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A Systematic Investigation of Conceptual Color Associations

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Associations with colors are a rich source of meaning, and there has been considerable interest in understanding the capacity of color to shape our functioning and behavior as a result of color associations. However, abstract conceptual color associations have not been comprehensively investigated, and many of the effects of color on psychological functioning reported in the literature are therefore reliant on ad hoc rationalizations of conceptual associations with color (e.g., blue = openness) to explain effects. In the present work we conduct a systematic, cross-cultural, mapping of conceptual color associations using the full set of hues from the World Color Survey (WCS). In Experiments 1a and 1b we explored the conceptual associations that English monolingual, Chinese bilingual, and Chinese monolingual speaking adults have with each of the 11 Basic English Color Terms (black, white, red, yellow, green, blue, brown, purple, pink, orange, gray). In Experiment 2 we determined which specific physical WCS colors are associated with which concepts in these three language groups. The findings reveal conceptual color associations that appear to be universal across all cultures (e.g., white – *purity*; blue – *water/sky related*; green – *health*; purple – *regal*; pink – *"female" traits*) as well as culture specific (e.g., red and orange – *enthusiastic* in Chinese; red – *attraction* in English). Importantly, the findings provide a crucial constraint on, and resource for, future work that seeks to understand the effect of color on cognition and behavior, enabling stronger a priori predictions about universal as well as culturally relative effects of conceptual color associations on cognition and behavior to be systematically tested.

Keywords: color association, color psychology, cross-cultural, color language, color cognition

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For most people color is an immediate and essential component of their perception of the world, and understanding color phenomena has been an area of highly productive research (e.g., Elliot, Fairchild, & Franklin, 2015; Hardin & Maffi, 1997; Hurlbert & Owen, 2015; Regier & Kay, 2009). The importance of color extends beyond simple perceptual experience to encompass rich symbolic functions, as emphasized by the many expressions of language specific sentiments or concepts (Hutchings, 1997, 2004; Mohammad, 2011) such as, in the English language, *green with envy* (jealous), *out of the blue* (randomly), *red hot* (exciting), *white as a ghost* (fear), and in Chinese, *bright white* (to understand), *red fire* (flourish, good luck), or *gray heart* (discouraged). However, at present, we lack a systematic and comprehensive understanding of the extent to which these abstract *conceptual,* color associations are shared by members of a culture, differ across culture, and are linked to specific points in colorimetric space.

Further, although abstract conceptual color associations are important to understand in their own right, the importance of building a systematic understanding of conceptual color associations is further emphasized when we consider their use in other areas of psychological research. One topic of enquiry that has attracted substantial interest in recent years has been the impact of color on psychological functioning (Elliot, 2015; Elliot & Maier, 2014 for a review). Color has been found to affect performance on IQ, anagram, and numeracy tests (e.g., Brooker & Franklin, 2016; Elliot, Maier, Moller, Friedman, & Meinhardt, 2007), creativity tasks (e.g., Mehta & Zhu, 2009), challenging cognitive tasks (e.g., Kumi, Conway, Limayem, & Goyal, 2013; Yamazaki, 2010), physical strength tasks (e.g., Elliot & Aarts, 2011), and in combat sports (e.g., Hill & Barton, 2005). Notably, explanations of many of these effects have been provided ad hoc through reference to conceptual color associations, which may arise ontogenetically through repeat pairings (Crozier, 1996; Mehta & Zhu, 2009).

Importantly, a number of the reported effects of color on cognition and behavior have been inconsistent across studies or have failed to replicate (e.g., Langguth et al., 2009; Larsson & von Stumm, 2015; Lynn, Giebelhausen, Garcia, Li, & Patumanon, 2016; O'Connor, 2010; Peperkoorn, Roberts, & Pollet, 2016). This variability in findings, coupled with the ad hoc reasoning that much previous research on the effects of color on cognition and behavior has had to rely upon, suggests that for further progress to be made in this field it is essential to build a more systematic understanding of conceptual color associations.

Thus, the central motivations for the present work are (a) to address the lack of a comprehensive and systematic understanding of conceptual color associations and (b) through identifying conceptual color associations for English- and monolingual and bilingual Chinese-speaking participants, to enable future work on the effects of color on cognition and behavior to make systematic a priori predictions that are both universal as well as culturally relative (e.g., Davies & Corbett, 1997; Grandison, Davies, & Sowden, 2014; Taylor, Clifford, & Franklin, 2013).

Varieties of Color Association

Color associations may take different forms including those that are bound to specific objects as well as nonobject related emotional and abstract conceptual color associations. Usually, color is viewed on an object within a particular psychological context and, further, the color's meaning and valence can be influenced by the object on which the color is viewed. Palmer and Schloss (2010) conducted an extensive investigation of the objects associated with a range of colors resulting in their proposal of an Ecological Valence Theory (EVT) of color preference (see also Strauss, Schloss, & Palmer, 2013; Taylor & Franklin, 2012). This argues that color preferences result from people's combined liking/disliking (valences) of all associated colored objects. For example, strongly disliked dark greenish yellow is associated with strongly disliked entities such as dirty water, bile, and rotten food, whereas strongly liked saturated blue is associated with strongly liked entities such as clear sky and clean water. The EVT suggests that the relevant factors determining one's preference for a particular color include an object's importance in one's life, its perceptual salience, the frequency with which it is experienced, and the strength of the affective response that it causes.

Color associations that are inspired either by objects or by physical aspects of the environment are likely to emerge cross culturally. For example, green is the color of vegetation, and so it has been suggested may have generic connotations with growth, life and health (Crozier, 1996). Indeed, in English, idioms containing the word *green* represent a connectedness with nature, such as *having a green thumb* or *green living.* Further, the connotations of the color green may in turn influence the naming of objects. For instance, an effective antiseptic solution "zelyonka," literally meaning "green thing," is widely used in Russia to treat and prevent infections, giving an example of a conceptual link between the color green and health in Russian. Similarly, object based associations may be culturally specific and give rise to new conceptual associations. For example, in Chinese there is a saying: "wearing a green hat," which symbolizes unfaithfulness. This saying dates back to the Yuan dynasty where the relatives of prostitutes were forced to wear green hats—a link that further reflects the grounding of some color associations in physical objects (see Taylor & Franklin, 2012).

In addition to work on color–object associations, a further body of work has explored color–emotion associations (Sutton and Altarriba, 2016). Thorstenson, Elliot, Pazda, Perrett, and Xiao (2018) investigated color–emotion associations in relation to facial stimuli. Participants were asked to manipulate the color of neutral faces to best match the emotions of anger, disgust, fear, happiness, sadness, and surprise. Increased redness was associated with anger, happiness, and surprise, whereas decreased redness was associated with disgust, fear, and sadness. Additionally, participants increased yellowness in relation to anger and happiness and decreased yellowness for fear and sadness. The authors highlight the link between increased redness and approach-oriented emotions and decreased redness and avoidance-oriented emotions. This pattern conveys color-emotion associations that are consistent with physiological signals of emotion, which may be akin to the color-object associations discussed previously. Further work has investigated color-emotion associations in other contexts. In a study aiming to create a large color-word association lexicon via crowdsourcing, Mohammad (2011) found consistent associations with a number of abstract concepts including emotions. For example, red was consistently linked with anger, black with disgust and white with honesty. Additionally, Hupka, Zaleski, Otto, Reidl, and Tarabrina (1997) employed a closed ended task with American, Russian, German, Mexican, and Polish subjects to derive a list of consistent color-emotion associations that varied across cultures. Participants were required to indicate the extent to which they associated anger, envy, fear, and jealousy with 12 focal colors. Americans associated envy with black, green and red, while for Russians it was black, purple, and yellow. Poles connected anger, envy, and jealousy with purple, whereas Germans associated envy and jealousy with yellow. This evidence that emotion-color associations vary across culture has been further substantiated (Barchard, Grob, & Roe, 2017), and this may be attributable to differences in the expression and perception of emotion across cultures. Thus, this body of research presents a complex pattern of findings with regard to color-emotion associations.

In contrast to the well-established work on color-object and additional work on color-emotion associations, other types of abstract conceptual color associations, such as the English association of pink with femininity, have been the focus of controversy and debate. For instance, corporations have capitalized on the pink-femininity association through targeted marketing, exploiting what is believed by some to be a harmful stereotype (Del Giudice, 2017). Work that systematically investigates abstract conceptual color associations of this nature is limited and key questions remain unanswered.

One issue is the extent to which abstract conceptual color associations vary across culture. For centuries, people from all over the world have used color to symbolize particular beliefs or events and it is suggested that, depending on the culture or the part of the world that they are from, the symbolism of a color varies according to a group's habits, traditions and myths (Hemming, 2012). For example, the color red is used to signal loss/failure/bad/danger in the American culture (Moller, Elliot, & Maier, 2009), whereas red is used to signal happiness or prosperity in the Chinese culture (Jacobs, Keown, Worthley, & Ghymn, 1991). Further, in recent research by Zhang and Han (2014), they found that in the Chinese population the same color could have opposite meanings based on professions. In the Chinese stock market, red refers to a rise in stock price and green indicates a decrease, which is the reverse of the typical use of red to denote negative meaning. The authors found that red undermined performance on an IQ test among college students from China whereas red enhanced performance on an IQ test among stockbrokers from the same culture. Thus, color effects may manifest through culturally learnt associations that are specific to country, geographical region or even cultural group. Consequently, there is a clear need to systematically assess conceptual color associations in multiple language groups using the same set of color stimuli to determine the extent to which conceptual color associations are universal or culturally relative.

