique Role of Face in Emotion and its Relationship with Colour

As colour is an effective cue to indicate people's emotional status, it is suggested that colour might help people to recognise emotions. Takei and Ima Imaizumi's study tested whether colour could facilitate people to recognise facial emotions [3]. In their first experiment, participants viewed pictures with different facial expressions against different coloured backgrounds. They were required to recognise emotions as fast and accurately as possible. In the second experiment, participants were shown coloured backgrounds before faces. From their results, they found a facilitation effect on emotion recognition with faster reaction times for some colour-emotion pairings, suggesting that there are some associations existing between colours and emotions. They also found that the effect of colour on facial emotion recognition was only observed when both face and colour were presented simultaneously, indicating the importance of temporal order for this effect. Thus, their study demonstrated the facilitative effect of colour on emotion recognition to work in specific colour-emotion pairs with colour and emotion representing simultaneously. Furthermore, their findings shifted the context of colour-emotion research to reflect expressive human emotions.

Building on the biopsychosocial model of challenge and threat, changes in human emotional states could cause physiological changes, including different facial colours due to changes in blood flow [8]. Because facial colour could function as expressive cues in interpersonal settings, the expressive facial colour-emotion association may show a different pattern from the subjective colour-emotion association. The study by Thorstenson and his colleagues applied different facial colours, comparing them to pure colours in the colour-emotion association [5]. Participants were in two conditions. Those in the face condition were required to manipulate the colour of the facial stimulus to match the target emotion, while those in the non-face condition made changes in the abstract shape. From their results,

they found colour-emotion associations with facial stimuli: red and yellow increased in approach-type emotions and decreased in avoidance-type emotions. Compared to the non-face stimuli, the magnitude of the colour differences was reduced. People showed less variation in manipulating red and yellow facial colours yellow while more variation in green and blue facial colours. Taken together, their findings have revealed the effect of face colour on emotion is significantly different from that of non-face stimuli. The facial colour could be a key perceptual feature of emotional states, helping recognition of others' feelings in everyday interactions.

In the real world, people receive colour information not only from faces, but also from the background, which can also influence their emotion recognition [3]. This makes one wonder if there is some difference in how people react to these two different sources of colours. A study by Minami and his colleagues compared the effects of facial colour and background colour on people's recognition of facial expressions [9]. In their experiment, participants were shown a series of images of facial emotions. These images differed in two respects: facial colour and background colour. Participants were asked to recognise the emotion expressed by the face as quickly and accurately as possible while ignoring the colour. From their results, firstly, they found that people were more likely to recognise the emotion of anger in the reddish face colour and background condition. The emotion of fear in the bluish face colour and background condition. In addition, they found that the effect of face colour was significantly stronger than background colour. According to their study, background colour can influence people's emotion recognition, although it is not as significant as facial colour. Their findings show how people process colours from different sources, shedding light on the possible interplay between the effects of different colour sources on emotions.

3.2 The Association between Symbolic Face and Colour

In addition to applying really facial colours, emoticons are also inextricably linked to colour in the current Internet Age for people to express their emotions in a virtual environment. It is believed that colour can also influence the emotions represented by emojis, and Liao and his colleagues used emojis as stimuli in their colour-emotion association study [8]. There were five emoticons in eight different colours. In the coloured trials, participants were asked to select the target emotion as quickly and accurately as possible from five emoticons that had one of the eight colours. Participants did the same task in the non-coloured condition. How participants made correspondences between the colours and emotions in the emoticons was recorded on a scale. From the participants' responses, they found a contingency effect in that participants responded more correctly to the emoticons when they were represented in the corresponding colours, suggesting that the association between the colour of the emoticons and the emotion influences the interpretation of the emotion. From their findings, it appears that both real and virtual facial emotion expressions are influenced by colour. Furthermore, they also revealed how colour-emotion associations play a role in human's social communications.

