

Colour Vision Deficiencies and Colour Emotion

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Abstract

The topic of how colour emotion and colour vision deficiencies interact with each other is barely researched, and existing studies have contradicting results. This study will investigate how these two topics interact with each other and try to prove that colour emotion is affected by colour vision deficiencies.

This was done through an online colour-emotion associations questionnaire in two phases. The first phase had 60 participants, of which 15 reported having colour vision deficiencies and the second had 18 participants, of which 8 were identified to have colour vision deficiencies. Within the questionnaires, the participants selected emotions from the Geneva Emotion Wheel which they associated with 12 colour patches or 4 colour terms and then rated how strong this association is from 1 to 5.

Results show indications that colour vision deficiencies lead to reduced strength of colour-emotion associations and a higher number of people who do not associate emotions with certain or all colours. Additionally, it was found that the colour vision deficiency group associates fewer emotions with each colour than the normal vision group and differences in specific colour-emotion associations were found between the two groups.

Introduction

Colour emotion itself has been studied plenty, however, the affect of colour vision deficiencies on colour emotion is barely considered or investigated [5]. The few existing studies on this topic have contradicting results [4] [5] [7].

Because of these reasons, this project will focus on the topic of how people with colour vision deficiencies perceive colour

emotion in comparison to people with normal colour vision.

To achieve this, two colour emotion surveys are conducted to investigate the topic in regards to CVD. The exact methodology is elaborated on in detail, followed by an examination of the results in combination with an examination of all limitations of this project. Finally, the conclusions will be discussed and potential future work will be elaborated on.

This project is based on the hypothesis that "Colour emotion is influenced by Colour Vision Deficiencies", which makes the null hypothesis "Colour emotion is not influenced by Colour Vision Deficiencies".

Related Work

This chapter will cover the related work that is relevant to this study. First, colour emotion and colour emotion studies will be explained, followed by an elaboration of studies on the interaction of colour vision deficiencies and colour emotion.

Colour Emotion

Colours can elicit many various emotional responses from people, such as happiness or sadness. These responses can be referred to as colour emotions [1] [6]. Colour emotions are influenced by many factors, but it has been found that mainly age [1] [8] [5] influences how colours affect people, while gender has very little to no effect [1]. Certain aspects of colour emotion are universal [7] [1], while others are dependant on culture or geographical location [6] [7] [1]. For example, red has many negative connotations in some European cultures, while in Indian culture, red has many positive connotations [6].

Within the study of Ou et al. [1] *A Study of Colour Emotion and Colour Preference. Part I: Colour Emotions for Single Colours*, four colour-emotion models were developed. This study found that depending on the scale, different colour attributes play an important role in colour emotions. For example, the scale of the colour emotion warm-cool is connected with chroma and hue angle [1].

Jonauskaite et al. [8] have conducted the study *A comparative analysis of colour-emotion associations in 16–88-year-old adults from 31 countries* with a focus on how age influences colour emotion. Across 7393 participants they have found small but clear differences in how the different age groups are affected by colour emotion. For example, older participants in their study associated more positive emotions with colours and generally associated fewer but more intense reactions to colours compared to the younger participants [8].

Colour Vision Deficiencies and Colour Emotion

Studies which focus on both colour vision deficiencies and their psychological effects are already quite rare, but only a small number specifically focus on CVD and colour emotion [5]. This section will elaborate on three studies which directly focus on the interaction between CVD and colour emotion.

The study *Perception of color emotions for single colors in red-green defective observers* of Keiko Sato and Takaaki Inoue [5] investigates among other aspects, how red-green defective men rate six colour emotions (hardness, freshness, cleanliness, warmth, weight and preference) differently compared to people with no colour vision deficiencies. They have found differences, especially in how normal vision women and men with CVD rated dark colours in the area of orange to cyan. They have concluded that red-green deficient people probably rely on a blue-yellow opponent mech-

anism as well as luminescence to rate the warmth of colours to compensate for their colour vision deficiency [5].

The study *Colour-emotion associations in individuals with red-green colour blindness* from Jonauskaite et al. [7] also investigates differences in colour-emotion associations between men with and without colour vision deficiencies. They have found a very high degree of similarities in the results between the two groups and concluded that intact colour vision is not necessary for colour emotion - it is instead based on conceptual mechanisms, knowledge and language [7]. In this study, the participants were shown either colour patches or colour terms and tasked to select which emotions of the Geneva Emotion Wheel they associated with the depicted colour. They rated the intensity of each colour-emotion association on a scale from 1 to 5. In the case that the participant was shown the colour patches, they were additionally asked to name each colour [7].

