A Website Game Colorphantom for Research on Simultaneous Color Contrast Effect

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Abstract

This paper addresses the phenomenon of simultaneous color contrast effect by introducing a website game application built by the authors and discussing the collected data from 310 players. The paper illustrates how the web-based game application was designed and developed, the process of user testing for the closed beta and improvements based on feedback, the data collected from 310 players after the release of new version and discussions of simultaneous color contrast according to the data. The datum reveals the fact that the accuracy of identifying colors is 70% which means people can make mistakes because of this visual illusion.

Introduction

This paper is based on a web-based application we developed named *ColorPhantom* which reflects the phenomenon of Simultaneous Contrast. This effect is when two adjacent colors, seen at the same time ("simultaneously") affect our perception or related performance. We will illustrate how we designed the game to reflect this effect and use the datum we collected to make a discussion.

We perceive the world through our eyes. The human eye can distinguish about 10 million colors and is possibly capable of detecting a single photon (Wyszecki, 824). People all tend to believe what they see by themselves. However, there are many interesting color illusions related to human visual perception when you feel you cannot really trust your own eyes, for instance, color illusion, dress color illusion, and color cube. One of the color illusions we want to explore is simultaneous color contrast effect. As shown in Figure 1, the two small rectangles are actually the exact same color, but because of different surroundings, the one with darker surrounding looks much lighter than the one with lighter surrounding.

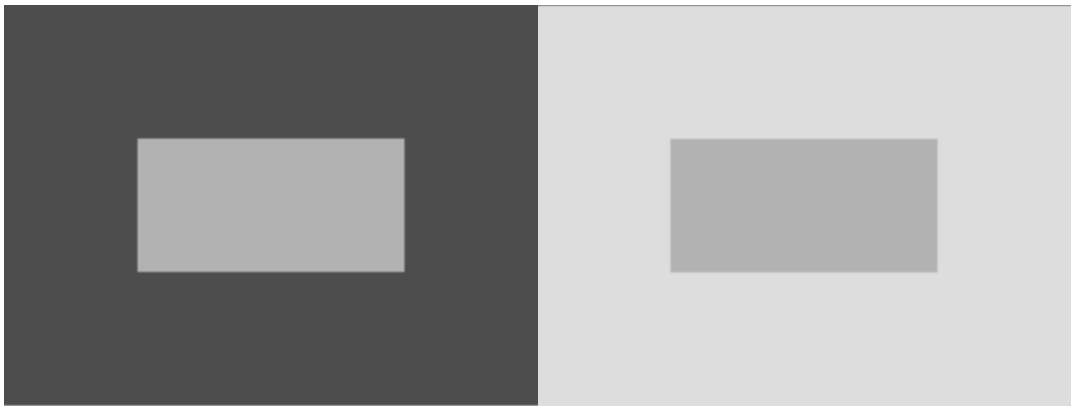

Figure 1. Example of simultaneous color contrast

The purpose of the project is to use the technique of gamification to investigate human skills in identifying colors, while also enabling more people to learn about simultaneous color contrast and be aware of the limitation of their eyes. The present study of this paper is to keep record of the process and quantitative results of human capabilities in distinguishing colors within color illusion.

Hypothesis

We expect the participants' average score to be around 70 out of 100 because we intentionally made 3 questions difficult to identify the color (Questions 4, 8, and 10). We believe that the Q8 ('The Dress') would be the most difficult question and that it should receive the lowest percentage of correct answers.

Method

Web-based Application

In order to publicize this interesting phenomenon, we decided to create a web-based application named *ColorPhantom*. The front-end of this application was created by using HTML, CSS and Javascript languages. There was no database for the back-end but we chose to use Google Sheets to record the results and implement a code that allows the application to submit the data into the online spreadsheet.

ColorPhantom has ten questions. There is one image in each question page and an arrow pointing to a colored region. There are four choices beside the image, where each choice consists of one small colored square in the center and a different color surrounding the square around the borders. Users need to recognize the pointed color from the four choices. One of the small squares is the right answer and other small squares are slightly different colors which are distinguishable when displayed alone. The added surroundings can affect how people perceive the colors in small squares. When the user selects the wrong color, the surroundings will disappear to help people realize how the colors are actually different on white background. The progress bar on the bottom will keep users informed of their progress: if they answered correctly the progress bar of that

section will become green, otherwise red. After answering all the questions, there will be a score indicating how many questions they got right, along with a paragraph explaining the phenomenon.

