Supporting Online Material for

Blue or Red? Exploring the Effect of Color on Cognitive Task Performances

Ravi Mehta and Rui (Juliet) Zhu*

*To whom correspondence should be addressed. E-mail: juliet.zhu@sauder.ubc.ca

Published 4 February 2009 on *Science* Express
DOI: 10.1126/science.1169144

This PDF file includes

Supporting Online Material

Materials and Methods

Color Association Task: Method and Analysis

Stimuli

In this auxiliary study, we examined the kinds of associations individuals have in relation to red versus blue color within the cognitive domain. Participants completed two questions, in random order, one at a time on a white background computer screen. The questions asked them to imagine themselves working on a cognitive task in a room painted with the blue (red) color and then list all the associations that this blue (red) color may trigger in their minds. Below the question a blue or red color (depending on the question), 8 cm X 8 cm square (Fig. S3), was presented, following which a text box was provided for participants to write their associations.

All associations listed were coded by two judges and were categorized into five groups of associations for red color (table S2) and five for blue color (table S3). The agreement between the two judges ranged between .92 and 1.00 for all the groups of associations. Participants generated an average of 3.89 vs. 4.59 associations to red vs. blue color. As summarized in table S2 and S3, on average, 70.15 % of the associations participants generated in the red color condition were related to dangers and mistakes, and 59.09 % of the associations generated in the blue color condition were related to openness, peace/tranquility and safety.

Procedure

Twenty-three (8 Males and 15 Females; ages: 17-38yrs) students participated in the study in exchange for $10 and completed this short computer based study at their own pace.

Study 1: Method and Analysis

Stimuli

Anagram Task. For this task participants were asked to solve a series of 12 anagrams with one on each screen. Among these anagrams, three of them had target words associated with the approach motivation (i.e., adventure, advance and Olympics), three of them had target words associated with the avoidance motivation (i.e., obligation, prevent and guarantee), and the remaining six anagrams had target words unrelated to either motivation (i.e., violin, drink, phone, count, computer, ranch). The presentation order of these anagrams was randomized. Each person's response time to the three approach related anagrams was averaged to create an approach motivation anagram response time (RT) index. Similarly, we averaged each person's response time to the three avoidance motivation anagrams to form an avoidance motivation anagram RT index and a neutral anagram RT index. All response time measures were based on correctly solved anagrams.

The anagram words were chosen based on previous literature. An approach motivation is characteristic of a promotion regulatory focus, which is concerned with adventure, advancement, and accomplishment while an avoidance motivation is characteristic of a prevention regulatory

focus, which is concerned with obligation, safety and security (*S1, S2*). Based on prior research (*S3*), a faster response time to approach words would imply the activation of the approach motivation while a faster response time to avoidance words would indicate that an activation of an avoidance motivation.

To test our hypothesis we ran a 3 (color) X 3 (RT indices) mixed design, with the second factor being a within-subject factor. Results revealed a significant interaction ($F(2, 66) = 8.79$, $p < .001$).

Brand Preference Task. Under this task participants were presented with descriptions of three pairs of brands and were asked to report their preferences along a scale from 1 (prefer Brand A) to 7(prefer Brand B). In the first pair (toothpastes), Brand A was particularly good for cavity prevention (avoidance motivation), and Brand B was particularly good for tooth whitening (approach motivation). In the second pair (snacks), Brand A was a rich and tasty chocolate cake (approach motivation), and Brand B was a healthy and fresh fruit salad (avoidance motivation). In the third pair (cars), Brand A focused primarily on style and performance (approach motivation), and Brand B focused primarily on safety and accident protection (avoidance motivation).

To test our hypothesis each person's responses to all three sets were averaged to create an overall brand preference index ($\alpha = .71$). Higher ratings indicated a greater approach rather than avoidance motivation. One way ANOVA revealed a significant main effect of color ($F(2, 66) = 4.26$, $p < .02$) on this index.