The study *Color vision defectives' color emotion association* by Woo et al. [4] on the other hand, did find differences between people with and without colour vision deficiency.

In contrast with the above-mentioned studies, this study was conducted by naming one of 9 emotions (happy, friendly, dislike,...), to which the participants selected one out of ten colour patches or terms they felt matched the emotion best. Between the two groups, plenty of differences were found. For example, the results include that normal vision people associate "sad" most with blue, while people with CVD associate purple most with this feeling. Green was chosen most as "friendly" by normal vision people, while people with CVD mostly selected blue.

Differences were not only found between people with and without colour vision deficiencies but also between people with deuteranomaly and people with protanomaly [4].

Methods

This chapter will cover the methodology of this study. First, the basic setup of the study will be elaborated on, followed by its limitations.

Basic Setup

This study is heavily based on the work of Jonauskaite et al. with a focus on their previously elaborated studies *A comparative analysis of colour–emotion associations in 16–88-year-old adults from 31 countries* [8] and *Colour-emotion associations in individuals with red-green colour blindness* [7]. This allows to compare and reference results, as well as to identify potential reasons for results, especially as the former study included over 7 thousand participants [8] which resulted in a great amount of data from all over the world.

Overall, this study consisted of two questionnaires, which were created using Nettskjema.no, the first of which being the pilot study, which was used to then improve upon the main questionnaire of the study. The most important attributes of this study are identical to the two studies of Jonauskaite et al. [7] [8], however, there were some adjustments made to better fit this study.

To reiterate, these two studies have the same setup: they contain questions about colour emotions in which the participants either see a colour patch or a colour name and then have to select none, one or several options from the Geneva Emotion Wheel for emotions they associate with this colour, as well as how strong they associate the colour and emotion on a scale from 1 to 5 [7] [8].

The Geneva Emotion Wheel consists of 40 emotions which are placed on a chart of two dimensions: high and low control as well as positive and negative valence [2]. The Geneva Emotion Wheel used was adapted by Scherer et al. [3] to only contain 20 emotions. The adapted Geneva Emotion Wheel is depicted in figure 1.

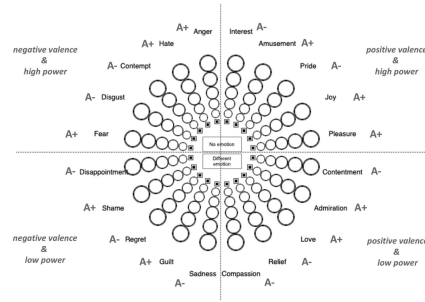


Figure 1. The Geneva Emotion Wheel as adapted by Scherer et al. [3]

The above mentioned adjustments made were grouped by topic and will be elaborated below:

Both colour patches and colour terms are used within the questions. However, in difference to the studies of Jonauskaite et al., all participants were shown both colour patches and colour terms. To be exact, the pilot study used 12 colour patches similar to Jonauskaite et al.'s as well as four colour terms. The main study used 10 colour patches which were taken from the study of Ou et al. [1], also with four colour terms. The colour terms were "red", "green", "blue" and "yellow". All colour patches can be seen in Appendix B.

The Geneva Emotion Wheel was used for the selection choices of emotion. However, the participants are first asked which emotions they associate with each of the colours and then asked how strong the overall association between all selected emotions to the colour is from 1 (least) to 5 (most) instead of having the participants giving this information about each individual emotion. The option "No emotion" was not explicitly given, as participants had the option to select none of the given emotions.

The colour vision deficiency test was not used for the pilot study, but the main study used 10 Ishihara test plates to identify people with CVD, as well as their types of CVD. These Plates were taken from the website Colorlite [9], an extended Ishihara Plate collection [10] and two were generated using the colour

scheme from the website Colorlite [9]. All 10 plates can be seen in appendix A.

Demographics

The demographics of this study are limited to nationality, as it is a known factor which influences colour emotion, and gender, as the study of Sato and Inoue [5] has found gender differences in regards to colour-emotion and colour vision deficiencies. It was chosen to not include additional questions, such as age, within the demographics section of this study to ensure anonymity of participants.