To date, two types of task have been established to understand conceptual color associations. First, closed-ended tasks that require participants to choose colors that are associated with a limited and predefined list of words. For example, in three closed-ended tasks using nine to 16 concepts, stereotypical color associations have been found in American (U.S.), Yunnan Chinese, and Hong Kong (HK) Chinese participants (Bergum & Bergum, 1981; Chan & Courtney, 2001; Courtney, 1986). For example, the association between *stop* and red was shown by 100% of U.S. participants, 66.4% of HK participants and only 48.5% of Yunnan participants. Additionally, the association between *go* and green was shown by 99.2% of U.S. participants, 62.6% of HK participants, and 44.7% of Yunnan, whereas *safe* and green were associated by 62.2% of Yunnan participants, 61.4% of U.S. participants, and only 38.2% of HK participants. Although closed-ended tasks have the advantage of obtaining elevated color-concept consensus (almost all had associations with $> 50\%$ consensus), they have the disadvantage of not eliciting knowledge of a considerable number of other concepts associated with a color.

Second, open-ended tasks (e.g., Bonnardel et al., 2014; Prado-León, Avila-Chaurand, & Rosales-Cinco, 2006) require participants to list words that are associated with a limited number of color stimuli (e.g., eight to 16). For example, Prado-Leon and colleagues (2006) instructed Mexican students to choose concepts from a list of 60 words that were evoked by each of 16 colors and to list any additional associations that were not on the initial list. Although the open ended nature of the latter part of the procedure resulted in a larger number of associations (399 concepts), it had the disadvantage of obtaining fairly low consensus (criterion of 20% minimum). Well-determined associations of more than 20% consensus were *sexuality* – red, *death* – black, *innocence* – white, *nature* – green, *dirtiness* – brown, whereas less-determined associations with consensus of 10% to 20% were *sadness* – gray, *femininity* – pink, *brightness* – yellow, *passivity* – blue, *activity* – orange.

Because of the higher consensus found in closed than open ended tasks, inconsistent apparent patterns of color association may emerge across these different types of study. For this reason, unlike previous research, in the present work we combine these approaches and use them to make cross-cultural comparisons between two or more language groups. Further, it is not clear whether color effects are mediated by categorical representations of color (e.g., the category of red colors), by individual color exemplars (e.g., a specific red) or how they are mediated by colorimetric dimensions such as lightness. For instance, while many English speakers might agree that red is associated with danger, is this association with the whole range of colors categorized as red or with more specific exemplars of red? No study has mapped associations onto color space systematically to inform these questions.

To address the limitations of the sparse nature of previous work on abstract conceptual color associations the present work seeks to comprehensively and systematically assess color-concept-color associations using a large number of (330) color stimuli from the World Color Survey (WCS stimulus grid; Kay, Berlin, Maffi, Merrifield, & Cook, 2009; see Figure 1 for an example of the WCS stimulus grid). Further, this will allow us to assess whether conceptual associations link to whole color categories, to particular exemplars, or to particular colorimetric dimensions.

The Effect of Context

A further factor that may influence conceptual color associations is the context in which they are invoked. As noted earlier, the pattern of findings about the effect of color on psychological functioning is not consistent across the field (e.g., Langguth et al., 2009; O'Connor, 2010). Different colors seem to impede or facilitate different types of tasks and the same color can have different effects on different tasks and in different situations. For instance, the red color of a traffic light will be rapidly understood by drivers as communicating the possibility of danger and the need to stop, whereas it is argued that in the context of a romantic dinner the

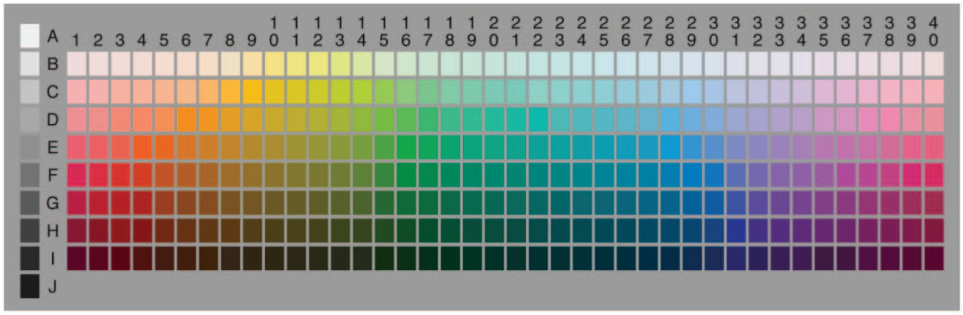

Figure 1. The stimulus grid taken from the World Color Survey (Kay et al., 2009), which samples stimuli from the Munsell color system at regular hue intervals, at various lightness levels and at high saturation for a given hue. See the online article for the color version of this figure.

same color could signal love or attraction. Elliot and Maier's (2012) color-in-context theory suggests that colors trigger different types of motivation, which can inhibit or enhance performance, depending on the context. For example, in achievement contexts red seems to promote avoidance motivation, which impedes cognitive performance. Conversely, in mating contexts red may trigger an approach motivation.

For the present research, an implication of these findings is that color associations may similarly be context sensitive. Here we focus on establishing generic conceptual color associations outside of any specific context and on developing the methods to systematically and comprehensively map concepts to particular points in colorimetric space. We hope that this will pave the way for future work to explore less dominant, context-specific color associations by conducting similar mapping exercises to that used in the present research on a context by context basis. This should facilitate the formulation of robust, *context-specific*, a priori predictions in future work in addition to the more dominant, noncontext specific, effects facilitated by the present work.

The Present Study

Thus, our main objective is to explore and compare the range of conceptual color associations that English (monolingual) language speakers from the U.K., and 2 groups of Chinese (English/Chinese bilingual and Chinese monolingual) language speakers from China have with the 11 basic color terms (BCTs) of the English language. A considerable amount of research has explored the way that color terms are represented in language. In 1969, Berlin and Kay suggested that the basic color terms in any language, including English, are those that are "psychologically salient." By this, they meant that the BCTs are used with high consensus and consistency by all competent speakers of the language. Berlin and Kay (1969/1991) used a set of stimulus materials developed by Lenneberg and Roberts (1956) to assess the basic color terms of 98 languages. They concluded that there are universals in the semantics of color in (probably) all languages, and a hierarchy of development of the BCTs:

[BLACK—WHITE] → RED → [YELLOW—GREEN] → BLUE → BROWN → [PURPLE—PINK—ORANGE—GREY]

There are six positions in the hierarchy shared by 11 color categories such that color categories grouped in brackets share a common position in the series. Although there are hundreds of individual words for colors (Boynton & Olson, 1990; Lindsey & Brown, 2014; Sturges & Whitfield, 1995), we are choosing to focus on basic color terms because these are the most salient. The English language has all 11 of Berlin and Kay's BCTs whereas Mandarin/Cantonese language has nine basic color terms (excluding brown and orange; Gao & Sutrop, 2014). Gao and Sutrop predict that the full set of 11 basic color terms will appear in Mandarin, suggesting that orange is the next candidate for basic status in Mandarin and brown will also ultimately become basic.

The descriptions of color stimuli and comparisons across studies in other areas of color research have been aided by the development of color order systems that relate the color stimulus to the dimensions of color such as hue (e.g., red, green, blue), chroma/saturation (the intensity or amount of pigment in a color; Fairchild, 2005), and lightness. However, a key limitation of much previous work on color and psychological functioning is inadequate stimulus control for saturation and lightness, and often a predominant focus on just *hue* (e.g., see Elliot & Maier, 2012, for a review). As a result of this limitation, two clear problems are highlighted. First, it makes replication impossible—replication requires the availability of precise and accurate information about the properties of the color stimuli being used, including hue, lightness, and saturation. Second, it is difficult to make predictions about effects of color on cognition and behavior because real-world colors typically vary on more than just the hue dimension. Further, much work on conceptual color associations has not presented a large variety of physical color stimuli to enable any accurate predictions on these relationships. Consequently, in the present work we make use of accurately specified stimuli described in the Munsell color system.[1] Through using a systematic and standardized color system, we will be able to identify if it is any red hue, for example, (regardless of

[1] Munsell is a standardized color metric system based on psychophysical judgments (Newhall, Nickerson, & Judd, 1943). Munsell colors vary on three dimensions: Hue (from red through yellow, green, blue to purple); Value or lightness scaled from zero (black) to 9 (white); and Chroma (saturation). Stimuli are specified using a notation that consists of three coordinates that each relate to one of the three dimensions. The standardized Munsell color chips consist of 320 chromatic chips representing 40 equally spaced hues at eight levels of lightness (Munsell Value), each at a high level of saturation, and an additional 10 achromatic chips.

lightness and saturation) or a specific red (with a specific hue, lightness, and saturation) that evokes a particular association.

Therefore, in a series of studies, we first explore the associations that English and Chinese speakers have with the 11 basic color terms, presented as physical color arrays drawn from the WCS stimulus grid, through an open-ended task (Experiments 1a and 1b). We then investigate which specific physical colors are associated with these meanings through a closed-ended task using the full WCS stimulus grid (Experiment 2). Our findings will yield a comprehensive mapping of conceptual color associations in two distinct languages and have important implications for predicting how particular colors might have reliable effects on human cognition and behavior via their associations.

Experiment 1: Identifying Concept → Color Associations

Experiment 1 was designed to explore the set of associations that participants have with each of the 11 basic color categories. In particular, we sought to identify those associations that participants have that are conceptual rather than grounded in specific object-color associations. While it might be expected that participants have many different associations with colors, our objective was to identify those associations about which there is agreement across participants (i.e., consensus) as distinct from those that are idiosyncratic to particular individuals. In doing this, we aimed to reveal the *basic* conceptual color associations of the English and Chinese languages.