4. The Mechanism and Pattern about the Colour-Emotion Association

Although research has provided evidence for the colour-emotion association from different perspectives, the mechanisms of this association remain undiscovered. For both concepts, they have their own representational spaces in which the dimensions can locate different colours or emotions using their own spatial coordinates. It is argued that the correspondence between their representational spaces can reveal potential patterns of colour-emotion associations. Hanada's study applied correspondence analysis to investigate colour-emotion associations based on the correspondence between the hue circles of colour space and Russell's cyclic model of emotion space [10]. Participants were asked to view different colours while reporting a word to express how they felt about that colour. The emotion words they reported were collected and placed in a contingency table for correspondence analysis along with the colour stimuli, resulting in an eight-dimensional biplane map. As seen on the map, although the hue circles are very similar to the emotion model, their order does not match, indicating that the two representational spaces do not correspond.

However, the connection between the two spaces still provides information about the mechanism of the colour-emotion link. Colour temperature mediates the association between colour and emotions. There were also secondary associations shaped by cultural and personal differences. In conclusion, although they did not find a correspondence between the two conceptual representation spaces, their correspondence analysis approach and identification of influencing factors suggest that a statistical approach on colour-emotion associations has the potential to clarify how colour and emotion correspond through which mechanisms.

Because of differences in how people associate colours and their emotional meanings, scientists have also examined factors that may influence the association between the two. Cultural differences are thought to influence how colour could be associated with emotional meanings, reflecting the specificity of colour-emotion associations. The study by Jonauskaitė and his colleagues analysed colour-emotion associations through a machine learning approach to figure out the extent to which these associations are country-specific [11]. They selected 11 basic colour terms as stimuli and used the Geneva emotion wheel to assess their associations with emotion terms. They presented an online survey to participants from different countries. Participants would see the colour term appear in the centre of the wheel and score it on a 6-point scale consisting of circles around the wheel, with larger circles indicating the strongest connection between the colour words and the emotion. Their classifier achieved an accuracy higher than chance level, suggesting that colour-emotions are somehow country-specific. They also found that small within-group benefits improved the accuracy of predicting colour decoding, suggesting that colour could associate with emotion both universally and culture-specifically. Based on their findings, they suggest that cultural differences in colour-emotion associations can be quantified by machine learning methods. Moreover, colour-emotion associations constitute with both culturally specific and shared components.

5. Conclusion

In summary, current research has taken different approaches and designs to examine different perspectives on colour-emotion associations. First, some studies have examined people's subjective feelings of colour. One study found that it is inaccurate to describe the colour-emotion association as people usually do through hue, suggesting that other colour dimensions are also involved in the colour-emotion association. Further research found that changes in each colour dimension affected mood, suggesting that the colour-emotion association is a combined effect of the three colour dimensions. In addition, other studies have explored colour-emotion associations through facial colour. These studies found a unique pattern in the effect of facial colour on emotion interpretation, compared to pure colour stimuli. They also found that colour-emotion associations in facial colour can facilitate the recognition of emotions in real faces and emojis, suggesting a unique role for facial colour in human social interaction. Plus, they found that influences of face colour were stronger than background colour on emotion recognition. It indicates that different factors are likely to be related with the different sources of colour-emotion associations. Finally, several studies have attempted to identify the mechanisms underlying colour-emotion associations. The representational dimensions of colour and emotion were mapped using correspondence analysis. It identified mediators and other influences in the colour-emotion association. Machine learning methods quantified the extent of the cultural influence, suggesting that there are both universal and culture-specific patterns underlying the colour-emotion associations.

Based on these recent studies, there are several recommendations for future research on colour-emotion associations. Firstly, it is important to control for differences in colour stimuli based on each single dimension when selecting colour stimuli. Secondly, future studies could use different measures of people's emotional responses. For example, they could measure the emotional effects of colour stimuli by both self-reporting and recording physiological responses to improve the reliability of the results. Finally, when it comes to colour-emotion associations in a social context, researchers could construct a more realistic environment in which people judge emotional states from facial colour to

improve the ecological validity of the findings. This review discussed the most recent findings in the field of colour-emotion association. It can provide some insights for future studies in this area. It can also give some suggestions for the relevant intervention programs at school.

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