Limitations

Conducting this study using an online questionnaire has the advantage of reaching a bigger audience and allowing more anonymity compared to a lab-based setting, however, there are many limitations to using an online questionnaire.

Many factors that are usually easily controllable within a lab-based setting could not be controlled at all. For example, the brightness of the device as well as the surrounding light can and will vary greatly, the viewing distance and the viewing angle cannot be controlled and colour calibrations may also vary across viewing devices. These factors are usually controlled in similar studies, such as in the study of Sato and Inoue [5] and Ou et al. [1].

Usually, colour emotion studies are conducted in the participants' native language, however, as this study ranges over many nationalities, the questionnaire was conducted uniformly in English. While this should not have been an issue for most participants, two participants reported having issues understanding the entirety of the questionnaire due to language reasons.

All other limitations are mentioned where relevant.

Results

In this chapter, all results of both the pilot and main questionnaire of the study will be discussed. First, the demographics of the participants will be elaborated, and then a closer look will be put onto the results of both questionnaires in regards to the interaction between colour vision deficiency and colour emotion. Afterwards, the colour emotion findings regardless of CVD will be explained.

Demographics

Overall, 60 participants answered the questionnaire of the pilot. These participants vary in nationality from Austrian (23), Norwegian (19), American (6), Dutch (2), British (2), Canadian (1), Singaporean (1) and Italian (1). 5 chose not to answer this question.

15 participants reported having colour vision deficiency, which equals 25% of all participants of this questionnaire.

It is also important to note that 12 out of the 15 people with CVD do not stem from Austria or Norway, where most people with normal colour vision stem from. This could potentially influence the results of the pilot study, as nationality is a known factor to influence colour emotion.

The main study included a total amount of 20 participants, 10 of which have been identified to have normal vision and 8 with colour vision deficiencies. 2 were eliminated from the participant pool due to invalid answers to the Ishihara test plates.

Nationalities are evenly distributed over the globe among both groups, with slight groupings. 3 out of 10 people with normal vision originate from Austria and 4 out of 8 people with CVD originate from the USA.

The other participants with normal vision originate from Peru, Hungary, Turkey, Denmark, Norway, and America and one preferred not to answer. The other participants with CVD originate from Ireland, Brazil, England and Switzerland.

Colour Emotion and Colour Vision Deficiency

Results

When comparing the results between the groups of colour vision deficiency and normal colour vision, they seem remarkably similar at first glance, which would support the findings of Jonauskaitė et al. [7] that there are no significant differences, however, certain aspects do show a noticeable difference between the groups, such as the results found in the studies *Color vision defectives' color emotion association* by Woo et al. [4] and *Perception of color emotions for single colors in red-green defective observers* by Sato and Inoue [5].

Results of both the pilot questionnaire and the main questionnaire will be discussed in this section, but it is important to point out the limitations of the pilot study and highlight the importance of handling these results carefully and critically, due to the following reasons:

The pilot questionnaire has significant nationality differences between the groups of participants with and without CVD, which could potentially influence the results. There is also a noticeable number difference in the CVD group and normal vision group (15 vs 45), and finally, the pilot questionnaire relied on self reporting of CVD.

However, the results of the main questionnaire follow the same trends as the results of the pilot, which shows that while the results of the pilot may have been heightened by its weaknesses, the overall results were not caused by them.

One of the biggest differences is the amount of participants per group who report no colour-emotion association for the colours. This effect is strongest in the pilot study in which 40% of participants with CVD chose no colour-emotion association for 3 colour patches (brown, grey, white) and over 20% of participants with CVD chose no colour-emotion association for 13 out of 16 colour

patches or terms.

In very high contrast, only two colour patches (brown and black) had a *singular* participant with normal vision selecting no associated emotions. This can be seen in figure 2 below.

The results of the main study follow the same trend, are however less intense, as seen in figure 3 below.