Procedure

A total of 69 undergraduate students (27 males and 42 females; age range 17-25 yrs) participated in the study in exchange for extra course credit. The study was run in small groups of no more than 10 people in each session. Participants were randomly assigned to red, blue, or neutral (white) background color condition and were instructed to complete a computer-based study. The computer background color was set to be red, blue, or white. Participants completed the above described tasks i.e. the anagram and the brand preference task. Finally, participants were asked what they think the study was about and were tested for color blindness. None of the participants could either guess the purpose of the study or failed the color blind test.

Ruling out mood as an alternative explanation

In an auxiliary study we tested whether the observed effects were driven by different affect induced by red versus blue color. We recruited 53 participants (19 males and 34 females) from the same population as those in study 1 to complete a short computer-based study. The computer background screen was set to be red, blue, or neutral as in study 1. Participants rated their current feelings on 10 adjectives. While five of these were positive moods (i.e., happy, excited, cheerful, enthusiastic, relaxed; $\alpha = .84$), the other five were negative moods (i.e., sad, anxious, jittery, tense, depressed; $\alpha = .88$). The presentation order of these items was randomized. Results revealed that our color manipulation did not affect either the positive mood index ($F < 1$; $M_{red} = 3.86$, SD = 1.25; $M_{blue} = 3.98$, SD = 1.43; $M_{neutral} = 4.05$, SD = .93) or the negative mood index ($F < 1$; $M_{red} = 1.69$, SD = .89; $M_{blue} = 1.84$, SD = .88; $M_{neutral} = 2.00$, SD = 1.10). Thus, mood cannot be an alternative explanation for our effects. The above results also echo the extant literature (*S4*) which suggests that non-affective cues are capable of inducing approach and avoidance motivations.

Study 2: Method and Analysis

Stimuli

Detail-Oriented Task. A memory task was used as the detail-oriented task for this study. It has been suggested that recall requires higher level of undivided attention (*S5*) and that more accurate recall (and fewer false alarms) in a memory task reflects attention to specific details and a motivation to avoid mistakes (*S6*). Hence it was expected that participants in red color condition would outperform those in blue color condition. Participants were asked to study a list of 36 words (e.g., violin, accountant, sweater) and their free recall of these items were measured after a delay of 20 mins. Each participant's responses were coded into three categories: (1) total number of items recalled, (2) total number of items recalled correctly, and (3) total number of items recalled incorrectly. The sum of (2) and (3) should equal to (1). One-way ANOVA revealed a significant main effect of color on both correctly recalled items ($F(2, 100) = 3.15$, $p< .05$) and incorrectly recalled items ($F(2, 100) = 3.64$, $p< .03$). Effect of color was however non-significant for total number of items recalled ($F(2, 100) = 2.28$, $p>.11$; $M_{red} = 16.23$, SD = 5.93; $M_{blue} = 13.17$, SD = 5.60; $M_{neutral} = 14.72$, SD = 6.61).

As the study was done on computers, we also recorded the amount of time each participant spent on the recall task. There was no main effect of color on this measure (M_{red} = 143.76secs, SD = 55.36; $M_{blue} = 123.69$secs, SD = 45.77; $M_{neutral} = 163.06$secs, SD = 83.93; $F(2, 100) = 2.19$, $p> .12$).

Creative task. For this task, participants were asked to list as many creative uses of a brick as they can think of (S7). We coded each person's responses into three categories: (1) total number of uses generated, (2) mean creativity score, and (3) total number of creative uses. The first category was a simple count of the uses produced by each participant. To calculate category (2), we first compiled all uses produced by all participants, which resulted in a total of 217 unique uses. Then, we recruited 12 judges from the same population as our study participants to rate how creative each of the 217 uses is on a 9-point Likert scale (1: very uncreative; 5: neither creative nor uncreative; 9: very creative). These judges' ratings for each use were averaged to create a mean creativity score for each use. With these numbers, we were able to calculate the mean creativity score for each participant (i.e., summation of mean creativity scores for all the uses generated by the participants, divided by total number of uses generated by this person). Finally, to calculate category (3), we counted the number of uses each participant generated that had mean creativity scores higher than 5 (i.e., the midpoint of the rating scale). An example of a creative use of a brick generated was "to use it as a scratch post for animals (for their nails)".

