https://doi.org/10.2352/CIC.2022.30.1.11

Relating Color Associations to Pill Colors and Expected Efficacy

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Abstract

Colors, generally, have effects on human interpretations that can manifest in a variety of emotions, reactions, and behaviors. The objective of this study is to understand the reasoning behind the choices of pill colors in relation to expected efficacy of drugs, as well as the color associations made by participants. The research was conducted at several university campuses in USA, UAE, Croatia, Kosovo, and China, and focused on different age brackets, gender, ethnic backgrounds, educational levels, and pill usage frequency. Understanding the reasoning and color associations helps us better comprehend the expected efficacy of drugs, and can therefore support pharmaceutical companies in designing and manufacturing drugs, thereby maximizing the potential effect on patients' adherence rates.

Introduction

This research extends previous work on the perceived and expected efficacy of pill colors on the effectiveness of drugs. Previously, several surveys were launched across university campuses in the USA, UAE, Croatia, Kosovo, and China to examine the expectations of drugs' effects based on their colors, and to understand the reasoning behind the choices made by participants, along with the color associations exhibited. The stimuli colors examined were blue, green, red, white and yellow, and the efficacies considered were sedative, stimulant, anti-anxiety, pain relief, antacid and hallucinogenic. These were commonly tested in previous studies [1, 2, 3]. The outcomes of our previous research have been published in two papers in 2022 [4, 5], with Figure 1 below highlighting the overall results. It is clear to note that red was strongly associated with the stimulant efficacy, and white was strongly associated with the pain relief efficacy. These two associations were quite consistent across all the surveys conducted.

The colors examined in this study have been popular with researchers. Kwallek et al., as well as Mahnke & Mahnke attributed lower levels of anxiety to blue than other colors [6, 7]. Hemphil associated it with calmness and serenity in a 1996 study [8, 9], while Soldat et al. in 1997 related blue with sadness [10]. Ballest in 2002, categorized blue as a cool color and associated it with restful and quiet [11], similar to Manav's association with calming in 2007 [12]. Chen associated it with sky [13] as well as Tham, who associated blue with water and sky in 2020 [14]. Jonauskaite et al. believed blue is related to positive experiences such as a clear sky or clean water [15]. Furthermore, in Yu's study in 2021, the top two associations with blue were calm and fresh [16].

Green, the color of nature, was also associated with lower anxiety levels according to [6, 7]. It is no surprise that Hemphil associated it with the environment in 1996 [8]. Green was also categorized as a cool color by Ballest who associated it with restful and quiet in 2002 [11]. Naz in 2004 reported that college students associated green with positive feelings such as relaxation and comfort due to the association of the color with nature. On the other hand, an intermediate hue such as green-yellow had the lowest of positive responses, due to its association with vomit, and therefore, feelings of sickness and disgust [17]. In 2009, Moller associated green with success [18], while Krenn stated in 2018 that green can be associated with fairness [19]. Tham believed that some color associations appear to be universal across cultures such as green with health [14] It is worth noting that the reference of green is to health, as in the case of a healthy individual, rather than healthcare and medications. Jonauskaite et al. related green color with positive and powerful emotions [15], and finally, the top two choices in Yu's study associated green color with fresh and grass [16].

Red color has been of interest to researchers since the 20th century where it has been associated with increased levels of anxiety in 1988 by Kwallek et al., and Mahnke & Mahnke in 1993 [7]. Hemphil associated it with excitement in 1996 [8], while Soldat et al. related it with happiness in 1997 [10]. In 2002, Ballest categorized colors in terms of temperatures: warm or cool. Warm colors such as red was associated with activity and stimulation [11]. According to Küller in 2009, strong room colors such as red put the brain in a more excited state [20]. On the other hand, Moller in 2009 associated red generally with failure [18]. Red color has also been associated with a wide range of emotions including but not limited to: love, romance, anger, aggression, danger, and attraction [14, 15, 21, 22, 23, 24]. Chen, related the color red to ripe berries and fruits [13], while Yu related it to culture and passion [16].