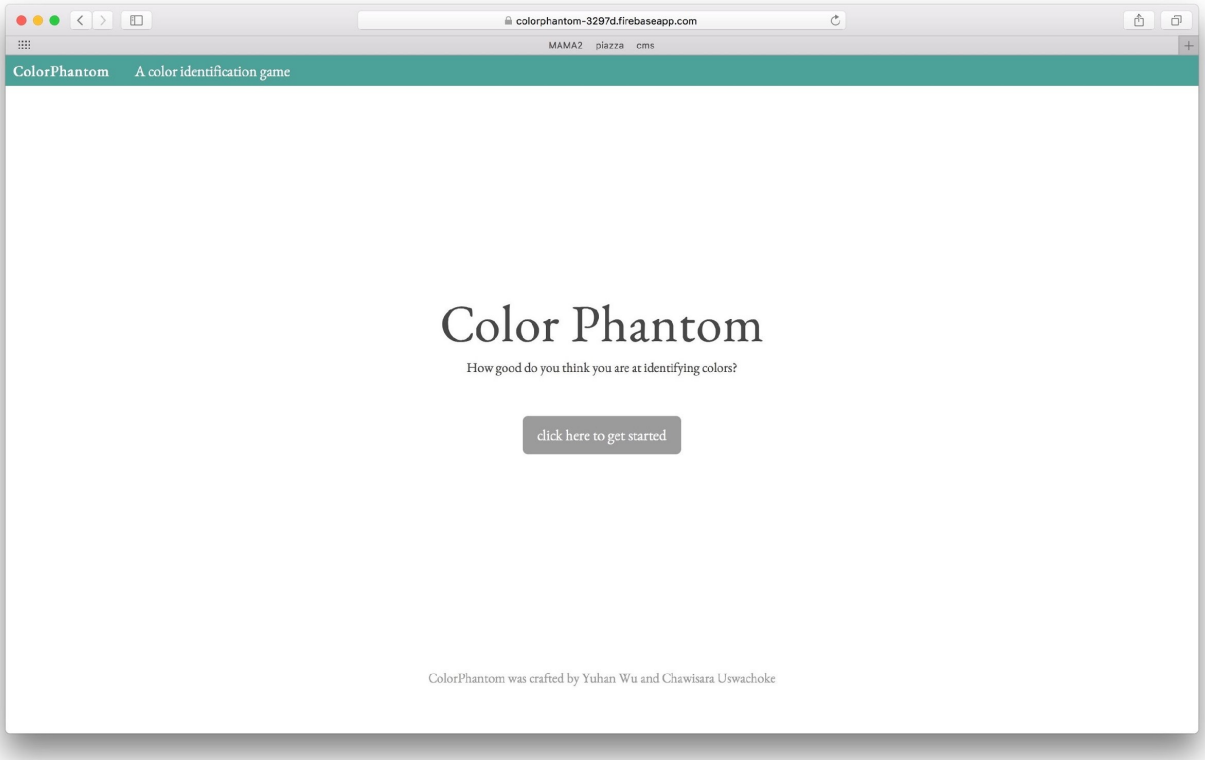

Figure 2. Homepage of color phantom

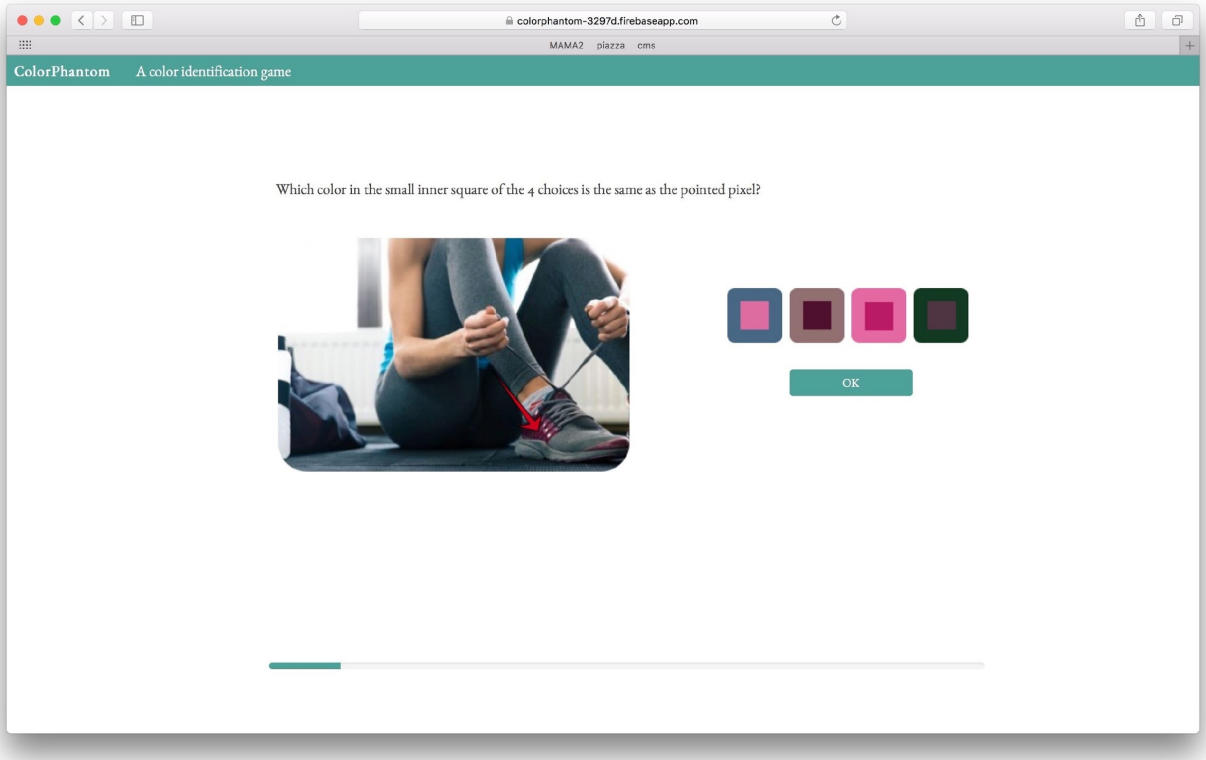

Figure 3. Question page in Color Phantom

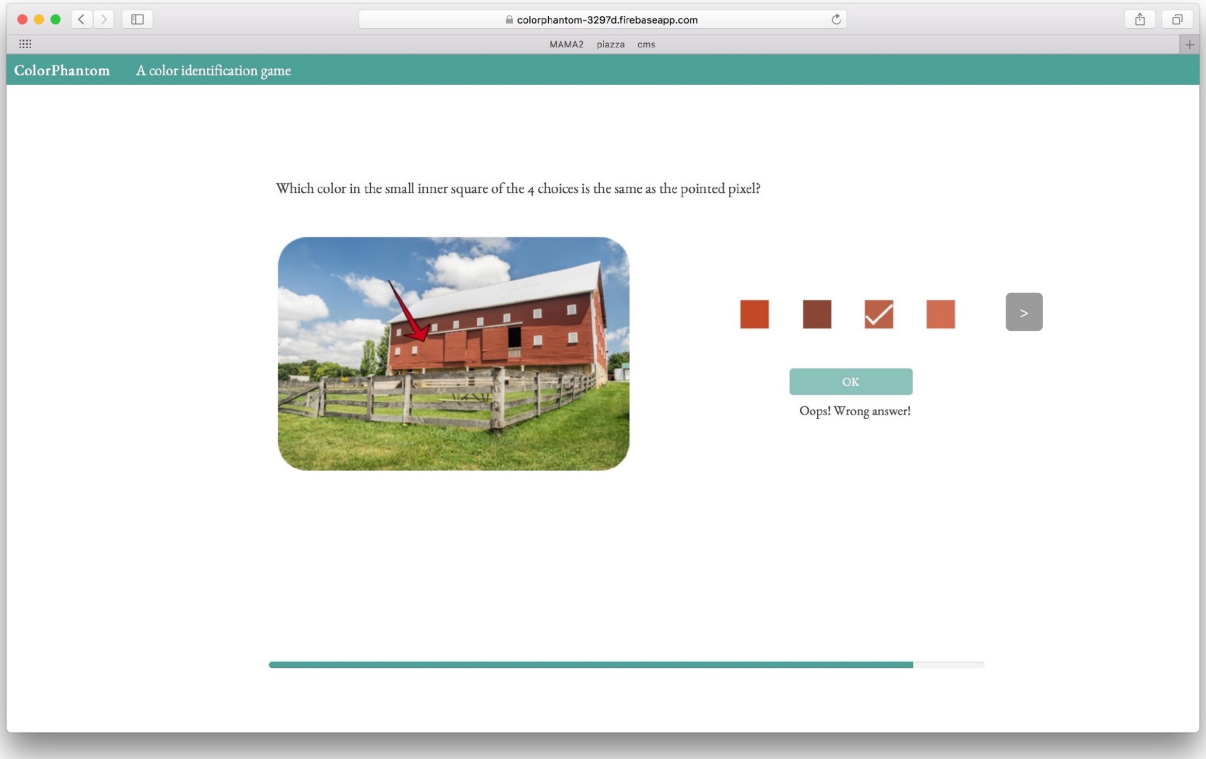

Figure 4. Answer page in Color Phantom

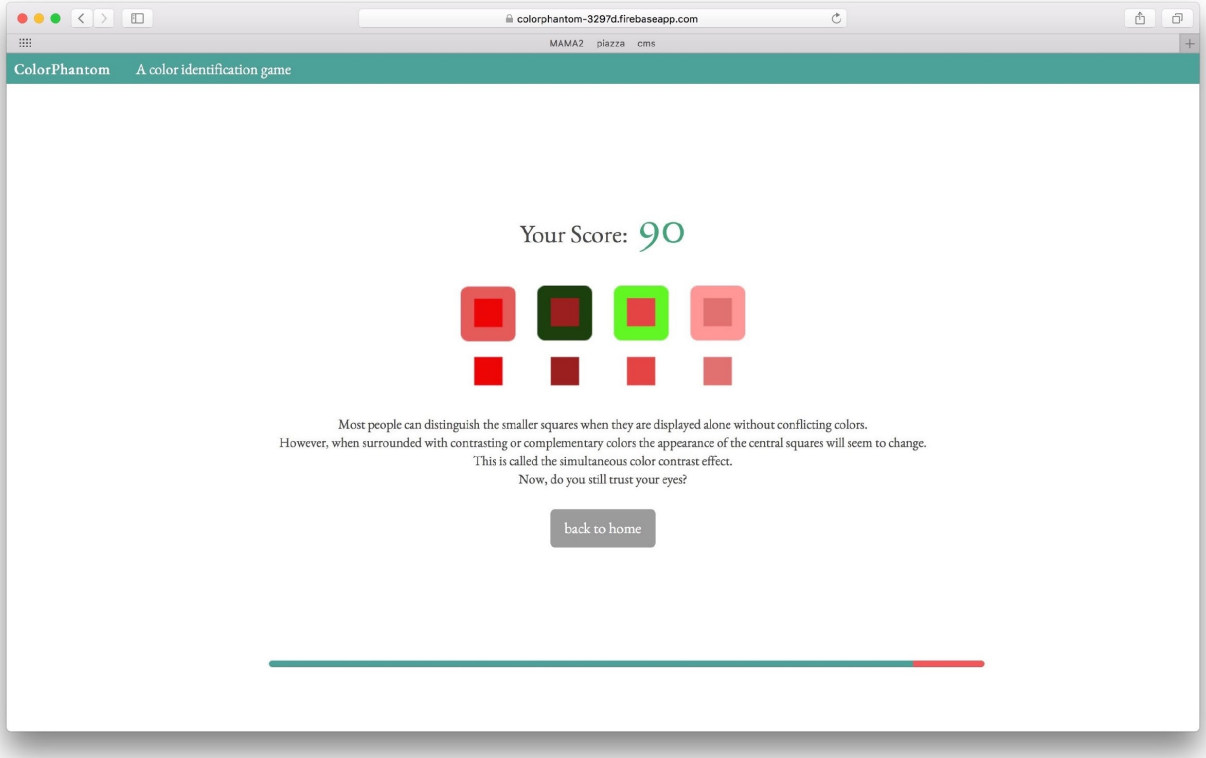

Figure 5. Result page in color phantom

Participants and Procedure

We first invited our friends to test the game for us as closed beta and made some changes according to their feedback. For example, we replaced one picture (Q10) which they find it difficult to know which pixel is being pointed as there were various colors within that region of the image. We slightly redesigned a few components based on user experience problems, such as changing the progress bar colors and rephrasing the questions to increase the intuitiveness of the application. We also adjusted the application to make it compatible to mobile devices. After the final version was done, we deployed the application online via Firebase and publicized it on social media (Facebook and Twitter). We instructed users to play only once to ensure the accuracy of the test, considering that our