To reveal these basic conceptual color associations, we undertook three steps. First, in an open-ended task (Experiment 1a), we asked participants to list nonobject words that they associated with each of the 11 basic color categories (concept → color association). Second, in Experiment 1b, we asked a further set of participants to categorize the words from Experiment 1a into different types of association (object, emotions, quality of things, actions and symbolic). Having categorized the words into different types of association we eliminated any object associations. Finally, we then looked for words that were essentially synonymous within culture to produce a final list of concepts that could be evaluated for (a) *consensus* level of agreement about the concept→color association across participants and (b) the *specificity* of the association to a particular color category. At the end of this process we were therefore able to identify those associations that had the greatest consensus and specificity to a color category. These were the candidate concepts for the basic conceptual color associations of English and/or Chinese languages.

Experiment 1a: Open-Ended List Task

Experiment 1a was an open-ended list task whereby participants were asked to list as many nonobject words (concepts) as possible associated with arrays of colors representing the 11 basic color categories.

Method

Participants. There were 80 participants comprising 23 monolingual English speaking participants from the U.K. (15 females), 23 bilingual Chinese (and English) speaking participants from China residing in the U.K. (18 females), and 34 monolingual Chinese speaking participants from China residing in China (31 females). Their ages ranged between 18 and 25 years. Monolingual English speaking participants and bilingual Chinese speaking participants were undergraduate students at the University of Surrey in England whereas monolingual Chinese speaking participants were undergraduate students at East China Normal University in Shanghai, China. Although our bilingual Chinese participants reported that they spoke Mandarin and/or Cantonese, we considered them as bilinguals because of the English language proficiency prerequisite to come to study at the University of Surrey and undertake a university qualification, which is also taught in English. Our monolingual Chinese participants on the other hand reported that they spoke Mandarin (see Table 1 in the online supplemental materials for more information on Chinese speaking participants' province of origin). Monolingual English speaking participants had a mean age of 21.7 years (SD = 1.77), bilingual Chinese speaking participants had a mean age of 21.5 years (SD = 1.34), and monolingual Chinese speaking participants had a mean age of 20.5 years (SD = 1.57). All participants were screened for color vision deficiencies using the City Color Vision Test (Fletcher, 1981) and Ishihara Test for Color Blindness (Ishihara, 2009). Participants from the University of Surrey were paid £5 for their participation, whereas participants from East China Normal University were paid ¥40 for their participation. The protocol was carried out in accordance with the ethical standards of the Research Ethics Committee of the University of Surrey.

Stimuli and experimental set-up. Munsell color tiles (measuring 2 cm × 1 cm) from the Munsell Book of Color[2] were used to reproduce the color stimuli of the World Color Survey (WCS stimulus grid; Cook, Kay, & Regier, 2005). The color category membership of the colors in the WCS stimulus grid were determined using Berlin and Kay's (1969/1991) English color naming data. We chose to use one language's color naming data so that we can make consistent comparison between the two cultures. These data show the colors in the WCS stimulus grid that fall into each of the 11 basic English color categories (see Figure 2). The color tiles that fell into each of the 11 basic color categories were arranged on 11 separate A4-size boards, one color category per board. The position of each color tile was as set out as in the WCS stimulus grid with 0.8 in. spacing in between tiles. All boards were painted with Munsell N5 gray to give a background matching the original WCS stimulus grid background. Each board was presented with a piece of clear acrylic sheet (1 cm thickness) on top of the stimulus grid to protect the color tiles.

CIE (1931) Yxy measurements made using a Minolta Colorimeter showed that with the clear acrylic sheet placed over the stimuli readings changed by reducing Y by .58 cd/m^2, while leaving x and y unchanged. A fluorescent light tube that simulated standard European natural daylight (D65 simulator) was used to illuminate the Munsell-WCS stimulus grid in an otherwise dark room.

Procedure. The arrays of stimuli representing the 11 basic color categories were presented one at a time in a random order.

[2] The *Munsell Book of Color* (Munsell Color Company, 1976) is based on the Munsell color system. The color samples are painted color tiles systematically arranged in terms of three coordinates: hue, value, and chroma; the tiles possess numerical values that represents uniform perceptual spacing for each coordinate (Romney, 2008).

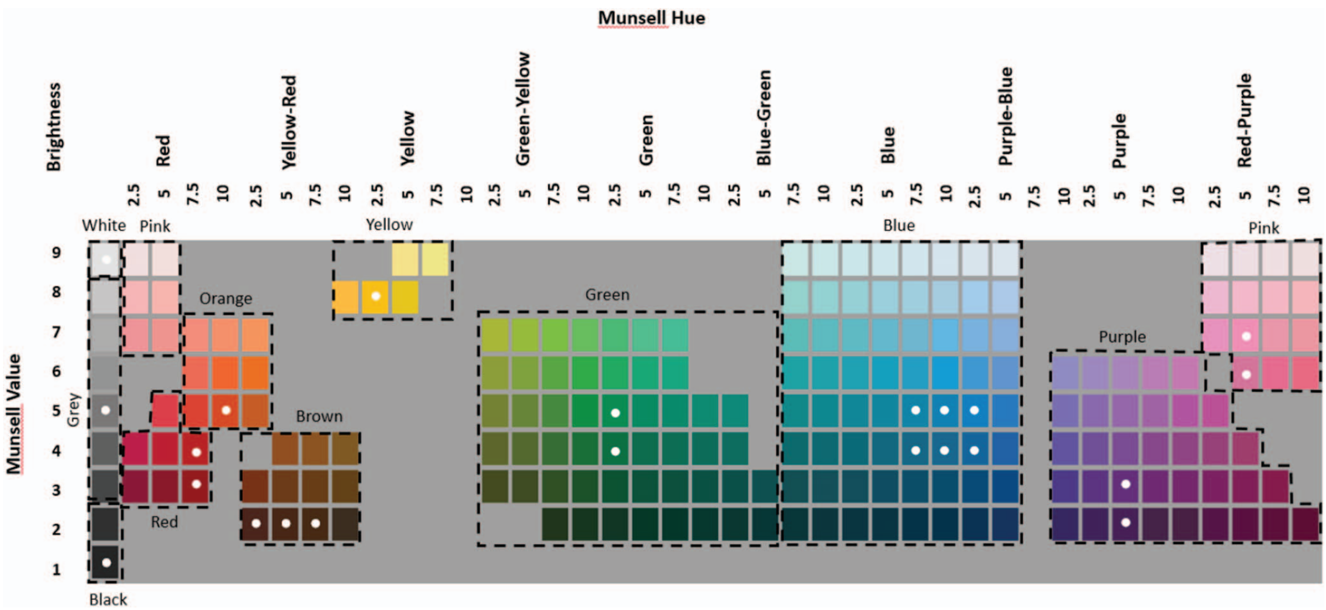

Figure 2. Color terms and mapping for (American) English. Only these tiles were used in Experiment 1a. White dots indicate focal colors. Reconstructed from *Basic Color Terms: Their Universality and Evolution* (p. 119), by B. Berlin & P. Kay, 1969, Berkeley: University of California Press. Copyright 1969 by CSLI Publications. Adapted with permission. See the online article for the color version of this figure.

Depending on the native language spoken, participants were asked either in English, Cantonese, or Mandarin to list concepts (in English or Chinese, respectively) that they associate with each of the color categories that are not specific objects. They were provided with the following instructions (either in English, Traditional Chinese for Cantonese speaking participants, or Simplified Chinese for Mandarin speaking participants):

> Here is an array of colors. Tell me any associations that you have with any of the colors before you that **are not** associations with specific objects. For instance, certainly, many people might associate green with grass. However, we would like you to think of symbolic associations (e.g. silence), emotions (e.g. happy), qualities of things (e.g. slippery), or actions (e.g. rolling) that you associate with the colors. Take as long as you need to list all the associations you can think of.

The instructions in Chinese were back-translated to English by three multilingual native Chinese speakers and checked by three English-speaking experts to ensure validity. The instructions were left in front of participants for reference. All participants wrote down the concepts they associated with each color category on separate 10 cm × 15 cm index cards. They were also allowed to return to previous color arrays and cards to list further associations when they came to mind.

Results and Discussion

The list task was designed to reveal conceptual associations with 11 basic color categories. Overall, there were a total of 1,672 (English) words from English monolinguals, 2,357 (Chinese) words from Chinese bilinguals, and 4,220 (Chinese) words from Chinese monolinguals associated with the 11 categories, although some of these words were specified to more than one color category. For example, *depressing* was listed in the color categories black and gray. After taking account of these duplications, there were 1,076 unique English words, 1,329 unique Chinese words (from bilinguals), and 2,170 unique Chinese words (from monolinguals), which will be used in the word categorization task. The raw data with the full list of associations produced by each participant are available at the Open Science Framework (https://osf.io/).

Experiment 1b: Word Categorization Task

Experiment 1b was designed to refine the list of unique English and Chinese associations by removing any object-based associations and by identifying concepts that were essentially synonymous and that could therefore be collapsed into a single term. Further, we assessed the extent of agreement about each concept → color association across participants (*consensus*) and the *specificity* of the association to a particular color category. From this process we aimed to extract a final list of words that were clearly conceptually associated with a specific color category and that had well-determined agreement across participants.

Method

Participants. There were 56 participants comprising 11 monolingual English participants (10 females; mean age = 20.5 years, *SD* = 2.07), 11 bilingual Chinese participants (eight females; mean age = 20.4 years, *SD* = 1.4), and 34 monolingual Chinese participants (29 females; mean age = 20.9 years, *SD* = 2.54). None had participated in Experiment 1a but their demographic was the same as participants in Experiment 1a. Participants from the University of Surrey were paid £20 for their participation whereas participants from East China Normal University were paid ¥120 for their participation.

Materials and procedure. The stimuli used in this task were the total list of English words (n = 1,076), Chinese words from bilinguals (n = 1,329), and Chinese words from monolinguals (n = 2,170) produced in the list task after taking account of duplications where the same word was associated with more than one color category.