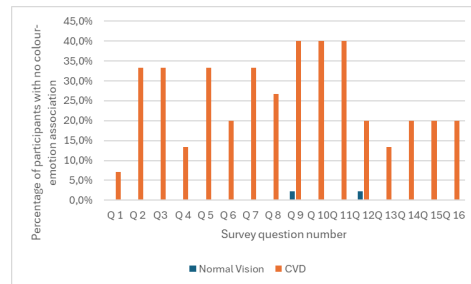


Figure 2. Rates of participants reporting no colour-emotion association, pilot questionnaire

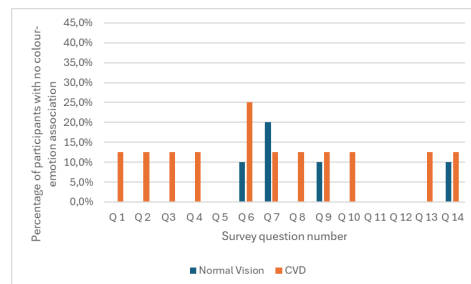


Figure 3. Rates of participants reporting no colour-emotion association, main questionnaire

It is to be noted that the option for no colour-emotion association was only given explicitly in the main study and was only available inexplicitly in the pilot study.

Another notable difference between the two groups is that people with CVD tended to rate their emotion association strength very low compared to the normal vision group, with a notably lower average in all questions of the pilot study and nearly all questions in the main study, which can be seen in figures 4 and 5 below. In addition, it is notable that participants with CVD selected less colour-emotion associations on average than the normal vision group. This effect can be seen in figure 6 and 7 below.

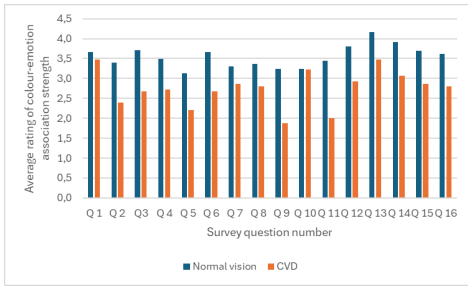


Figure 4. Average rating of colour-emotion association strength, pilot questionnaire

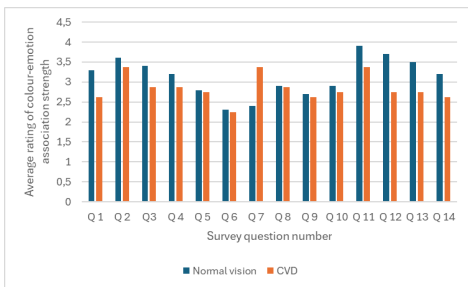


Figure 5. Average ratings of colour-emotion association strength, main questionnaire

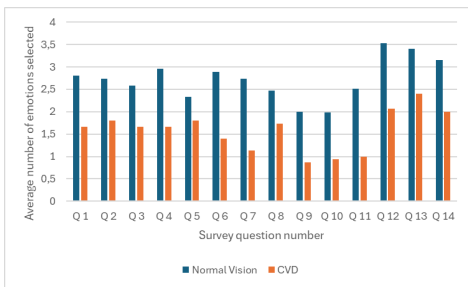


Figure 6. Average number of selected emotion terms, pilot questionnaire

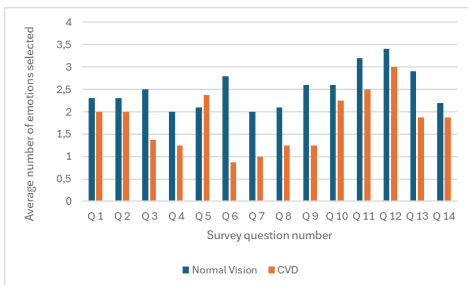


Figure 7. Average selected Emotion Terms per Person, main questionnaire

Specifically comparing the average numbers of selected "positive" or "negative" emotions, as defined by the Geneva Emotion Wheel, more insights can be gained, as seen in figures 8, 9, 10

and 11. Despite having an overall significantly lower average of associated emotions, participants with CVD associate on average noticeably more negative emotions with the colour patches of orange (Q 2, pilot) and yellow (Q 3, pilot), as well as the colour term Green (Q 14, main) when compared to the normal vision participants. Participants with CVD additionally associated significantly more positive emotions with the colour patch blue (Q 10, main) and significantly less negative emotions compared to the normal vision group. Blue also stands out in regards to specific colour-emotion associations in the pilot study, in which people with CVD chose the term "sadness" significantly less (16%) compared to people with normal vision (60%) in connection to the blue patch. This aligns with the study of Woo et al. [4] in which several colour-emotion differences specific to blue between people with and without CVD were found.