White has been associated with positive emotions according to Sutton in 2016 [25] and Jonauskaite et al. in 2020 [15], and had the largest number of positive responses according to Takahashi et al. in 2018 [26]. White has also been associated with traits such as cleanliness, purity, and emptiness by Hanada in 2018 [27], purity by Tham [14], calming, peaceful and gentle by Demir in 2020 [28], and relief by Jonauskaite et al. in 2020 [15].

Yellow is considered to have increased levels of anxiety according to Kwallek et al. [6] and Mahnke & Mahnke [7]. Hemphil related it with the sun in his 1996 study [8], in addition to Ballest's categorization of yellow as a warm color and its association with activity and stimulation [9, 11, 29]. Similarly, and as mentioned above, the intermediate hue of green-yellow solicited negative responses, in a 2004 study by Naz due to the association with vomit and feelings of sickness and disgust [17]. Manav associated yellow with vivid, dynamic, and cheerful [12]. Jonauskaite et al. associated the color yellow with joy and amusement in a 2020 study [15], while Yu associated it with lemon and bright in a 2021 study [16].

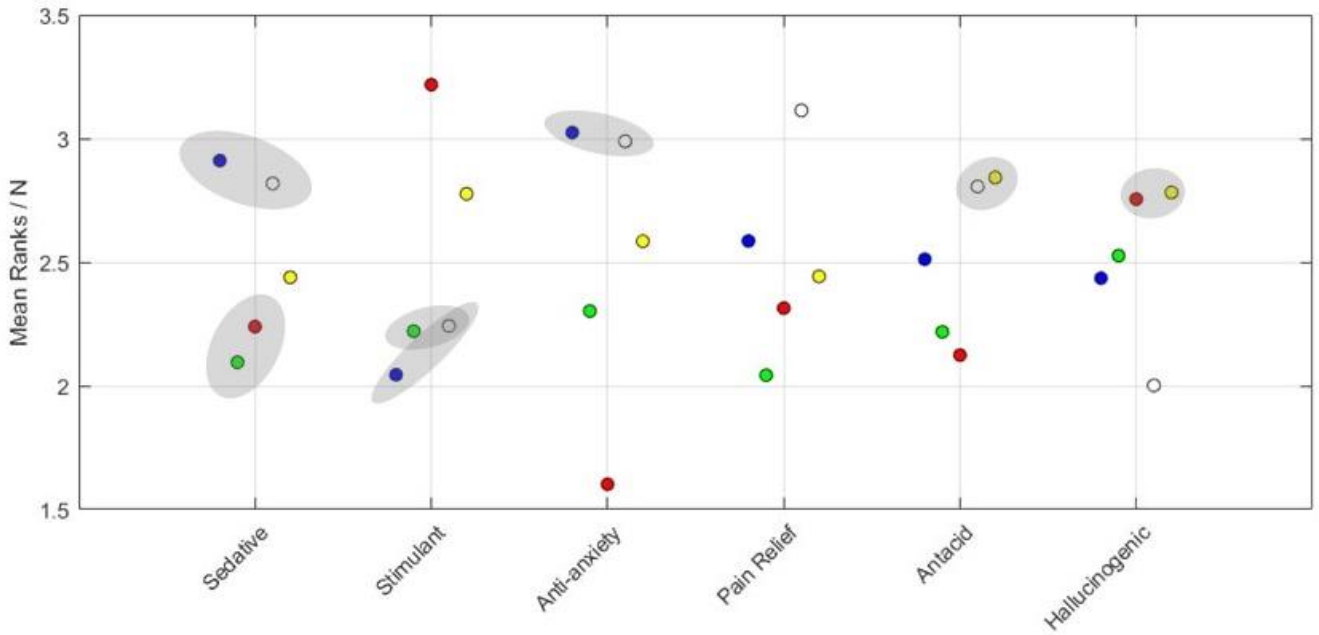

Figure 1. *Relative expectation of pill efficacy for different pill colors for each efficacy category, based on rankings. Gray-shaded ovals include colors where no significant difference was found between them.*

Method

Design & Procedure

A survey was launched at several university global campuses in the USA (n=232), UAE (n=109), Croatia (n=18), Kosovo (n=36) and China (n=16). Participants were asked to complete an online interactive survey, starting by agreeing to a consent form, and providing their demographic information. Participants then moved on to performing a color identification test where they were presented with seven colored circles and asked to identify their colors by selecting from a pre-defined list (blue, green, red, yellow, orange, pink, and grey). If successful, participants were able to proceed to part A of the experiment: Reasoning. This part was divided into six tasks: in each task, participants were asked to select which single color (of blue, green, red, white, and yellow) they expected to be most effective for a particular efficacy category (sedative, stimulant, anti-anxiety, pain relief, antacid or hallucinogenic) (See Figure 2). Once the color was chosen, they were requested to specify one or more reason(s) behind their choice by selecting from a pre-defined list (See Table 1). This task was repeated for each of the six efficacies.