Participants read through the randomized word list appropriate for their language and identified if each word belonged to one of five categories informed by previous research (Hemming, 2012; Ludwig & Simner, 2013; Mohammad, 2011) and identified in a pilot test (object, quality of things, actions, emotions, symbolic word). Participants were encouraged to choose one category per word but they were also allowed to choose more than one category if necessary. They were also allowed to choose a sixth category, unsure, if they could not otherwise categorize the word. The following instructions were provided to the participants (either in English, Traditional Chinese for Cantonese speaking participants, or Simplified Chinese for Mandarin speaking participants):

> Here is a list of words that people associate with one or more colors. We would like you to categorize each word into one or more of the following categories by ticking the appropriate choice on your response sheet. *Object* includes actual things such as a post-box or the sea. *Quality of things* includes perceptual qualities of things that you would perceive using your senses such as shiny or slippery. *Actions* includes physical actions such as bouncing or rolling. *Emotions* includes things that you feel or experience such as angry or happy. *Symbolic associations* includes conceptual associations such as spirituality or danger. If you feel that a word doesn't fit any of these categories you can select the unsure response. Please try and think carefully before you make your selection. Where possible you should choose the single category that you think is best for a particular word. However, sometimes you may feel that a word falls into more than one of the categories, and in this case, you may choose more than one category if necessary. Once you have completed a page, you can have a 2-minute break before moving on to the next page.

We included certain example words in the instructions based on a pilot test that showed 100% agreement that those particular words belonged in the respective individual category. As in Experiment 1a, the Chinese versions were checked via back translation. The instructions were left in front of participants for reference. Participants were allowed to take as long as they needed to choose the appropriate category for each word.

Results and Discussion

Word categorization. Any words that were primarily categorized as object-based associations (defined as more than 50% agreement across participants) were removed from the list. Although we instructed Experiment 1a participants not to list object words, it would seem as though the majority of our participants (if not all) found it challenging to completely avoid this, in line with the importance of color-object associations found in previous research (Palmer & Schloss, 2010). The number of object words listed by our monolingual English participants ranged between 1 and 15 words (M = 4.28, SD = 3.46), bilingual Chinese participants ranged between 1 and 24 words (M = 7.14, SD = 6.07), and monolingual Chinese participants ranged between 1 and 24 words (M = 5.19, SD = 6.35). Further, any words for which there was not good agreement, defined as less than 50% agreement across participants, about the category of association were removed from the list. This categorization process was undertaken to ensure that (a) we identified those words that were clearly conceptual associations and (b) we retained the maximum number of words for further reduction (collapsing synonymous words).

Of the list of 1,076 English words, 791 words were categorized as concepts (nonobject) with more than 50% agreement. Three hundred concepts were categorized as color associations to do with the quality of things, 190 as actions, 206 as emotions, and 95 as symbolic associations. Of the list of 1,329 Chinese words from bilinguals, 803 were categorized as concepts. More than 50% agreement on a single category was achieved for 276 quality of things, 231 actions, 130 emotions, and 166 symbolic words. Finally, of the list of 2,170 Chinese words from monolinguals, 1586 were categorized as concepts with more than 50% agreement: 701 quality of things, 488 actions, 153 emotions, and 244 symbolic words.

In the list of concepts, there were also occasions where participants chose slightly different concepts that meant essentially the same thing (e.g., *joy* and *joyful*). Two steps were taken to aggregate synonymous concepts. First, concepts were combined provided that they shared the same root word (e.g., *boredom* and *bored*), were produced for the same color category, and were produced by different people. This last stipulation was because we assumed that if the same person produced two related concepts in response to the same color category (e.g., a participant listed anger and angry for the color category red) he or she presumably meant somewhat different things by them. Second, concepts were collapsed only if they were categorized in the same conceptual category. For example, if *bored* and *boredom* were both categorized as emotions then they were collapsed. However, if *bored* was categorized as emotions whereas *boredom* as actions, then both concepts were retained separately.

Assessing consensus and specificity of concept → color associations. Finally, in addition to filtering our list to remove any object associations and to collapse concepts that had the same meaning, we also wanted to determine the extent to which each association listed from Experiment 1a was agreed upon by participants (consensus), and specific to a particular color category (specificity). The concept → color association consensus was defined as the percentage of participants from Experiment 1a that produced the same concept for a given color term. The concept→color association specificity on the other hand refers to the specificity of any given concept to one or more color terms (ranging from 1 to 11 BCT). For example, if participants produced the concept danger 10 times, seven times associated with the color red and three times associated with the color black, then the specificity of the concept danger to the color red is 70% whereas the specificity of the same concept to the color black is 30%.

For the purpose of creating a manageable candidate list of concepts that showed the clearest associations with specific color terms, inclusion criteria were introduced following each of the two calculations. Therefore, the final list of concepts for each language only included concepts with consensus ≥17% (listed by four or more participants from the University of Surrey [of 23 participants] or listed by six or more participants from East China Normal University [of 34 participants]), and specificity ≥31% to a particular color term. Applying these criteria resulted in a final list of 59 English concepts, 30 Chinese concepts from bilinguals, and 33 Chinese concepts from monolinguals.

We ran a hierarchical cluster analysis based on proportional counts for the data from Experiment 1 using correlation-based distance to explore participants' words listed for each color category. This started with each concept in its own cluster and then, at each stage relaxed the criterion for separation so that the next most similar concept to the existing cluster was linked until all of the concepts were joined in a complete classification tree. Eleven, 10, and nine cluster solutions were selected for the English, bilingual Chinese, and monolingual Chinese samples, respectively.[3] These are visualized in the Dendrograms shown in Figures 3–5 (full details of the associated color category, consensus, and specificity are listed in Tables 2–4 in the online supplemental materials). It can be seen that each cluster contains related concepts that are primarily associated with one or a very limited range of color categories.

Six English concepts (italicized) exceeded the consensus and specificity thresholds for more than one color category (*depressing* – black, gray; *love* – red, pink; *loud* – red, orange; *bright* – yellow, orange; *pretty, feminine* – purple, pink), only one Chinese concept from bilinguals exceeded the same thresholds (*fresh* – green, blue), and four Chinese concepts from monolinguals exceeded the same thresholds (*dark* – black, gray; *clean* – white, blue; *cool (temperature)* – green, blue; *hot* – red, orange). However, the English concepts *depressing* and *feminine*, Chinese concept *fresh* from bilinguals, and Chinese concept *hot* from monolinguals were still strongly specified (≥50%) to the respective colors, black, pink, green, and red. In contrast, the remaining four jointly specified English concepts (*love, loud, bright, pretty*) and three Chinese concepts from monolinguals (*dark, clean, cool*) were not as strongly specified to a particular color (<50%).

There were also similarities between cultures in the final list of concepts. Eight concepts (hereafter referred to as universal concepts) that were listed by the English (E), Chinese bilingual (CBil), and Chinese monolingual (CMon) participants in the same word category were *excited*, *fear*, *clean*, *fresh*, *warm*, *hot*, *bright*, and *cold*. The remaining concepts were either produced by at least two cultures (*anger*, *sad*, *sweet*, *soft*, *deep* – CBil & E; *pure* (symbolic), *holy*, *fly*, *broad*, *mysterious*, *noble* – CBil & CMon; *depressing (ed), pure* (quality of things), *cool*, *dark*, *danger*, *swim(ing)* – CMon & E), or were culture specific. Although there was universality in concept → color association (*fear* – black; *clean* – white; *fresh* – green; *warm* – yellow; *hot* – red; *bright* – yellow), two of the universal concepts were listed for a different color category across languages (*excited* – orange [E], red [CBil & CMon]; *cold* – white [CMon], blue [CBil & E]), suggesting cross-cultural differences in colors associated with concepts that have similar meaning.

Experiment 2: Identifying Color → Concept Associations

Experiment 2 sought to explore whether there were specific physical colors that were consistently associated with the final list of concepts identified in Experiment 1. Although participants might agree that, for instance, *feminine* is associated with the color category pink, we were interested to see whether participants agreed on exactly which pink(s) was/were *feminine*. This allowed us to see how associations are mapped onto the color space and explore: (a) whether specific associations are mapped to specific points of the color space or particular values on color dimensions (e.g., good concepts lighter colors; bad concepts darker color) and (b) whether associations relate to entire basic color categories or specific exemplars within color categories. Finally, the color → concept associations from Experiment 2 were checked against the concept → color associations from Experiment 1 to demonstrate associations that are reliable across tasks.

For color to have a common influence on cognition and behavior there needs to be a demonstrable, specific mapping between the relevant association and either a specific point in color space (tile), specific values on a dimension of color space (e.g., the lightness dimension), or a specific color category. Furthermore, this mapping needs to be consistent across observers. As a starting point, we chose to present the WCS stimulus grid, which has 320 chromatic color chips that vary on hue and lightness dimensions and an additional 10 achromatic chips. Thus, in this experiment we required participants to select those colors from the WCS stimulus grid that represented each of the concepts identified in Experiment 1. We were interested in whether these associations were tile specific, categorical or driven by particular values on colorimetric dimensions such as lightness.

Two types of response from the WCS stimulus grid were recorded: *unlimited color choice* and *best exemplar* for each concept. The unlimited color choice task required participants to select as many color tiles as they associated with each of the concepts. This provided a range of color → concept associations, showing all the specific points in color space that participants associated with each of the concepts from Experiment 1. In the best exemplar task, participants were required to choose the single color tile that they most strongly associated with each of the concepts. This enabled cross checking across experiments to explore whether participants made the same concept→color and color→concept associations when their color choices were restricted and unlimited.