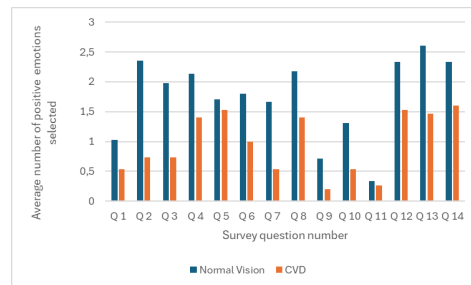


Figure 8. Average number of positive colour-emotion associations, pilot questionnaire

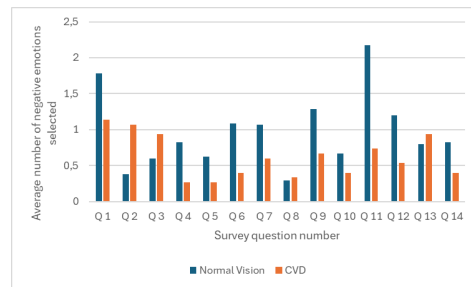


Figure 9. Average number of negative colour-emotion associations, pilot questionnaire

When comparing which specific emotions the two groups chose in association with the colour patches and terms, there seems to be a general overlap and consensus, but with a few things worth pointing out.

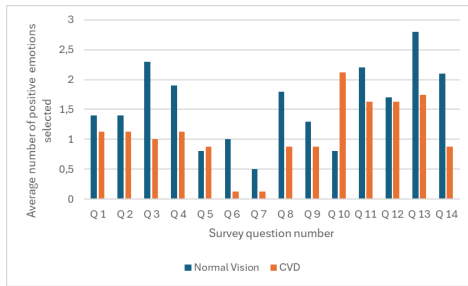


Figure 10. Average number of positive colour-emotion associations per participant, main questionnaire

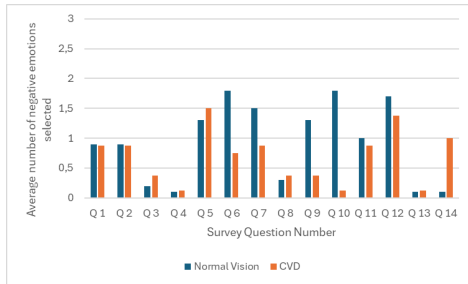


Figure 11. Average number of negative colour-emotion associations per participant, main questionnaire

In the pilot questionnaire, the normal vision group mostly associates sadness (60%) or relief (44%) with the term blue, which the group with CVD does not - sadness received 2 votes at 16% and relief only a singular vote at 8%. Instead, the CVD group mostly voted contentment at 50%, while only 30% of the normal vision group associated this emotion.

Most colours do not have a big spread over all emotions in the CVD group, however, the colour patch black is extremely spread out, with nearly all of the 20 emotions having received one or two votes. The normal vision group, on the other hand, seems to strongly associate black with what the Geneva Emotion Wheel classifies as negative emotions.

The colour term red is associated with "Love" by 71% of the normal vision group, but only by 40% of the CVD group.

Most of the participants with CVD are men, which opens up the possibility of the results being influenced by gender factors, however, this is unlikely as gender is known not to influence colour emotion [1] and no gender differences were reported within the study of Jonauskaite et al. [8]. Additionally, men without CVD tended to e.g. rate their colour-emotion associa-

tion strength higher than men with CVD, which also makes CVD as the leading cause more likely.

Colour Emotion Results

This chapter will have a closer look at the results that are interesting from a colour emotion perspective without any focus on colour vision deficiency. Within this subsection only the results from the pilot study will be discussed, as it is more suitable due to the higher number in participants.

9 colour-emotion associations could be identified using an unfiltered pool of all participants. The colour-emotion associations were chosen by at least 40% of the participants, which equals the criterion that was used by Jonauskaite et al. [8]. Red stands out as the colour with most associations which reach this criterion, with love, hate and anger. The other colour-emotion associations are yellow-joy, green-contentment, turquoise-relief, black-sadness and lastly grey-sadness as well as grey-disappointment. These results are somewhat similar, but not equal to the findings of Jonauskaite et al. [8]. They found 14 frequent colour-emotion associations, six out of which are also found in this study. Four more were just barely underneath the 40% line within this study, while the last 4 associations had comparatively very low frequencies.