One way ANOVA revealed that color significantly affected both the mean creativity score ($F(2, 102) = 4.43$, $p< .02$) and the number of creative uses ($F(2, 102) = 5.34$, $p< .01$). However, no effect was found for total number of uses generated ($F<1$).

Procedure

A total of 208 undergraduate students participated in the study for extra course credit.. Upon arrival, participants were randomly assigned to red, blue or neutral color condition. Half of the participants (N = 103; 39 males and 64 females; age range 18-29 yrs) completed the detailed-oriented memory task i.e. they were presented with the list of 36 words and were asked to study

these words for two minutes. The program moved on to the next screen automatically after two minutes. Next, participants completed unrelated filler tasks which took about 20 minutes before they worked on an unaided, free recall task.

The other half of the participants (N = 105, 45 males and 60 females; age range 17-27yrs) completed the creative use of brick task. They were given one minute to generate as many creative uses for a 'brick' as they could think of but refrain from listing typical uses or the uses that are virtually impossible. For both groups of participants, the study ended with demographic questions and color-blindness test. None of the participants failed the color blind test.

Study 3: Method and Analysis

Stimuli

Motivation Items. To gauge whether color-induced motivations were the underlying force driving our effect, we asked participants' agreement to three questions as they were completing the focal task. Seven-point scales (1: strongly disagree; 7: strongly agree) were used to solicit answers to the following three questions: (1) I focused on completing the tasks as quickly as possible, (2) I was concerned about making mistakes, and (3) I was more concerned about accuracy than speed. For people completing the detail-oriented task, the first item was reverse coded, and then the three items were averaged to create an avoidance motivation index ($\alpha = .73$), such that higher ratings indicated greater avoidance motivation. For participants completing the creative task, the same three motivation-related items ($\alpha = .70$) were used, however the latter two questions were reverse coded and the three items were then averaged to create an approach motivation index, such as that higher ratings indicated greater approach motivation.

Detail-oriented task. A proofreading task was used as a detail-oriented task as it has been widely used in testing people's focus on details, such as in clerical examinations (*S8*). This task included five sets of items, with each set containing a pair of names or addresses which were either identical or slightly different in spelling or punctuation (i.e., Peitro Sundergard & Sons, Ltd. and Peitro Sundergard & Sons, Ltd.; 36974 South Main Street NW and 39674 South Main Street NW; Travis Jemesaston Millar, III and Travis Jemesaston Miller, III; Sonseretti & Tansareski Cable Co. and Sonseretti & Tanseraski Cable Co.; Martin-Senour Paints and Martin-Senour Paints). Participants were asked to judge whether each pair of items are identical or not.

We first calculated the total number of correct responses produced by each participant. The value could range from 0 to 5. One-way ANOVA revealed a significant main effect of color ($F(2,51) = 3.56$, $p < .04$). To assess whether the above effect was mediated by color-induced motivation, we conducted mediation analysis (S9). Color was recoded using two dummy variables. The red condition was set as the baseline, and β_1 represents the difference between blue and red and b_2 represents the difference between neutral and red. First, regression analysis revealed that color significantly affected proofreading accuracy ($\beta_1 = -.80$, $p < .02$; $\beta_2 = -.65$, $p < .05$). Next, color also significantly affected the avoidance motivation index ($\beta_1 = -1.21$, $p < .01$; $\beta_2 = -.67$, $p < .08$). Finally, when the motivation index was included as a predictor in the first regression, it was significant ($\beta = .33$, $p < .01$), but the effect of color became non-significant ($\beta_1 = -.41$, $p > .22$; $\beta = -.43$, $p > .16$). Sobel test revealed significant result for the red and blue condition ($Z = -2.17$, $p < .03$), but non-significant result for the red and neutral condition ($Z = -1.54$, $p = .12$).

Creative Task. For the creative task, we chose the Remote Associates Test (RAT). The five RAT items included in this task were: (1). Shelf, Read, End (Answer: Book); (2) Nurse, Sick, Hospital, Occupation (Answer: Doctor); (3) Web, Insect, Bug, Creepy (Answer: Spider); (4) Shoe, Kick, Soccer, Toe (Answer: Foot); and (5) Bed, Rest, Pillow, Dream (Answer: Sleep).