Method

Participants. There were 120 participants comprising 40 monolingual English speaking participants from the U.K. (28 females; mean age 21 years, $SD = 1.93$), 40 bilingual Chinese speaking participants from China, resident in the U.K. (29 females; mean age 21.3 years, $SD = 2.29$), and 40 monolingual Chinese speaking participants resident in China (32 females; mean age 21.4 years, $SD = 1.97$). None had participated in the previous experiments but they were drawn from the same demographic described

[3] Prior to determining the best solution for clustering, we used the average silhouette approach in an earlier analysis to determine how well (or the stability of quality of cluster result) each object (word) lay within its cluster. A higher average silhouette value indicates a better clustering. The optimal number of clusters k is the one that maximizes the average silhouette over a range of possible values of k (Kaufman & Rousseeuw, 1990). According to this criterion, the optimal number of clusters for each experiment were: for the English participants, E1 = 12, E2 = 10; Chinese bilingual participants, E1 = 8, E2 = 11; Chinese monolingual participants, E1 = 8, E2 = 9. To facilitate direct comparison of clusters between experiments we therefore opted for a best average solution across cluster analyses in both experiments of 11, 10, and 9 cluster solutions for the English, Chinese bilingual and Chinese monolingual samples respectively.

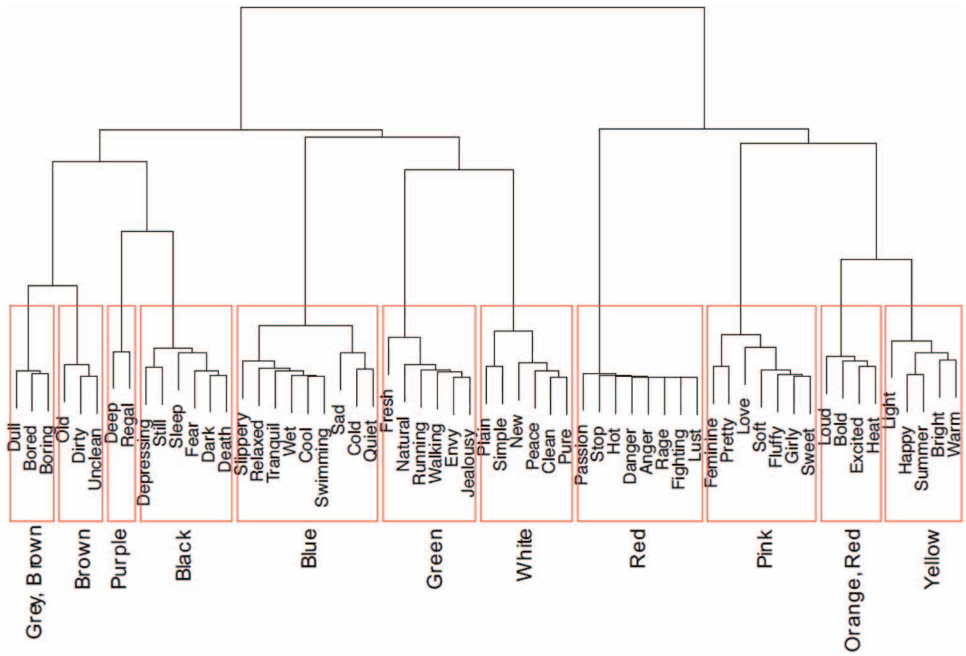

Figure 3. Dendrogram of English concept → color associations produced in Experiment 1a and meeting minimum criteria of consensus and specificity for inclusion in Experiment 2. See the online article for the color version of this figure.

in Experiment 1. Participants from the University of Surrey were paid £10 for their participation, whereas participants from East China University were paid ¥40 for their participation. Participants were also screened for color vision deficiencies using the City Color Vision Test (Fletcher, 1981) and Ishihara Test for Color Blindness (Ishihara, 2009).

Stimuli displays and set-up. Munsell color tiles were used to reproduce the color stimuli of the WCS stimulus grid on a Munsell N5 gray board, which was also illuminated by a D65 illuminant. A complete reproduction of the Munsell-WCS stimulus grid (Figure 1) was produced on a large board measuring 120 cm × 50 cm. A clear acrylic sheet with the same thickness as for Experiment 1a was attached above the large Munsell-WCS stimulus grid to protect the tiles. Counters (measuring 0.8 cm × 1.8 cm) painted in Munsell N5 were used as markers of the color tiles associated with a particular concept.

The final list of 59 English concepts, 30 Chinese concepts from bilinguals, and 33 concepts from monolinguals from Experiment 1b was presented to the English and Chinese participants respectively.

Procedure. The concepts were presented in a random order. Two different responses were recorded. First, participants were told to freely choose any color tile(s) from the large Munsell-WCS stimulus grid (using counters spread just below the stimulus grid) that they associated with that concept. As in Experiment 1a and 1b, depending on the native language spoken, participants were provided with verbal instructions either in English, Cantonese, or Mandarin. The translated version (in Cantonese and Mandarin) was back-translated to ensure that instructions did not differ across culture. Participants were read out the following instructions:

> Here is an array of colors. I will read a series of words out to you one at a time that you may associate with some of these colors. I would like you to use the counters just below the array to mark on the clear acrylic sheet any individual colors that you associate with each word I read out. If there is more than one color that you associate the word with, I would like you to mark them one by one using these counters. You may take as long as you need.

Once participants were satisfied with each of their unlimited color choices, the experimenter then asked them to choose the best exemplar for the same concept, "Which color best represents this word." Participants pointed to the color within the stimulus grid that best represented the concept. Their responses were coded during the experiment using Microsoft Excel.

Results and Discussion

First, we establish whether participants systematically map concepts to specific points in the color space defined by coordinates on the dimension of hue, saturation, and lightness: tile-concept association. Second, we establish the extent to which particular concepts were associated with particular lightness ranges (lightness-concept association) and color categories (category-concept association). We did not analyze saturation-concept association because the WCS stimulus grid has deliberately high levels of saturation for all hues. Finally, we compare data from Experiment 1 and Experiment 2 to assess consistency between listing concepts associated with colors (concept → color association) and choosing colors associated with concepts (color → concept association).

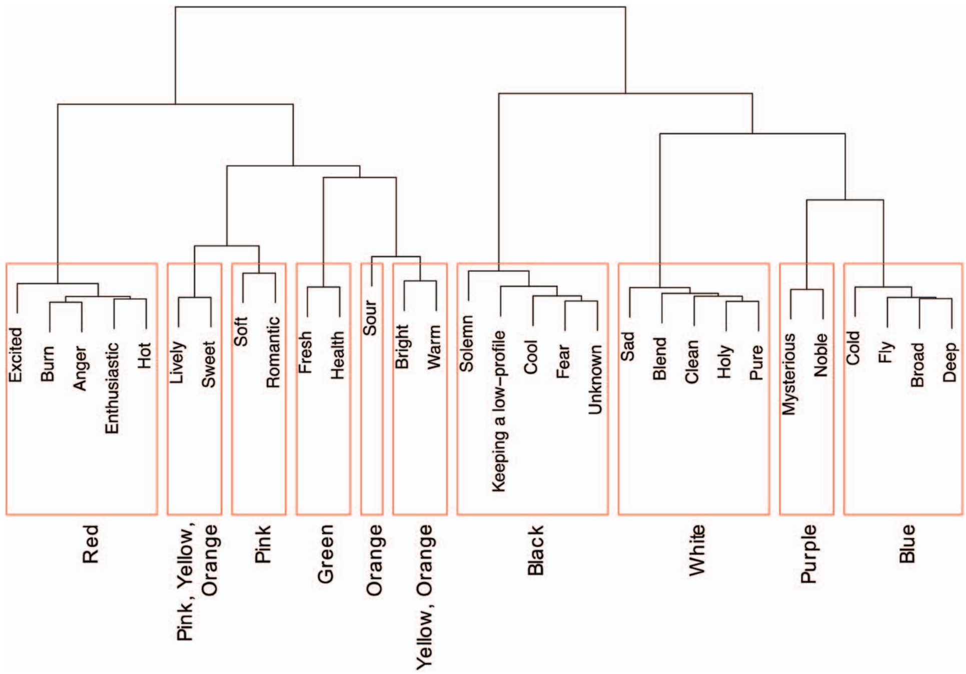

Figure 4. Dendrogram of bilingual Chinese concept → color associations produced in Experiment 1a and meeting minimum criteria of consensus and specificity for inclusion in Experiment 2. See the online article for the color version of this figure.

Because there were two data sets in this experiment (unlimited color choice and best exemplar for each concept), we use the frequency data from the unlimited color choice and best exemplar for each concept to explore consistency for tile–concept, lightness–concept, and category–concept associations. Illustrative visualizations for these data can be seen in Figure 6, which shows contour plots for the eight Universal concepts identified in Experiment 1 (see Figure 1 in the online supplemental materials for a full set of contour plots of the Experiment 2 data for all words and language groups).

The contour plots show both clear universal tendencies in terms of the colors selected for specific concepts by participants in Experiment 2 as well as clear differences. For example, the contours for the concept *excited* were very similar across languages in terms of the frequency with which different tiles were chosen and therefore the color categories associated with this concept, but it is clear that the best exemplar differed considerably across language group with English participants selecting a much lighter hue than Chinese monolingual participants. In contrast, for the concept *clean*, the English and Chinese bilingual participants selected very different hues as the best exemplar (English & Chinese bilingual—white; Chinese monolingual—blue), but all groups selected a similarly light hue. Finally, for some concepts all three groups show similar contours and selected the same best exemplar, as seen for the concept bright. We next explore these tile-specific, lightness-specific, and categorical associations with color in more detail.

Tile–concept association. In the unlimited color choice response, the 40 English speaking participants made a total of 3,881 color tile selections associated with 59 concepts, the 40 bilingual Chinese-speaking participants made a total of 1,618 color tile selections associated with 30 concepts, whereas the 40 monolingual speaking participants made a total of 2076 color tile selections associated with 33 concepts. We wanted to know whether participants systematically mapped color tiles to concepts and whether this mapping was consistent across participants in terms of the unlimited color tiles selected and in terms of the best exemplar for each concept.