Table 1. List of reasons provided to participants

Advertisements - Branding and marketing campaigns on TV, radio, or social media
Known Medications - Previous and/or current knowledge of similar drugs
Environment - Similarity to landscape and/or nature
Cultural Significance - Influenced by cultural or traditional norms
Emotional - The way it makes me feel
Old Memory - Reminds me of a previous memory/connection
Food - First food thought that comes to mind
Symbol - What this color represents to me personally

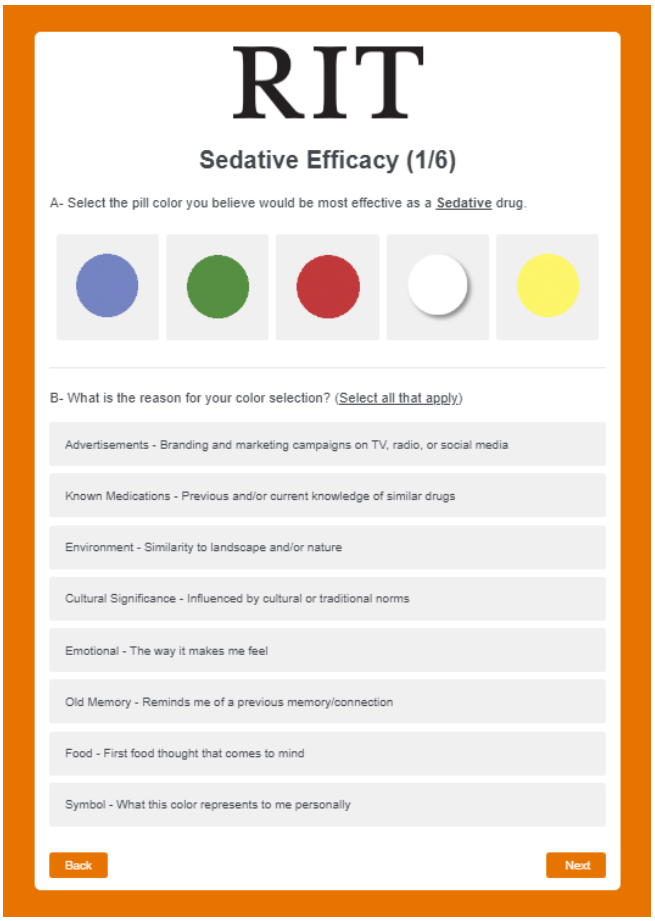

Figure 2. *Color selection and reasoning*

After completing part A, participants moved to part B: Color Association, where they were presented with each color, one at a time (blue, green, red, white, and yellow), and asked to select one or more items of what do they strongly associate the color with from a pre-defined list (See Table 2).

Table 2. List of color associations provided to participants

Aggression	Cold	Happiness	Power
Anger	Competitiveness	Health	Purity
Anxiety	Energy	Inactivity	Sadness
Bravery	Evil	Love	Warmth
Calm	Fear	Nature	Wealth

Color Stimuli

The color input sRGB values and measured CIE 1931 XYZ and CIELAB values, relative to a D65 white XYZ of 486 cd/m^2, for the five colors (blue, green, red, white and yellow) which are representatives of the chosen pill colors are presented in Table 3. Since the surveys were done online, some variation in color reproduction is expected, and unfortunately impossible to quantify. It is worth noting that conducting online surveys in an uncontrolled manner poses certain limitations with regards to conditions that would rather be measured and monitored such as the type of light, light angle, distance from the screen, screen brightness, viewing angles, and background lighting [23, 30]. For more details about the experiment and methodology employed, please refer to our previous paper [5].