Using the approach motivation index, we conducted mediation analysis on RAT results. Again, color was coded using two dummy variables. The blue condition was set to be the base condition, and b_1 represents the difference between red and blue and b_2 represents the difference between neutral and blue. Regression analysis revealed that color significantly affected RAT scores ($\beta_1 = -.55$, $p < .03$; $\beta_2 = -.62$, $p < .01$), as well as the approach motivation index ($\beta_1 = -.88$, $p < .01$; $\beta_2 = -.78$, $p < .02$). When the motivation index was included as a predictor in the first regression, it was still significant ($\beta = .25$, $p < .01$), but the effect of color dropped in significance($\beta_1 = -.33$, $p > .17$; $\beta_2 = -.43$, $p > .07$). Sobel tests revealed significant result for the red and blue conditions ($Z = -1.96$, $p < .05$), and marginal significant result for the blue and neutral condition ($Z = -1.85$, $p < .06$).

Procedure

A total of 118 students participated in the study in small groups in exchange for $10. Upon arrival, they were randomly assigned to red, blue or neutral color condition. Next, about half of the participants (N = 54, 12 males and 42 females; age range 18-37yrs) completed the detailed-oriented proofreading task. Then, participants responded to three motivation related questions. The rest of the participants (N = 64, 23 males and 41 females; age range 17-39yrs) completed the RAT and completed the same three motivation-related items. For both groups of participants, no time limit was set for completing the tasks and the study ended with demographic questions and color-blindness test. None of the participants failed the color blindness test.

Study 4: Method and Analysis

Stimuli

For this task participants were presented with one sheet of paper which had drawings of 20 different parts either in red or blue color (*S10*) (Fig. S1).

Procedure

Forty-two participants (10 males and 32 females, age range 17-28yrs) were recruited for this study in exchange for a course credit. They were invited to the lab in groups of not more than five. They were then presented with a sheet of paper with drawings of 20 different parts in either red or blue color as detailed above. Participants were then asked to use any five parts to draw a design of a toy, anything a child (age 5–11) can use to play with. Participants were required to circle the five parts they decided to use for their designs and were then asked to draw their toy design on a blank sheet of paper provided to them. They could only use each part once and were not allowed to use any of the non-selected parts. No time limit was imposed.

As soon as participants finished drawing their toy designs, they completed a set of 10 anagrams, 3 of them were related to the approach motivation (Adventure, Triumph, Accomplish), another 3 related to the avoidance motivation (Virus, Vigilant, Guarantee), and the

remaining 4 were neutral and didn't relate to either type of motivation (Violin, Computer, Fruit, Phone). The presentation order of these anagrams was randomized. We measured participants' response time for each correctly solved anagram. Each person's response times to each type of correctly solved anagrams were averaged to create, an approach motivation anagrams response time (RT) index, an avoidance motivation anagrams RT index, and a neutral anagrams RT index. Participants finally answered a few demographic questions and were tested for color blindness. None of the participants failed the test.

In the second stage of this study we recruited twelve judges, from the same population, to evaluate each design on two dimensions, one assessing the originality/novelty and the other practicality/appropriateness of the design on a 1-7 scale. Each judge received a separate booklet containing black and white photocopies of 42 designs in random orders. The judges were blind to the identity of the students, to one another, and to the purpose of the experiment. The correlation between the two dimensions i.e. originality and appropriateness was found to be non-significant, ($r(42) = .29$, $p = .08$). Inter-judge reliabilities ($\alpha = .75$ for originality and $\alpha = .83$ for appropriateness) were at acceptable levels and in range as reported in the extant literature (*S11*)

Mediation Analysis

It was observed that participants who designed the toys using red color parts responded faster to the avoidance-related anagrams (M=9.64secs, SD = 3.47) (indicating an activation of an avoidance motivation) as compared to the participants who used blue color parts to design their toys (M=15.84secs, SD = 8.65; $F(1, 40) = 6.04$, $p < .05$). A series of regressions were conducted to test if the red color induced avoidance motivation led to higher ratings on appropriateness of design. First, regression analysis revealed that red color indeed led to higher appropriateness of design ($\beta = -.307$, $p < .05$). Next, color also significantly affected the avoidance motivation index ($\beta = .366$, $p < .05$). Finally, when the avoidance motivation index was included as a predictor in the first regression, it was significant ($\beta = -.334$, $p < .05$), but the effect of color became non-significant ($\beta = -.173$, $p > .27$).