There were differences in the strength of tile-concept associations when English and Chinese speaking participants were allowed unlimited choice and a best tile choice for each concept. When participants were allowed unlimited choice for each concept, the English group consistently made more high agreement (≥50% of participants associating a particular color tile with a given concept) tile–concept associations (0J – *dark, death*; 0A – *clean, plain, pure, simple*; 3G – *danger, anger*; 3H – *fighting, rage;* 9C – *bright*) than the bilingual Chinese group (0A – *holy, clean*; 3G – *burn*) and the monolingual Chinese group (3G – *fiery*). Across the groups these high agreement associations were limited to black, white, red, and yellow tiles. When participants were asked to choose one tile that best represents that concept, only black and white tiles were consistently chosen (≥50% of the time) for the English concepts *dark* and *death* (0J), and *clean* (0A). However, none were consistently chosen for any of the Chinese concepts.

Overall, 29 English concepts (*Dark*, *Death*, *Depressing*, *Fear*, *Clean*, *Pure*, *Plain*, *New*, *Simple*, *Rage*, *Anger*, *Danger*, *Fighting*, *Lust*, *Passion*, *Happy*, *Bright*, *Swimming*, *Deep*, *Still*, *Sleep*, *Peace*, *Sweet*, *Fluffy*, *Bold*, *Heat*, *Dull*, *Boring*, *Bored*), 11 Chinese concepts from bilinguals (*Solemn*, *Fear*, *Holy*, *Clean*, *Pure*, *Blend*,

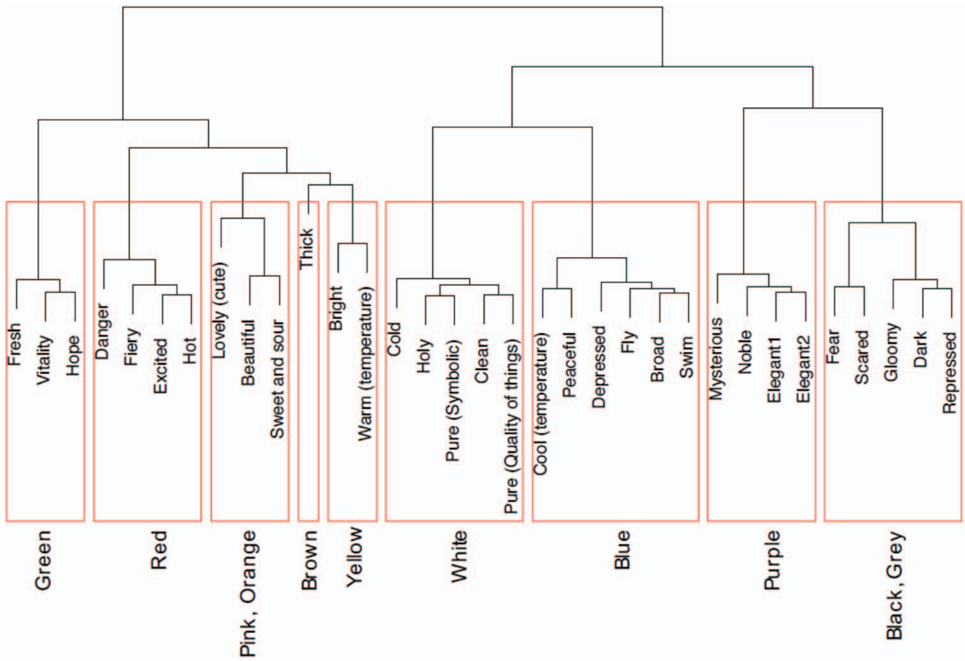

Figure 5. Dendrogram of monolingual Chinese concept → color associations produced in Experiment 1a and meeting minimum criteria of consensus and specificity for inclusion in Experiment 2. See the online article for the color version of this figure.

Burn, *Hot*, *Fly*, *Cool/ruthless*, *Noble*), and 10 Chinese concepts from monolinguals *Gloomy*, *Fiery*, *Danger*, *Bright*, *Holy*, *Pure* (quality of things), *Cold*, *Swim*, *Lovely* (cute), *Warm* (temperature) showed agreement between the color tile chosen with greatest consensus when *unlimited color choice* was allowed and the tile chosen as the *best exemplar* for the concept (see the tile column in Tables 5, 6, and 7 in the online supplemental materials for the associated tile in each case).

Lightness-concept association. For the lightness–concept association analysis, the tiles were collated into three lightness ranges by dividing the WCS stimulus grid (Figure 1) into three sections. The first three rows (A, B, and C) were classified as Light (Munsell values 8, 9, 9.5), the middle four rows (D, E, F, and G) were classified as Medium (Munsell values 4, 5, 6, 7), and the remaining three rows (H, I, and J) were classified as Dark (Munsell values 1.5, 2, 3). In this analysis, we were interested in which particular concepts were associated with a range of color tiles that are consistently categorized as one of the three lightness range in both unlimited choice and best exemplar dataset. In other words, which concepts are specified to light, medium, and dark across both tasks? We chose to focus on concepts with less than 50% consensus to a specific tile to ensure that the majority of the associations were not just with one tile (i.e., *dark and death* – 0J; *clean* – 0A) that happens to be dark or light. For the English data, 56 English concepts met the criterion whereas for the Chinese data all 30 Chinese concepts (from bilingual Chinese) and all 33 Chinese concepts (from monolingual Chinese) met the criterion. Of these, 41 (or 73%) English concepts (light lightness category - *Light*, *Simple*, *Plain*, *Quiet*, *Pure*, *Soft*, *Still*, *Fluffy*, *New*, *Peace*, *Fresh*, *Tranquil*; medium lightness category – *Swimming*, *Wet*, *Running*, *Love*, *Feminine*, *Jealousy*, *Hot*, *Pretty*, *Excited*, *Girly*, *Heat*, *Loud*, *Warm*, *Envy*, *Passion*, *Slippery*, *Bold*, *Relaxed*, *Walking*; dark lightness category – *Depressing*, *Deep*, *Dirty*, *Unclean*, *Fear*, *Fighting*, *Sad*, *Old*, *Anger*), 21 (or 70%) Chinese concepts from bilinguals (light lightness category – *Pure*, *Holy*, *Clean*, *Fresh*, *Bright*, *Soft*; medium lightness category – *Enthusiastic*, *Excited*, *Warm*, *Romantic*, *Burn*, *Sweet*, *Hot*, *Lively*, *Broad*, *Fly*; dark lightness category – *Deep*, *Fear*, *Solemn*, *Mysterious*, *Sad*), and 29 (or 88%) Chinese concepts from monolinguals (light lightness category – *Pure* (symbolic), *Pure* (quality of things), *Clean*, *Bright*, *Fresh*, *Lovely* (cute), *Holy*; medium lightness category – *Excited*, *Swim*, *Hot*, *Fiery*, *Warm* (temperature), *Broad*, *Beautiful*, *Vitality*, *Elegant1*, *Cool* (temperature), *Sweet & Sour*, *Fly*, *Peaceful*, *Hope*; dark lightness category – *Gloomy*, *Fear*, *Dark*, *Repressed*, *Scared*, *Thick*, *Mysterious*, *Danger*) had clear association to a particular lightness range (i.e., ≥50% of tiles selected in both data sets fell in the same lightness range; see Table 8 in the online supplemental materials). It seems clear that both the English and Chinese speaking participants tended to associate positive concepts with lighter colors and negative concepts with darker colors.

The remaining 17 English, nine bilingual Chinese, and four monolingual Chinese concepts had less than 50% association to any one of the three-lightness ranges.

Color category–concept association. We used the color naming data from two separate studies to label each of the 330 tiles in the WCS stimulus grid with one of the 11 basic color terms (BCT). As for Experiment 1, Berlin and Kay's (1969/1991) data were used to determine the name of each tile associated with a BCT (see Figure 2). Non-BCT tiles were defined as those tiles not belonging to any of the 11 BCT categories in Berlin and Kay's English color naming data. Although most of the tiles selected by English, bilingual Chinese, and monolingual Chinese participants

Figure 6. Contour maps for 8 universal concepts (identified in Experiment 1) in English (E: left), bilingual Chinese (CBil: middle), and monolingual Chinese (CMon: right). Contour lines show the frequency with which each color tile was selected for each concept in the unlimited color choice. White dots represent the best exemplar for each concept. See the online article for the color version of this figure.

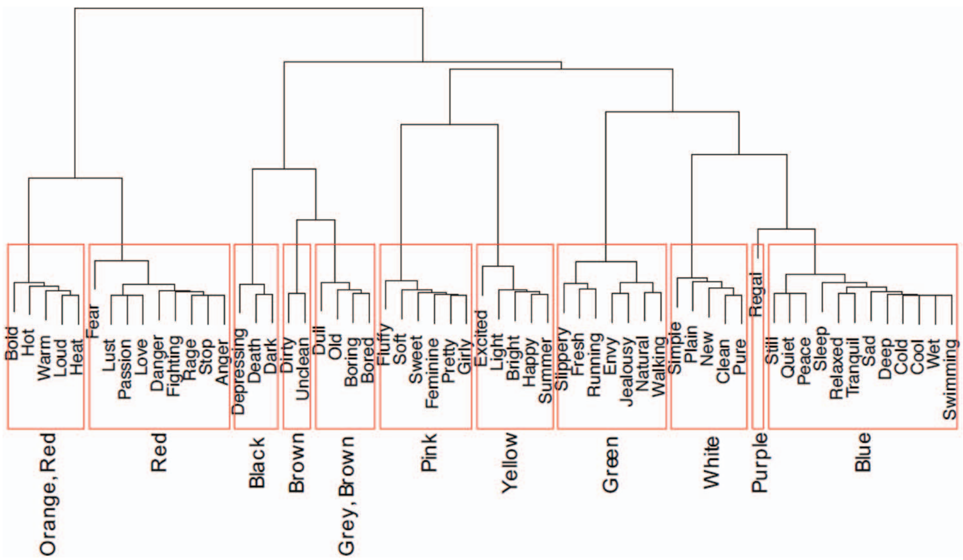

Figure 7. Dendrograms of English color → concept associations derived from the best exemplar tile data collected in Experiment 2. See the online article for the color version of this figure.

fell within one of Berlin and Kay's BCTs (73%, 75%, and 67.5%, respectively), some BCT tiles were selected only marginally more often than non-BCT tiles. This includes the English concept *unclean* (51% of tiles selected were BCT tiles), and monolingual Chinese concepts *sweet and sour* (52%), *bright* (51%), and *fresh* (50%). Next, we extended the color categories by using Lindsey and Brown's (2014) color naming data to identify the color category of all those tiles in the WCS that were unnamed in Berlin and Kay's data. Thus, all tiles in the WCS were categorized into one of the 11 basic color categories. This classification system was used to explore the frequency of color-concept associations in relation to these broader color categories. In this analysis, we were interested in (a) whether the choice of color category (color category → concept associations) was similar for the unlimited choice dataset and the best exemplar dataset and (b) whether the most consistent concept-color category association (Experiment 1) is similar to the most consistent color category-concept association (Experiment 2).