Factor Analysis

Factor Analysis (FA), a common statistical method for dimensionality reduction, was used to reduce the number of observed variables in the collected data set to a more manageable and explainable number of unobserved factors. FA assumes the existence of a linear relationship and a correlation between the observed variables and a predetermined number of unobserved factors [31, 32]. Furthermore, FA enables the output to be rotated, according to one of several methods, in order to simplify the interpretation of the solution. FA was used in this research, with a Promax rotation solution which performed an oblique rotation on the data collected in our survey covering the associations' data.

Table 3. Pill color input RGB values and measured CIE 1931 XYZ and CIELAB values

Color	R	G	B	X	Y (cd/m^2)	Z	L*	a*	b*	C^*_{ab}	h_{ab}
Blue	116	133	195	130	125	283	58	10	-35	36	285°
Green	85	143	65	76	115	43	56	-36	37	52	134°
Red	193	58	60	114	68	24	44	55	32	63	31°
White	255	255	255	464	486	538	100	0	0	0	0°
Yellow	255	247	107	394	454	139	97	-17	68	70	104°

Results & Discussion

Factor analysis (FA) was conducted with 20 associations and the results are shown below in Figure 3 and Figure 4 below. FA was run with two factors and a Promax rotation solution for projection simplicity and clarity. The five color stimuli were plotted in the same FA space to validate their placement against the relative position of the associations. It is clear that based on the comparison with the previous results that the colors' position is fairly aligned with the positions of the associations with which a strong connection exists. Figure 3 adds the efficacies to the FA space while Figure 4 presents an example of the location demographic in the FA space, without the efficacies for ease of visualization. The objective of both figures is to demonstrate the relationships of the efficacies and demographics with the colors and their associations.

Looking at the blue color and its association with the word calm as per the survey results, blue has been constantly associated with calm in the literature as well [8, 9, 11, 12, 16]. This in turn explains its association with the sedative efficacy, and being second highest color for the anti-anxiety efficacy, as well as the lowest for the stimulant efficacy.

As for the red color, the survey results and previous literature has associated it with activity, stimulations, excitement, anger, aggression, and power [8, 11, 14, 15, 20, 21, 22, 23, 24]. This in turn explains why red scored the highest for the stimulant efficacy, hallucinogenic efficacy, and the least for both the sedative and anti-anxiety efficacies.

White color was mainly associated with both purity and calm as per the survey results, in addition to prior studies [14, 15, 27, 28]. White was perceived as most effective for the anti-anxiety efficacy, pain relief, and antacid efficacies, and scored the second highest for the sedative efficacy.

With regards to the yellow color, this color was mainly associated with energy and warmth as per the survey results, which is supporting Ballast's findings in 2002 [11], Manav's in 2007 [12], Jones's in 2015 [29], and AL-Ayash's findings in 2016 [9]. Yellow was the second top choice for both the stimulant and hallucinogenic efficacies.

Similar to our previous research, the green color did not have any strong association with any of the efficacy categories, and this again may be due its association with health [14], rather than medications or the expected efficacies included in this research.

Valence & Arousal

Two common terms referred to in psychology are Valence and Arousal [33, 34], where the common definitions of valence being the positive affectivity or the negative affectivity of the emotion, and therefore, the ability and tendency to experience those emotions as being either a positive or a negative one. On the other hand, arousal in this context of psychology refers to the strength and intensity of the emotion ranging from excitement to relaxation. It is evident that the results align with the Arousal and Valence concepts, which is a further confirmation of the saliency or importance of these dimensions.