application simply has one set of questions and that some users could remember the answers. We did not have any restrictions on the characteristics because this test is suitable for people of all kinds and all the results are valid.

Our closed beta version had 35 participants, all college students with either Thai, Chinese or U.S. nationality. The game was still offline during the closed beta version so the participants were given, via private messaging, the whole game file to play it on their own computers. The brightness of the screen, the participant's total duration of playing the game, and screen resolution were not controlled. With the game file, the participants could also open the source code and look up the answers (if they understand the programming language) albeit we instructed them to not cheat.

Similarly, the open beta version had no restrictions on how to play the game. They were also allowed to play on mobile phones instead of only on computers. The participant pool this time was as large as 310 participants in total. This batch is more diverse than the previous, given that *ColorPhantom* was deployed online and was shared on social media. Consequently, the participants could be from any nationality, age, gender, major or field of study. We did not ask them to give feedback, although many people did provide productive comments, so there were several anonymous participants. Some might have played more than one round even though the instructions

were to play only once. The only controlled variable is the application itself, where the participants were given the same set of images and choices.

Results

Summarized results for closed beta (for full results see appendix)

Average, highest and lowest scores (out of 100) from 35 participants:

Table 1.Average score for closed beta

Average Score	Highest Score	Lowest Score
67.43	90	30

Mode (most frequent answer for each question) out of the 4 choices and the percentage of people who got the answer correct:

Table 2. Score analysis of each question for closed beta

	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10
Answer key	3	2	1	4	1	3	2	4	1	3
Mode	3	2	1	3	1	3	2	1	1	1
% Correct	80.00	94.29	77.14	34.29	91.43	94.29	85.71	22.86	82.86	11.43

Percentage of people who answered correctly for each question:

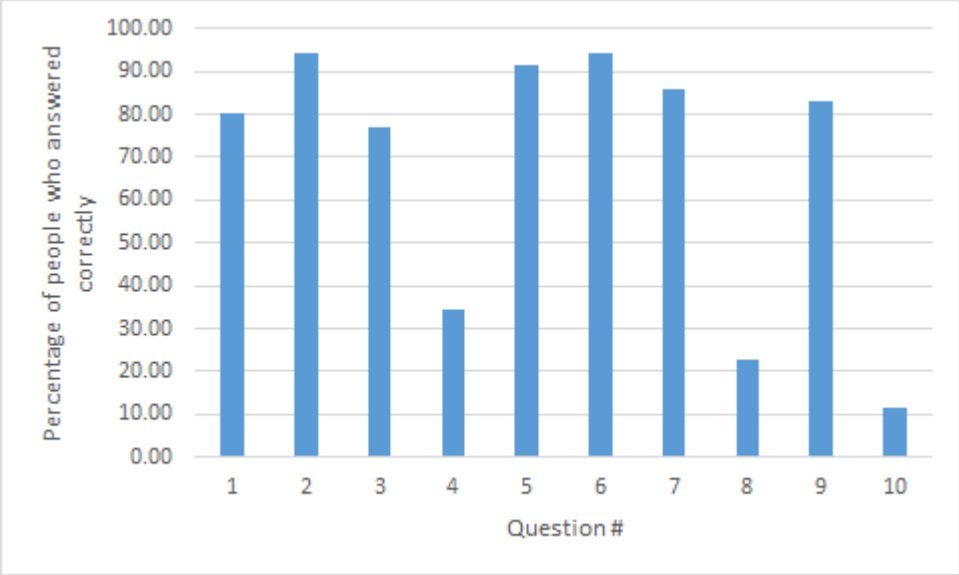

Figure 6.Chart of percentage for closed beta

Summarized results for open beta (for full results see appendix)

Average, highest and lowest scores (out of 100) from 310 participants:

Table 3.Average score for open beta

Average Score	Highest Score	Lowest Score
70.23	100	30

Mode (most frequent answer for each question) out of the 4 choices and the percentage of people who got the answer correct:

Table 4. Score analysis of each question for open beta

	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10
Answer key	3	2	1	4	1	3	2	4	1	3
Mode	3	2	1	3	1	3	2	4	1	3
% Correct	85.16	65.48	79.68	36.77	84.19	91.29	77.10	41.94	86.45	54.19

Percentage of people who answered correctly for each question:

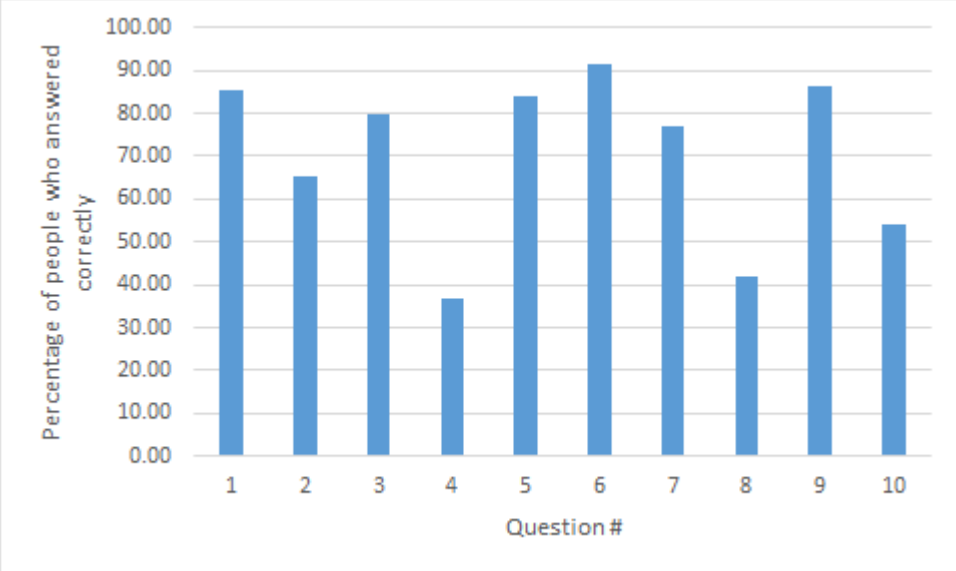

Figure 6.Chart of percentage for open beta

Discussion

We accept our hypothesis as the average score for both versions are approximately 70 out of 100, and the three questions that most participants answered incorrectly were Q4, Q8 and Q10. The average score also increased from the closed beta in the open beta. However, we were surprised to see how the mode values for each question in the open beta version tend to be correct for 9 questions out of 10. We thought the image that the participants will find most difficult would be Q8 ('The Dress'), but it turned out to be Q4. The most frequent answer for Q4 is 3 while the right answer is Choice 4.