On the other hand participants who designed the toys using blue color parts responded faster to the approach-related anagrams (M=10.96secs, SD = 7.68) (indicating an activation of an approach motivation) as compared to the participants who used red color parts to design their toys (M=16.50secs, SD = 9.00; $F(1, 40) = 5.48$, $p < .05$). A series of regressions were conducted to test if the blue color induced approach motivation led to higher ratings on originality/novelty of design. First, regression analysis revealed that blue color indeed led to higher originality/novelty of design ($\beta = .317$, $p < .05$). Next, color also significantly affected the approach motivation index ($\beta = -.355$, $p < .05$). Finally, when the approach motivation index was included as a predictor in the first regression, it was significant ($\beta = -.409$, $p < .05$), but the effect of color became non-significant ($\beta = .21$, $p > .15$).

Study 5: Method and Analysis

Stimuli

Two versions of a camera ad were employed for this study (*S12*). Both ads featured the same camera image in the middle, but it was surrounded by two different sets of visuals. In one version, the surrounding visuals represented specific product details of the camera (e.g., a roll of film, the zoon lens, and the remote control), which we expected to be more consistent with a

detail-oriented processing style. In the other version, the ad visuals represented rather ambiguously related associations (e.g., a road sign, a dining table in a restaurant, and a map). Although these images are not directly related to the focal camera product, creative cognition can help individuals to figure out that they are all linked to a camera-related theme, i.e., travel. This version was expected to be more compatible with a creative processing style (Fig. S2). Both ad versions featured the same headline and ad copy. The ad was placed in the middle of the computer screen and took about 60% of the total area, the remaining area or the background was set to have either red or blue color. Thus, the study had a 2 (ad visual type: product details vs. remote associations) X 2 (background color: red vs. blue).

Procedure

One hundred and sixty one undergraduate students participated in this study, for extra course credit, in small groups. Upon arrival, participants were seated in front of computers and were randomly assigned to one of the four experimental conditions. They were asked to evaluate an ad which was under development and were asked to examine it in a normal way as they would do it in their daily life. Next, participants were shown one version of the ad, and there was no time limit for ad viewing. Then, participants evaluated the ad on three 7-point items which assessed how appealing, favourable, and effective they thought the ad was (1: not at all; 7: very much). Responses to these three items were averaged to form an overall ad evaluation index (α= .94). Upon finishing the ad evaluation task, participants completed a thought-listing task. The study ended with demographic questions and color-blindness test.

Analysis

Seven participants either did not complete the study or failed the color blindness test and were therefore excluded from the dataset. Thus, a total of 154 responses (62 males and 92 females; age range 17-25yrs) were included for data analysis. All data were analyzed using 2 (Color) X 2 (Ad visual type) between-subjects ANOVA. A significant two-way interaction emerged for the ad evaluation index ($F(1, 150) = 9.29$, $p < .01$).

Study 6: Method

Procedure

A total of 68 undergraduate students (17 males and 51 females, age range 18-26yrs) completed the short computer-based survey, in exchange for a course credit. Upon arrival, participants were seated in front of a computer. After the introduction screen, participants were told that they will be asked to complete a series of tasks in this study, and one of them requires detailed, careful, and systematic processing of information. Further, the task can be presented either with a red or a blue background color. Participants were asked to select one color that they think would enhance their performance on this task. A sample of the red and blue color was presented in form of 8cm X 8cm color squares (Fig. S3). On the next screen, participants were told that another task in this study would require creative, imaginative, and outside of the box thinking. Again, they were asked to select one out of the two colors that they think can enhance their performance on this creative task. The presentation sequence of these two tasks was counter-balanced. No order effect was observed for these two tasks. Participants were tested for color blindness and debriefed after making these two choices.