Looking specifically at the questions in which the participants were asked to rate the strength of their colour-emotion associations from 1 (least strong) to 5 (most strong), some conclusions can be made. The overall results follow a general shape of most people selecting 4, which is usually around 25% to 35% of the participants, with a steady decline to both sides for the other choices. However, a few colours stand out because they do not follow this pattern. For example, three colour patches stand out by having a comparatively very high number of people rating their emotional association strength at a 1. Most other colours are only

rated at 1 by 3% to 13% of the participants, however, brown was rated at 1 by 23% of people, turquoise/bright blue by 21.7% and white by 20%.

Conclusions and Future Work

This study has found distinct differences between the participant groups with and without colour vision deficiencies, which show that people with CVD associate less emotions with colours as well as associate these emotions less strongly. Participants with CVD reported having no emotional associations with colours noticeably more frequently than the normal vision group. Additionally, differences in the specific emotions the two groups associated with certain colours were found, as well as differences in the numbers of positive and negative emotions can be seen.

This aligns heavily with the hypothesis that colour emotion is affected by colour vision deficiencies. The results of the pilot questionnaire should be interpreted with scepticism due to its limitations, however, the main questionnaire of the study addressed these limitations and shows the same or similar trends and results.

Understanding how CVD and colour emotion are affected by each other can potentially give valuable insights into understanding further how people are affected psychologically by colour vision deficiencies, as well as understanding the causes of colour emotion better. However, there is a general lack of studies on the topic of how colour vision deficiencies affect colour emotion, which creates many opportunities for future work to inspect these topics together from varying viewpoints and approaches. Especially the aspect of women with colour vision deficiencies and colour emotion are still an open topic, as it seems that women with CVD have been ignored in previous studies. Despite the rarity of women with CVD, this can still give important insights into both colour vision deficiencies as well as colour emotion, which could help understand each topic as a whole.

References

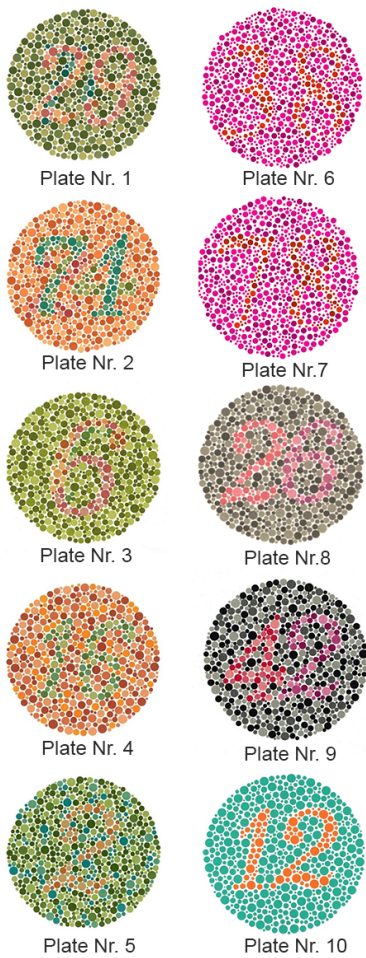
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Author Biography

Miriam Pia Kagerer has received her Bachelor of Science in Engineering from the University of Applied Sciences Upper Austria (2023) and is currently doing her Masters in Interaction Design at the Norwegian University of Science and Technology.

Appendices

A) Ishihara Test Plates



B) Colour Plates

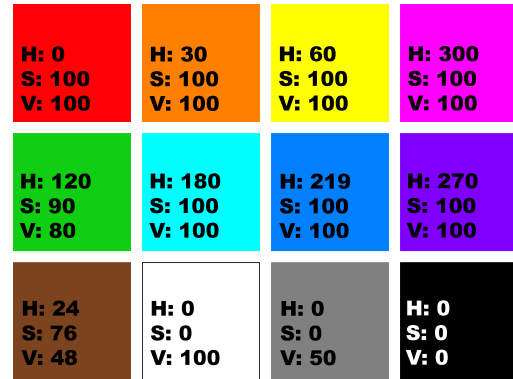


Figure 12. Colour patches, pilot study



Figure 13. Colour patches, main study