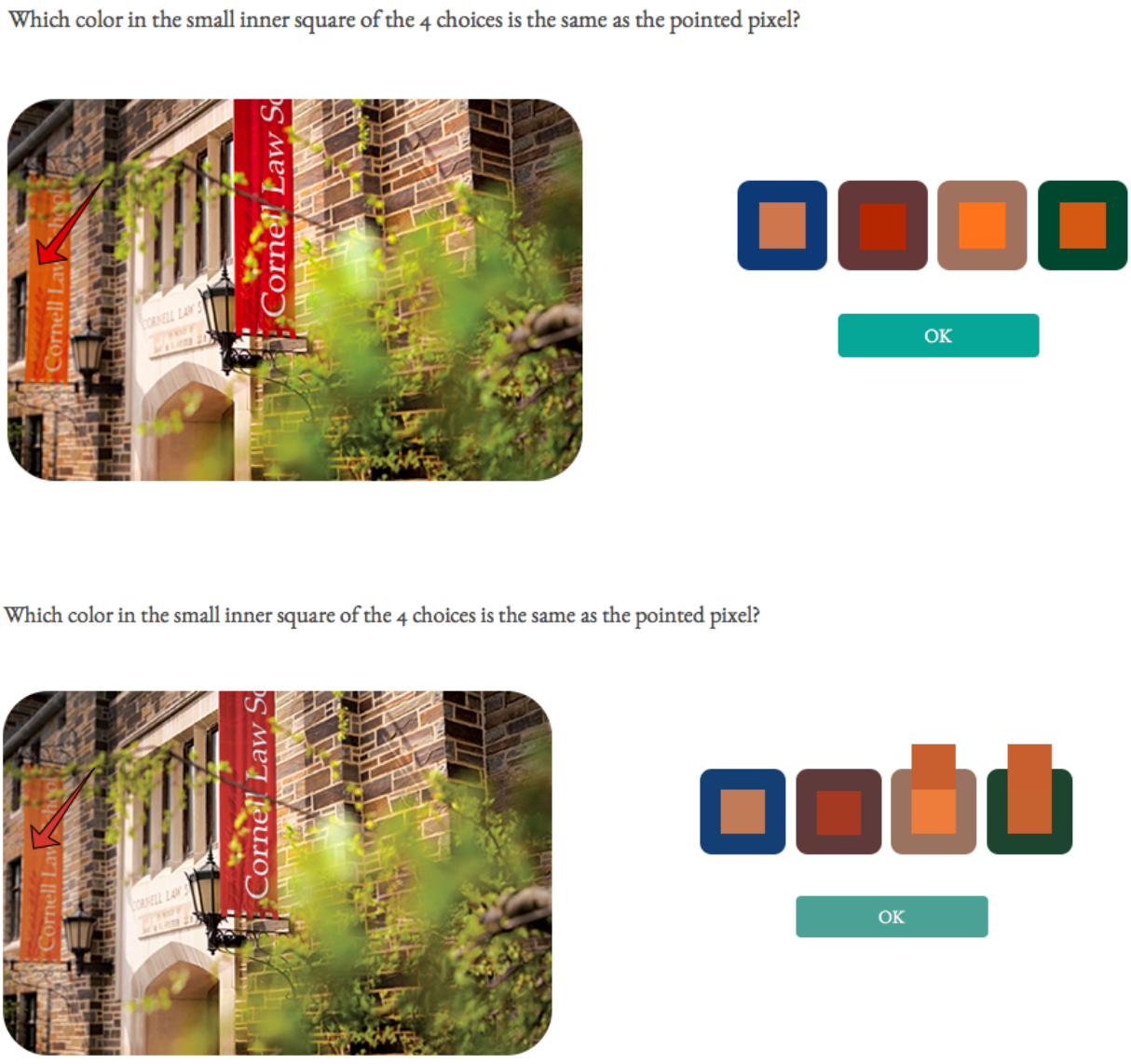

Figure 7. Question page for Q4

At first glance, perhaps most of us will think Choice 3 is the right answer. However, as shown in FigureX, we used color picker to pick the color in the pointed region. We can see it is exactly the same with Choice 4. The reason why people perceived the region is more like Choice 3 was probably because of four reasons: The first is when the color covers a large area, people may perceive it lighter than in a small area. So people will think Choice 4 is darker than the flag while Choice 3 is much closer. The second reason is the effect of border. The dark green border in Choice 4 makes the small square look more greenish than it really is. Another reason is conjecture. The border of Choice 3 is closer to the wall in the picture which might have made the participants feel they are somehow related. The last reason is because the oddity of the color brown (Ware, 118). Brown has to have a white reference in the same frame in order to be perceived, but when it is presented with other colors excluding white, most people will perceive it as dark yellow or dark orange. Consequently, our webpage is mainly white, so participants would see the color as brown even if it is surrounded by green. When the color is presented in the image as a shade of the orange flag, on the other hand, it is more blended into the flag texture. Participants were likely to take the colors in the image as references instead of the webpage's plain white color. This therefore possibly caused people to perceive it as orange instead of brown.