Figures

Fig. S1: Blue vs. red parts sheets presented to participants (Study 4)

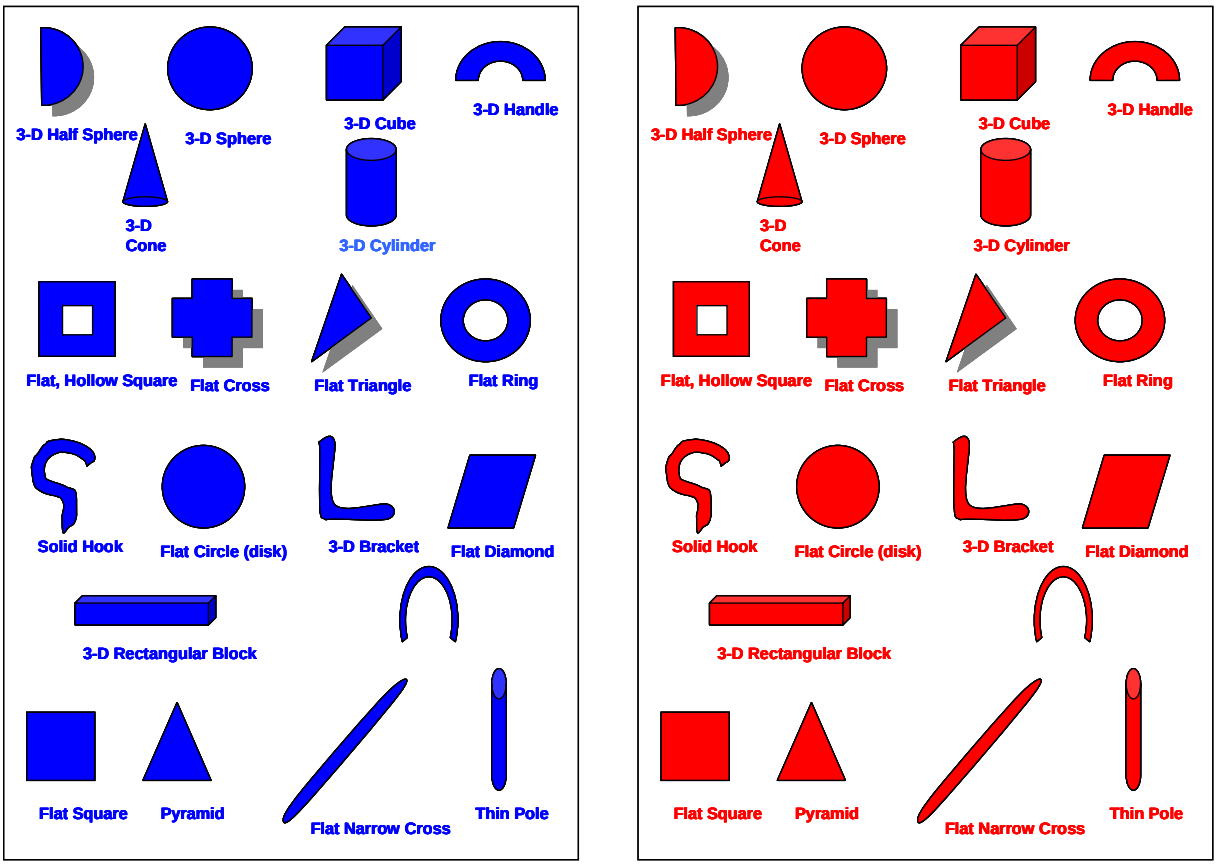


Fig. S2: Two versions of the advertisements (Study 5).

Note: The left one features visuals that are remotely related to the focal camera product; the right version features visuals that depict specific product details.