To examine whether the participants' choice of color category associated with a concept was similar or different across the unlimited choice and best exemplar data sets we conducted a likelihood ratio chi-square test (LRT) for each word on a two-way contingency table of color category by dataset. The LRT assumes that color responses to each word follow a multinomial distribution. We used a LRT, rather than a chi-square test of independence, as there were cells with zeros (i.e., for a given word there were some colors that were never associated with that word). There was no evidence of independence of the color category choices for the best exemplar and unlimited choice data sets for any concept for any language group, thus suggesting that there is consistency in the color category-concept association across both data sets. Because both the unlimited choice dataset and the best exemplar dataset were not independent, we decided to use data from the best exemplar task to illustrate any universal, common, and cultural specific themes emerging from the category-concept association.

Emerging themes in category-concept associations. To explore participants' patterns of responding on the 11 color categories, as for Experiment 1, we ran a hierarchical cluster analysis based on proportional counts for the best exemplar dataset using correlation based distance. This started with each concept in its own cluster and then, using participants' best exemplar for each concept response, at each stage relaxed the criterion for separation so that the next most similar concept to the existing cluster was linked until all of the concepts were joined in a complete classification tree. An 11-cluster solution was suggested for the English participants, a 10 clusters solution was suggested for the bilingual Chinese participants, whereas a nine-cluster solution was suggested for the monolingual Chinese participants (see Figures 7, 8, and 9 for color → concept dendrograms for each population; see also Tables 5, 6, and 7 in the online supplemental materials for full details; see footnote 3).

Although there were 11 clusters for 59 English concepts, 10 clusters for 30 Chinese concepts (from bilinguals), and nine clusters for 33 Chinese concepts (from monolinguals), each associated with particular color categories, these could be further split into themes within each color category. Some themes were universal whereas others were culture specific. Universal color category themes across all three cultures were: *negative concepts* – black; *fresh*, *health* – green; *purity* – white; *water/sky related* – blue; *regal* – purple; *female traits* – pink; *bright* – yellow (see Tables 5–7 in the online supplemental materials for full set of themes). There were also culture specific themes when associating colors with concepts (e.g., English, *boring/old* – gray, brown; Chinese bilingual, *keeping a low profile* – blue, gray).

Further emphasizing the important role of lightness in conceptual color associations, words within a color category could also be grouped around light, medium, and dark colors, particularly, for the color categories blue, pink, red, yellow, purple, and green. For the English concepts, groupings were dark blue (DBlue) – *sad, deep*; medium blue (MBlue) – *swimming*, *cool*, *wet*, *relaxed*,

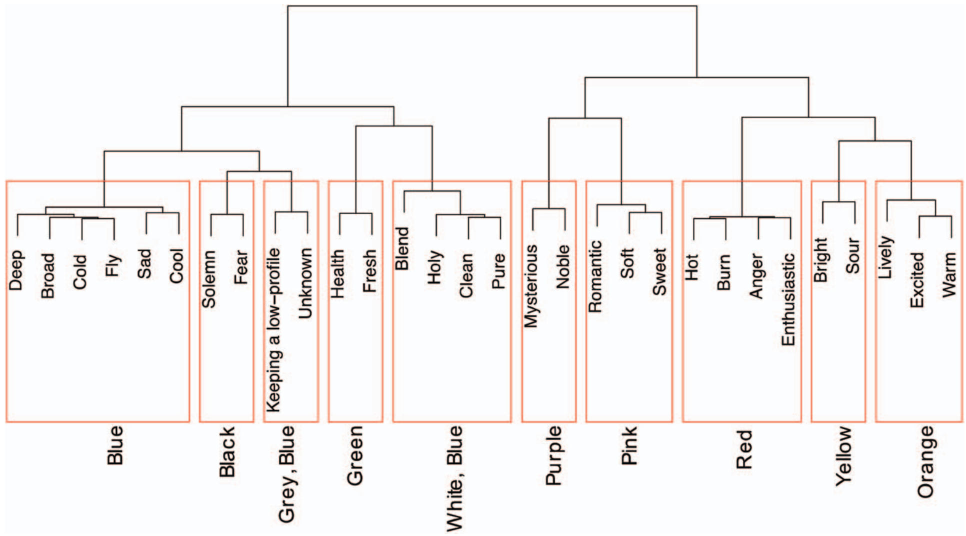

Figure 8. Dendrograms of Chinese bilingual color → concept associations derived from the best exemplar tile data collected in Experiment 2. See the online article for the color version of this figure.

slippery; light blue (LBlue) – *still*, *quiet*, *peace*, *tranquil*; medium pink (MPink) – *girly*, *feminine*, *sweet*, *pretty*; light pink (LPink) – *soft*, *fluffy*; dark red (DRed) – *fighting*, *fear*; medium red (MRed) – *lust*, *passion*, *love*; medium green (MGreen) – *envy*, *jealousy*, *walking*, *running*, *slippery*; light green (LGreen) – *fresh*; medium yellow (MYellow) - *excited*; light yellow (LYellow) – *light*.

For bilingual Chinese concepts: DBLue – *deep*, *sad*; MBlue – *broad*, *cool (temperature)*, *fly*; MPink – *romantic*, *sweet*; LPink – *soft*; DRed – *anger*; MRed – *enthusiastic*, *burn*; MGreen – *health*; LGreen – *fresh.*

For monolingual Chinese concepts: MBlue – *cool (temperature)*, *peaceful*, *broad*, *fly*, *swim*; LBlue – *clean*, *pure (quality)*; medium pink (MPink) – *beautiful*; light pink (LPink) – *lovely (cute)*; DRed – *danger*; MRed – *fiery*; MGreen – *hope*, *vitality*, *sweet and sour*; LGreen – *fresh*; dark purple (DPurple) – *mysterious*; medium purple (MPurple) – *elegant1*.

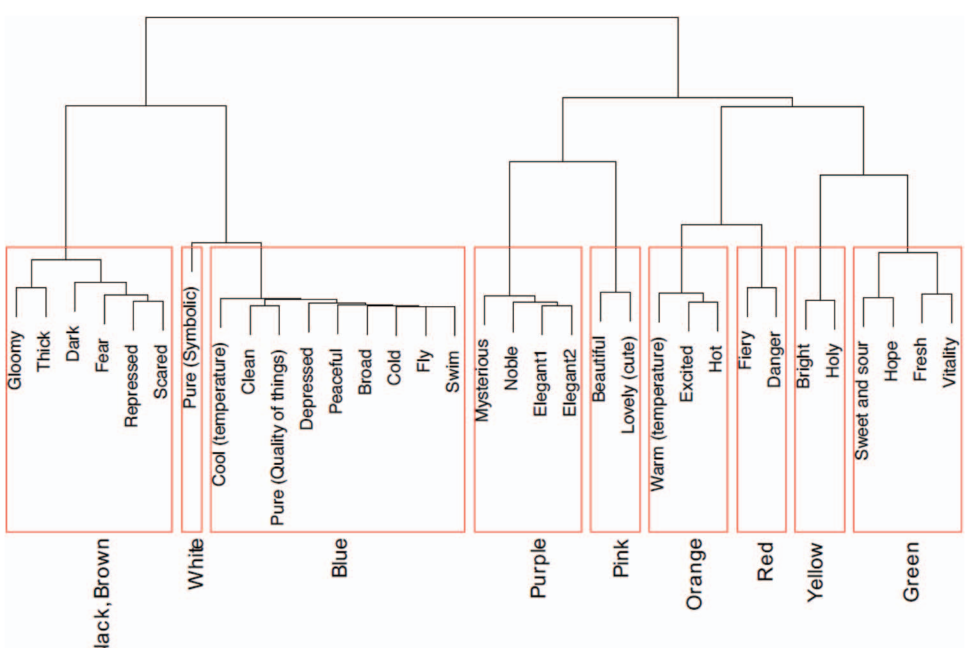

Figure 9. Dendrograms of Chinese monolingual color → concept associations derived from the best exemplar tile data collected in Experiment 2. See the online article for the color version of this figure.

Thus, lightness and hue can be seen to interact when specifying conceptual color associations.

It is worth noting that these themes are identified in relation to the data from Experiment 2 (closed-ended task) where participants were provided with 330 tiles that varied in both hue and lightness. Next, we explore themes that are consistent between Experiments 1 and 2.