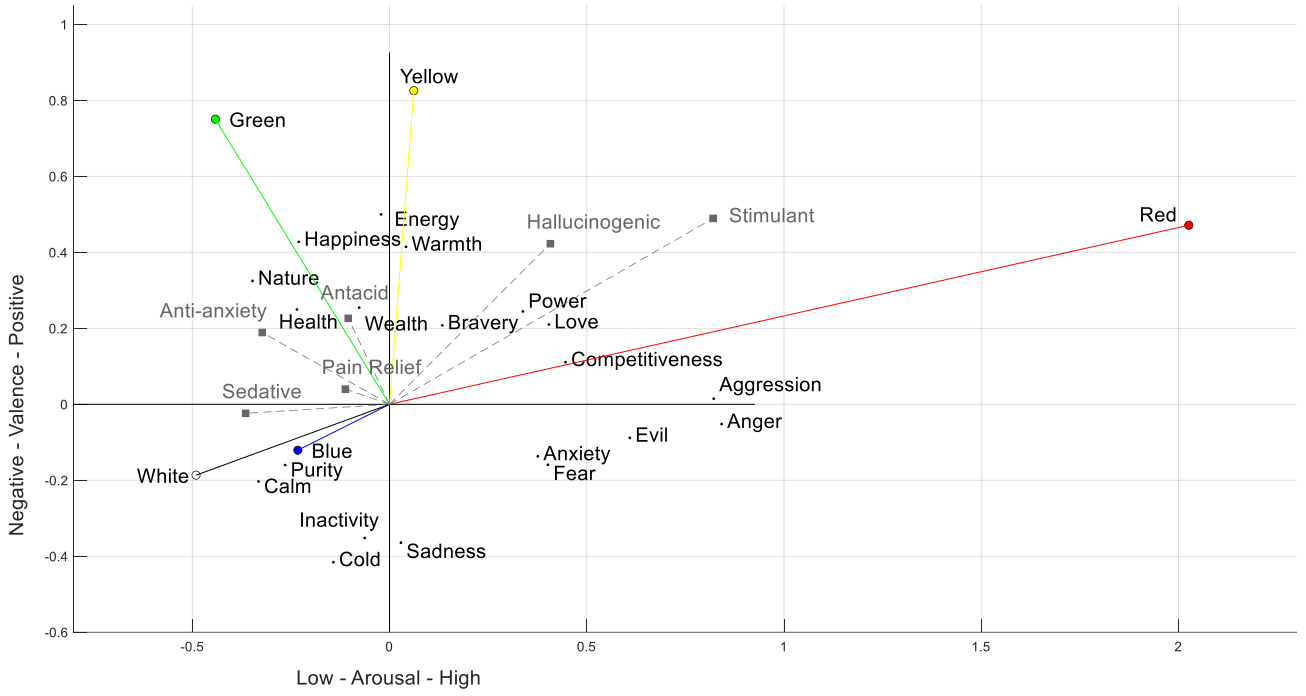

Figure 3. *Factor Analysis with two factors and a Promax rotation solution showing the efficacies in the FA color space. Axis labels of Valence and Arousal are the interpretation of the authors.*