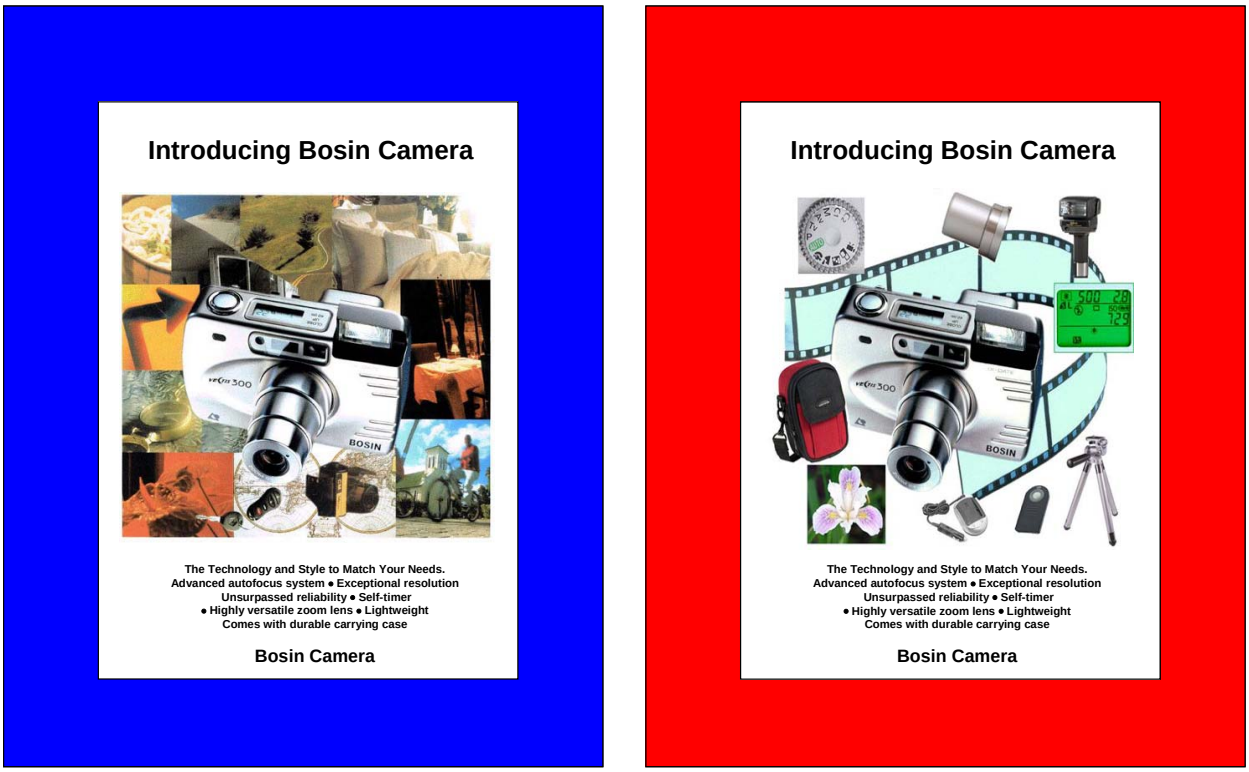
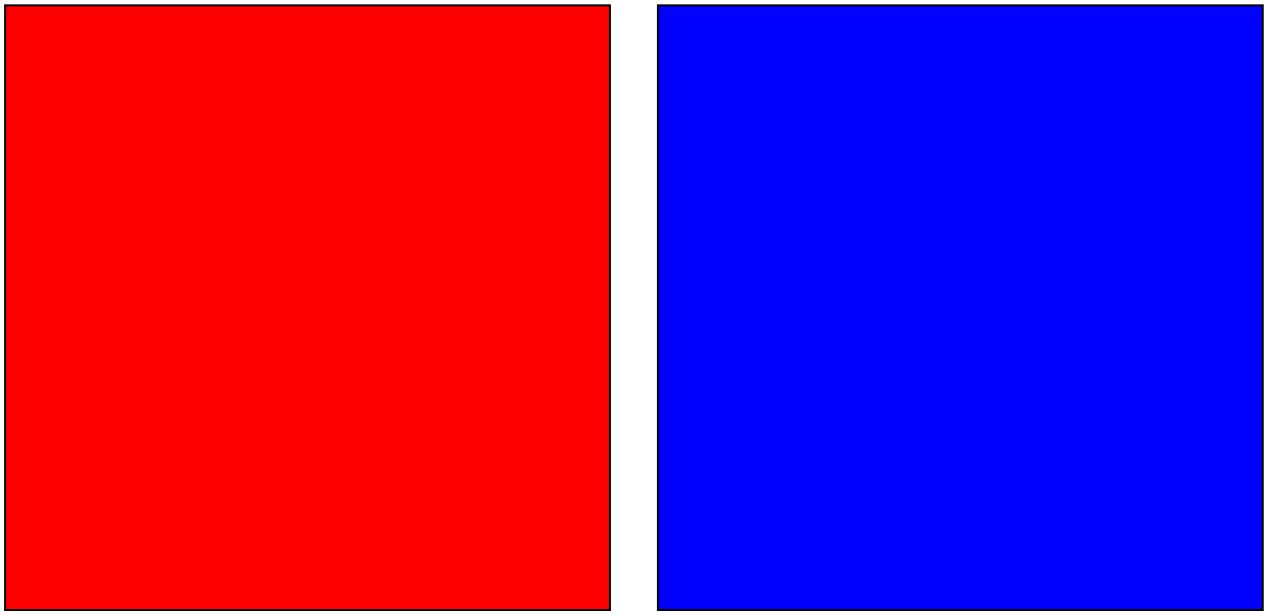