As for Q8, The Dress, which achieves the second least percentage of correct answers, we discovered that the most participants confused Choice 2 with the correct Choice 4:

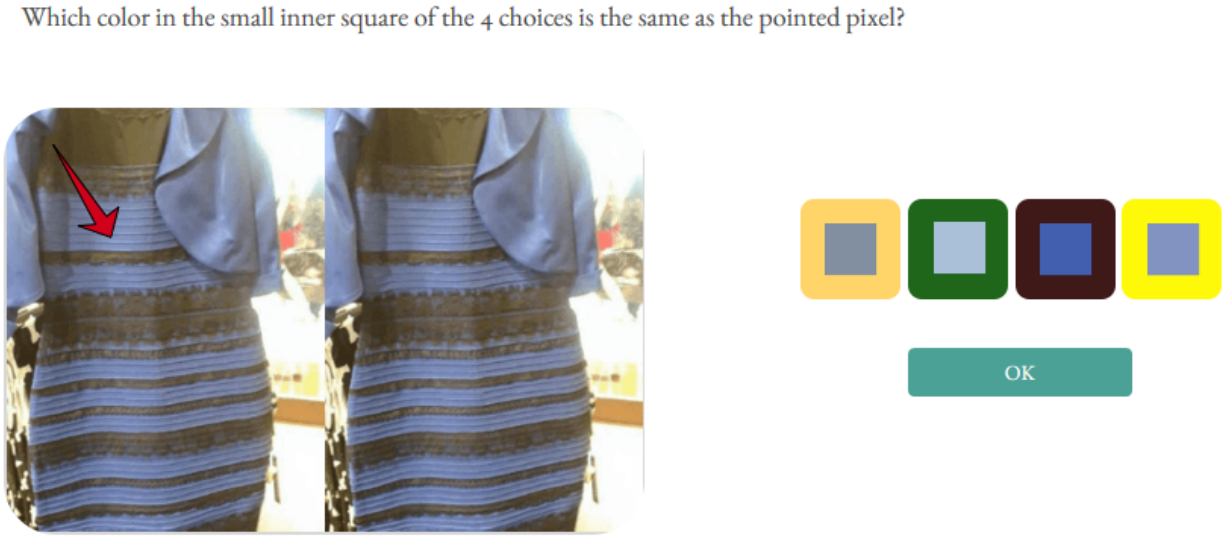

Figure 8. Question page for Q8

There are several factors that influence the participant's perception of the color of the dress. One of them is interpretation of the light source. Those who interpret that the room is dark would perceive the dress brighter than those who interpret that the room is light. Furthermore, those who thought the light source was from behind, most of them would perceive the dress as white-gold, making the pointed region of the dress be 'white' in their eyes. We believe that those who identify the dress as white-gold were the ones who selected Choice 2. On the other hand, there were a large group of participants who answered Choice 4 correctly, which is a darker shade of blue. We deduced that this group of participants were likely to regard the dress as blue-black, and that the light source in their perception originated from the front. Another factor that might have affected the partcipants' color perception would be how they determine the reflectance of the dress' material. Some participants could have thought that the dress was made from a shiny material, thus selecting a lighter tone of color from the four choices.

For Q10, the main reason is simultaneous color contrast effect: the dark border made Choice 3 lighter and the light yellow border made Choice 4 look darker which could have confused the participants. We inferred that the other reason might be that the color pointed is slightly unusual so people would not know how to name it. There is a possible phenomenon, according to Sapir-Whorf

Hypothesis, that the ability of distinguishing color will increase if people know the name of the color which may make it hard to distinguish.

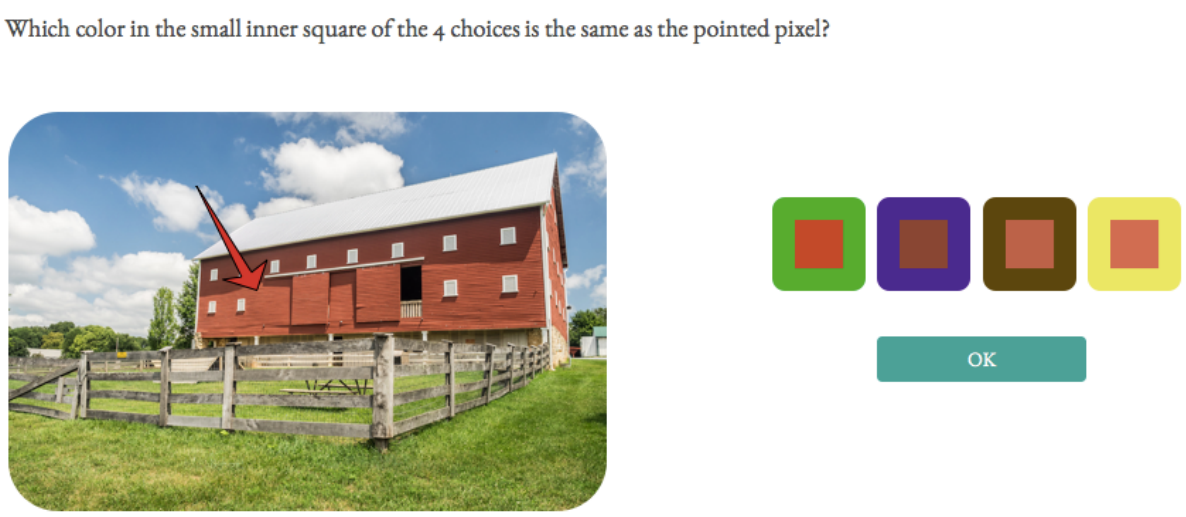

Figure 9. Question page for Q9

Furthermore, none of the questions that we did not add extra tricks or illusions (like in Q4 and Q8) and merely applied the simultaneous color contrast to the choices by surrounding them with various colors also achieved 100% of correct answers. The highest percentage is from Q6 with 91.29%, which is indeed high albeit still not perfect, suggesting that not everyone is capable of distinguishing colors that most people find easy to identify.