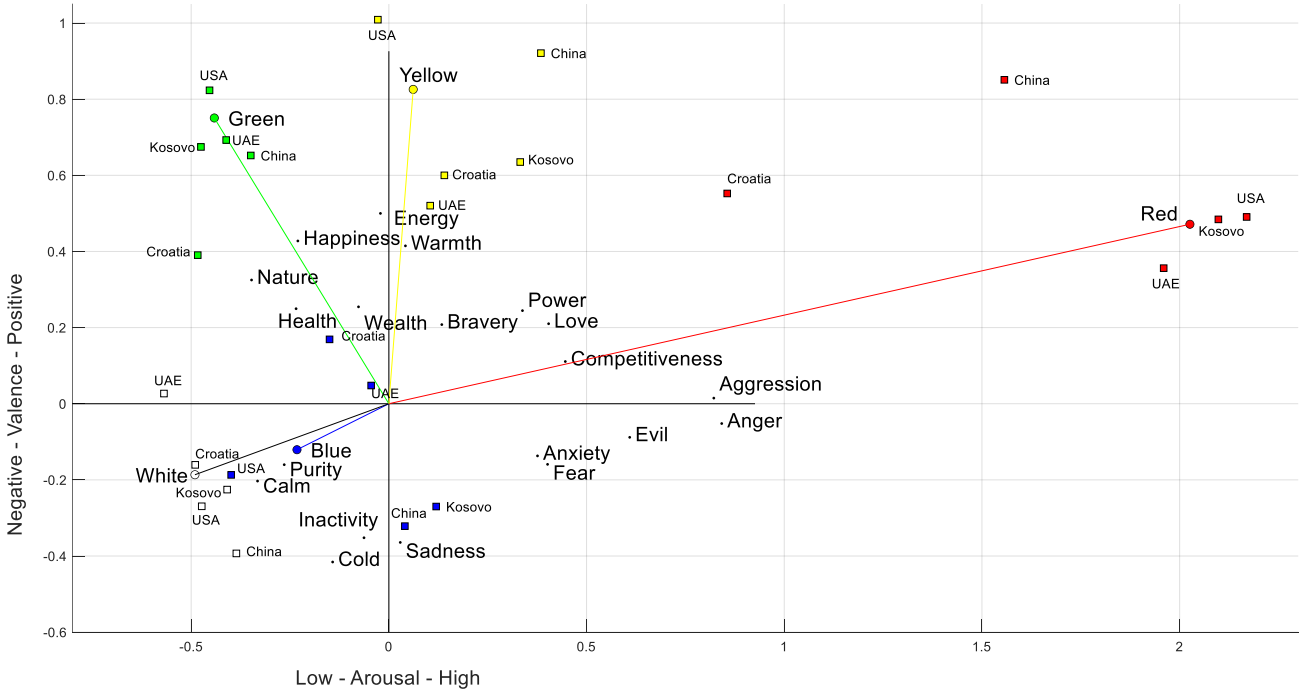

Figure 4. *Factor Analysis with two factors and a Promax rotation solution showing the location demographic in the FA color space. Axis labels of Valence and Arousal are the interpretation of the authors.*

As per the results of the factor analysis results, and the general associations of the participants with regards to the emotions with colors, one can wonder if this can be taken a step further and associate the emotions with efficacies, as well. This is demonstrated in Figure 3 where efficacies are added to the FA space. Blue is strongly associated with the sedative efficacy and is located in the low arousal/negative valence quadrant, and it is strongly associated with calm and cold. As mentioned earlier, green was not strongly associated with any of the efficacies, yet, it is found in the same quadrant as health and nature on the low arousal/positive valence scales. Red being strongly associated with the stimulant and hallucinogenic efficacies, and therefore, would be on the high arousal/positive quadrant as aggression, competitiveness, power and love. White is associated with the sedative efficacy, and in turn, is on the low arousal/negative valence quadrant as purity and calm. Yellow being associated with the stimulant, antacid, and hallucinogenic efficacies, is on the positive valence scale, and is very close to the margin between the high and low sides of the arousal scale, but leaning more towards the high quadrant. Yellow is associated with energy and warmth.

As previously stated, Figure 4 adds the location demographic to the FA space, as an example, to demonstrate the different locations with respect to the arousal and valence scales. It is evident that the clusters of locations are mainly centered around the main color, and given the fact that the USA data includes the largest set of participants, it is no surprise that it is mainly located closest to each color point, which can be interpreted as the grand mean. It is interesting to see that all locations are mainly in the same arousal and valence quadrant as the main color, with the exception of blue and white. With regards to blue, while the main blue point is located in the low arousal/negative valence quadrant along with the USA blue, the UAE and Croatia blues are in the low arousal/positive valence quadrant. Furthermore, Kosovo and China blues are located in the high arousal/negative valence quadrant. As for white, the main color point is located in the low arousal/negative valence quadrant, along with the whites for USA, Croatia, Kosovo and China being in the same quadrant. UAE white stood out as the exception of being located in the low arousal/positive valence quadrant instead. These two examples demonstrate the effect of demographics on the overall outcome.

Considering the arousal and valence scales mentioned earlier, one can notice that perhaps the efficacies can be categorized accordingly, where the stimulant and hallucinogenic are in the high arousal/positive valence quadrant based on their association with yellow and red, while the anti-anxiety, pain relief, and antacid efficacies are in the low arousal/positive valence quadrant. The sedative efficacy, in particular, can be found in the low arousal/negative valence quadrant based on its associations with blue mainly, in addition to white.

Conclusion

Several conclusions can be drawn from this study which are significant in the color field. First, we can successfully conclude that general color associations mostly follow the valence-arousal concepts, widely known in the psychology field. Observed trends mainly follow the study by Jonauskaite et al., where color emotion association has a universal basis shared by participants with different languages, geographical, and cultural backgrounds [35]. Second, our findings appear mainly to be stable over different locations and demographics. Third, color associations can be successfully applied to pill colors and expected efficacy, which can have a significant impact on the pharmaceutical industry.

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