Fig. S3: Color samples presented to participants (Color Association Task, Study 6)



Tables

Table S1: Color Manipulation Specifications
For studies 1, 2, 3 and 5, computer background screen color was used to accomplish the color manipulation. The background screen color was manipulated using HSL scheme. This table indicates the values used for HSL scheme and also the corresponding RGB scheme.

HSL Scheme			Corresponding RGB Scheme		
	Red Color	Blue Color		Red Color	Blue Color
Hue	0	160	R	255	0
Saturation	240	240	G	0	0
Lightness	120	120	B	0	255

Table S2: Associations to Color Red (Color Association Task)

Association	Examples	Average Percentage of Associations*
Danger	Danger, Scared, Emergency, Alert, Attention	56.07%
Caution/Mistake	Caution, Stop, Stop sign, Mistake, Exam	14.08%
Happy	Happy, Bright	4.76%
Love/Passion	Rose, Heart, Love, Passion, Valentine	9.72%
Others	Watch, Paint, Convertible, Playground slide, Apple	15.36%

* Average percentage of associations each person generated that falls into each of the following categories.

Table S3: Associations to Color Blue (Color Association Task)

Association	Examples	Average Percentage of Associations*
Peace/Calm	Peace, Tranquil, Clam, Cool, Quite	31.78%
Openness/Freedom	Open, Free/Freedom, Sky, Ocean, Sand	22.77%
Protection	Protection, Navy, Safe,	4.53%
Sad/depressing	Unhappy, Choking, Crying, Cloudy, Mood	17.79%
Others	Nemo, Robot, Jeans, Artwork, Boat	23.12%

* Average percentage of associations each person generated that falls into each of the following categories.

References

S1. E. T. Higgins, *Ameri. Psychol.* **52**, 1280 (1997).
S2. E. T. Higgins, in *Adv. Exper. Soc. Psychol.*, M. P. Zanna, Ed. (Academic Press, New York, 1998), pp. 1-46.
S3. A. J. Elliot, M. V. Coviogton, *Educ. Psychol. Rev.* **13**, 73 (2001)
S4. R. S. Friedman, J. Forster, *J. Pers. Soc. Psychol.* **79**, 477 (2000).
S5. F. I. Craik, J. M. McDowd, *J. Exp. Psychol. Learn., Mem., Cog.* **13**, 474 (1987)
S6. E. Crowe, E. T. Higgins, *Org. Behav. Hum. Decis. Proc.* **69**, 117 (1997).
S7. R. S. Friedman, J. Forster, *J. Pers. Soc. Psychol.* **81**, 1001 (2001).
S8. S. Kaplan, *J. Environ. Psychol.* **16**, 169 (1995).
S9. R. M. Baron, D. A. Kenny, *J. Pers. Soc. Psychol.* **51**, 1173 (1986).
S10. C. P. Moreau, D. W. Dahl, *J. Consumer Res.* **32**, 13 (2005).
S11. D. W. Dahl, A. Chattopadhyay, G. J. Gorn, *J Mktg Research* **36**, 18 (1999).
S12. R. J. Zhu, J. Meyers-Levy, *J. Consumer Res.* **34**, 89 (2007).