Other additional factors that might have affected the results, decreasing the accuracy of the data, could be the fact that we did not control how the participants play the game. Some participants' screens might be more defined than others and allowed them to perform better. Some might simply became lazy towards the end of the quiz, as we received several comments saying that they felt like their eyes became quite tired by the end of the quiz and that their performance might have declined along the way.

Overall, nevertheless, we would say that we succeeded in testing human abilities in perceiving colors while also educating them. None of the questions received 100% correct answers and none received 100% incorrect answers. Only 15 participants out of 310 achieved a perfect score

of 100, making it only 4.84% of the participant pool. This proves that human's perception of colors is flawed and even more so when influenced by visual illusions.

Conclusion

Based on our data, we can see that even people are identifying the colors seriously and they know there are some tricks here, they only got an average of 70. Looking around into our daily life, there are many situations where we can be deceived by our own eyes and make unwise decisions. For example, for girls who love lipsticks, when they like the lipstick color on their friend's lips, they might ask for the brand and color to buy it afterwards. After they received it and tried it on their own lips, it might look like a totally different color because they two have different colors of skin and different colors of hair which would affect how the lipstick color looked like. When people are aware of this limit of themselves, they might be more cautious next time before making a decision.

References

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Appendices

Closed Beta Results

Participant #	q1	q2	q3	q4	q5	q6	q7	q8	q9	q10	Score
KEY	3	2	1	4	1	3	2	4	1	3	100
1	3	2	1	3	1	3	4	4	1	2	70
2	1	2	1	3	1	3	2	3	4	4	50
3	3	2	3	4	1	3	2	1	1	4	70
4	3	2	1	3	1	3	2	1	1	1	70
5	3	2	2	4	1	3	2	4	1	1	80
6	1	2	3	4	1	2	3	4	1	2	50
7	3	2	3	4	1	3	2	1	1	1	70
8	3	2	1	4	1	3	2	2	1	4	80
9	3	2	1	3	1	3	1	2	1	1	60
10	3	2	1	3	1	3	2	4	1	3	90
11	3	2	1	3	1	2	2	4	1	1	70
12	3	4	2	3	1	3	2	3	4	1	40
13	3	2	1	3	1	3	2	1	1	1	70
14	3	2	1	4	1	3	2	2	1	2	80
15	3	2	1	3	1	3	2	1	1	1	70
16	3	2	1	3	1	3	2	1	1	4	70
17	3	2	1	3	1	3	2	3	1	4	70
18	3	2	1	3	1	3	2	3	1	4	70
19	3	2	1	4	1	3	2	4	1	4	90
20	3	2	1	3	1	3	2	3	1	3	80
21	3	2	1	4	1	3	2	2	1	1	80
22	3	2	3	4	1	3	2	2	1	1	70
23	4	2	1	3	1	3	2	2	1	4	60
24	2	2	2	3	1	3	2	1	4	1	40
25	3	2	1	3	1	3	2	1	1	4	70
26	3	2	1	4	1	3	2	2	1	1	80
27	3	2	1	3	1	3	2	1	1	1	70
28	3	2	1	4	1	3	2	4	1	2	90
29	3	2	1	3	1	3	2	4	3	1	70
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31	3	2	1	3	2	3	4	1	1	1	50
32	3	2	1	3	1	3	2	1	1	1	70
33	1	3	1	3	1	3	2	1	1	2	50
34	4	2	1	3	3	3	2	2	1	1	50
35	1	2	2	2	3	3	3	3	3	3	30

Open Beta Results

Participant #	q1	q2	q3	q4	q5	q6	q7	q8	q9	q10	Score
KEY	3	2	1	4	1	3	2	4	1	3	100
1	3	2	1	3	1	3	2	4	1	4	80
2	3	3	1	2	1	3	3	4	1	3	70
3	3	3	1	3	1	3	4	4	1	3	70
4	3	2	1	3	1	3	2	3	1	1	70
5	3	2	1	3	1	3	2	2	1	4	70
6	3	2	1	4	1	3	2	4	1	1	90
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37	3	2	1	4	1	3	2	4	1	3	100

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67	1	2	1	4	1	3	2	4	1	3	90
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84	3	4	1	3	1	3	4	2	1	3	60
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89	3	3	1	3	1	3	2	2	2	3	60
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91	3	2	1	3	1	3	2	3	1	3	80
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99	3	2	1	3	1	3	4	1	1	3	70
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