Comparison between open-ended (Experiment 1) and closed-ended (Experiment 2) tasks. To determine whether the most consistent concept → color (Experiment 1: open-ended task) and color → concept (Experiment 2: closed-ended task) associations were similar or different, we compared the data from Experiment 1 with the best exemplar data (color category of the best exemplar) from Experiment 2 (see Tables 5, 6, and 7 in the online supplemental materials for respective associations between color category and concept in Experiments 1 & 2, for English, bilingual Chinese, and monolingual speakers, respectively). For each word we conducted a likelihood ratio chi-square test (LRT) on a two-way contingency table of color category by experiment. Given that multiple tests were being conducted for each language group, we used Bonferroni corrected *p* values to assess statistical significance. Overall, the results suggested that for most concepts there was no significant evidence that Experiment 1 and 2 responses were independent. The only exceptions were *cold*, $\chi^2(10) = 45.89$ $p < .001$, *gloomy*, $\chi^2(10) = 32.65$ $p < .001$, and *scared*, $\chi^2(10) = 29.61$ $p = .001$, for Chinese monolinguals. It is plausible that these concepts in monolingual Chinese participants were mostly associated with dark in the lightness dimension (in Experiment 2) rather than just relying on the hue dimension (in Experiment 1). For example, for the concept *gloomy,* monolingual Chinese participants in Experiment 1 strongly associated *gloomy* with gray whereas participants in Experiment 2 strongly associated *gloomy* with blue and brown, and were choosing tiles that were dark in the lightness dimension.

Although the likelihood ratio test showed that the majority of concept → color category associations generated in Experiment 1 were consistent with the color category → concept associations generated in Experiment 2, the cluster analyses suggested that there were still notable differences between the open-ended task used in Experiment 1 and the closed-ended task used in Experiment 2. Comparing the cluster analysis solutions generated for each language group and experiment (Experiment 1, Figures 4–6; Experiment 2, Figures 7–9), it is clear that some words were consistently clustered together across both experiments (e.g., English, *dull*, *boring*, *bored* – gray, brown) whereas others were not (e.g., Chinese monolingual *sweet and sour* – Experiment 1 pink, orange, Experiment 2, green).

Next, using the themes identified following the cluster analysis of data from Experiment 2, we explored which of these themes could also be applied in a consistent way to the cluster solutions from Experiment 1, with the additional constraint of only including concepts that were most strongly associated with the same color across experiments (see Tables 5–7 in the online supplemental materials). Table 1 summarizes theme-color associations that were consistent across Experiment 1 and Experiment 2 for all language groups (universal themes), across two language groups (common themes), or specific to one language group. Overall, the proportion of associations that were consistently clustered together in the same color category across both experiments was higher in the English group (84.7%) than the Chinese bilinguals (73.3%) and the lowest in the Chinese monolinguals (63.6%).

In addition to concepts clustering according to color dimension, concepts within a color category were also grouped around positive, neutral, and negative concepts. Specifically, this was found for the color categories green, red, and blue. For the English concepts groupings were green positive (GP) – *fresh*, *running*, *walking;* green neutral (GNeu) –*natural;* green negative (GNeg) – *jealousy*, *envy;* red positive (RP) – *passion*, *lust*; red negative (RNeg) – *fighting*, *anger*, *rage*, *stop*, *danger;* blue neutral (BNeu) – *slippery*, *cold*, *cool*, *wet*, *swimming*; blue negative (BNeg) – *sad.* This is also found in bilingual Chinese concepts: RP – *enthusiastic;* RNeg – *anger*, *hot*, *burn;* GP – *fresh*, *health.* Whereas in monolingual Chinese concepts, they were RP – *excited;* RNeg – *danger*, *fiery*, *hot;* GP – *fresh*, *vitality;* blue positive (BP) – *peaceful*, *broad;* BNeu – *cool (temperature)*, *broad*, *fly*, *swim*, BNeg - *depressed.* This suggests that color associations in particular, for the color category red, green, and blue may relate to positive, neutral, and negative concepts in English and Chinese culture.

Finally, for those associations that were inconsistent between Experiment 1 and Experiment 2, it is likely that those concepts are loosely associated with more than one color category or that those concepts are more associated with a range on the lightness dimension instead of the color category dimension. For example, for the former, the concept *lively* (CBil) is associated with pink and yellow in Experiment 1 but orange and green in Experiment 2, and the concept *beautiful* (CMon) is associated with orange in Experiment 1 but pink in Experiment 2. As for the latter, the concept *peace* (E) is perhaps associated more with the light colors (Experiment 1 – white; Experiment 2 – light blue and white) than a particular color, and the concept *unknown* (CBil) is perhaps more associated with the dark colors (Experiment 1 – black; Experiment 2 – dark gray, dark blue) than a particular color.

General Discussion

This systematic investigation aimed to explore and compare the range of color associations for concepts in English and/or Chinese speaking adults. In addition, we were also interested in whether these associations are categorical, specific to particular exemplars of colors or driven by lightness. By understanding the associations made with different colors, we can then develop systematic predictions about the effects of a wider range of colors on cognition and behavior.

The range of color associations with concepts, meeting minimum criteria for consensus and specificity, was greater for English speaking adults (59 concepts) than for bilingual Chinese speaking adults (30 concepts) and monolingual Chinese speaking adults (33 concepts). Across open-ended and closed-ended tasks, there were universal (across all culture), common (across two culture), and culturally specific associations evidence from the present data and those reported by previous research (e.g., Bonnardel et al., 2014; Prado-León et al., 2006). The universal themes associated with specific color categories were: *purity* – white; *negative* concepts—black; *fresh*, *health*, *nature* – green; *water/sky related* – blue; *regal* – purple; *female traits* – pink; *bright* – yellow; *heat* – orange, red. The common themes associated with specific colors were: *depressed* – black & blue; *anger*, *stop/danger*, *enthusiastic/excited* –

Table 1
Theme–Color Associations for Each Culture That Were Consistent Between Experiments 1 and 2 (Actual Concepts Are in Brackets)

Theme	Color category (words) for each culture		
	English	Chinese bilingual	Chinese monolingual
Universal themes			
Clean, pure	White (clean, pure, new)	White (clean, pure, holy)	White (pure (symbolic)) & blue (clean)
Negative concepts	Black (death, dark)	Black (solemn, fear)	Black (scared, dark)
Water/sky related	Blue (slippery, cold, cool, wet, swimming)	Blue (deep, broad, fly)	Blue (cool, broad, fly, swim)
Fresh, health, nature	Green (fresh, running, natural, walking)	Green (health) & blue (fresh)	Green (vitality, fresh)
"Female" traits	Pink (soft, sweet, feminine, pretty, girly)	Pink (soft, sweet)	Pink (lovely)
Heat	Orange (heat)	Red (burn, hot)	Red (fiery), orange (warm (temperature))
Bright	Yellow (light, bright)	Yellow (bright)	Yellow (bright)
Regal	Purple (regal)	Purple (noble)	Purple (elegant1, elegant2, noble)
Common themes			
Anger	Red (anger, fighting, rage)	Red (anger)	
Stop/danger	Red (stop, danger)		Red (danger)
Enthusiastic/excited		Red (enthusiastic)	Orange & red (excited)
Depressed	Black (depressing)		Blue (depressed)
Relaxed	Blue (quiet, relaxed, tranquil)		Blue (peaceful)
Mysterious		Purple (mysterious)	Purple (mysterious)
Culture-specific themes			
Attraction	Red (lust, passion)		
Bold	Orange (bold, loud)		
Summer	Yellow (summer, happy)		
Sad	Blue (sad)		
Old, boring	Grey & brown (dull, old, boring, bored)		
Plain	White (plain, simple)		
Dirty	Brown (dirty, unclean)		
Envy	Green (envy, jealousy)		
Fluffy	Pink (fluffy)		
Blend		White (blend)	
Romantic		Pink (romantic)	
Hope			Green (hope)
Thick			Brown (thick)

Note. Themes are grouped according to universal (across three cultures), common (across two cultures), and culture-specific. Dominant colors are listed first.

red; *relaxed* – blue; *mysterious* – purple. These associations are consistent with previous findings on conceptual color pairings (e.g., Dael et al., 2016; Frank & Gilovich, 1988; Hanafy & Reham, 2016; Ludwig & Simner, 2013; Mohammad, 2011; Palmer, Schloss, Xu, & Prado-León, 2013; Soldat, Sinclair, & Mark, 1997). In contrast, there were also culturally specific themes/concepts shown by the Chinese bilingual participants that were not seen in either the Chinese monolingual or the English participants and vice versa. For example, only the Chinese bilingual group associated pink with *romantic* and white with *blend*.

Some concepts were found to be associated with a particular color category (of the English Basic Color Terms) that was consistent across open-ended and closed-ended tasks, suggesting strongly established conceptual color associations. For the English population, all 11 color categories had strong association with at least one concept whereas for both the Chinese bilingual and Chinese monolingual there were eight (all except gray, orange, and brown) and 10 (all except gray) color categories respectively with strong association to at least one concept. Interestingly, orange and brown, which had no consistently associated concepts across tasks in the bilingual group, are not basic color terms in Mandarin or Cantonese (Gao & Sutrop, 2014) and gray is among those in the last group of colors to emerge in Berlin & Kay's hierarchy. Thus, it may be that less established color terms are also used less consistently (if at all) with respect to conceptual color associations.

Critically, when participants were provided with a large array of color tiles to choose from, we found that they made choices that were not always related to whole color categories. First, we found that associations can also be to particular points in color space. For example, tiles 0J (black), 0A (white), 2G (red), 3G (red), 3H (red), 9C (yellow), and so forth were shown to be specifically associated to certain concepts (e.g., 3G – *anger*). These specific tile mappings were largely to colors from the top positions in Berlin and Kay's hierarchy of color terms (black, white, and red) particularly in the English speaking and Chinese bilingual samples. Instead of relying on just hue category information in making predictions about color-behavior relationships (e.g., red-*danger*), the current work, which used a systematic and standardized color system, demonstrated that there is a point in color space (e.g., tile 3G) that is most strongly associated with a particular concept (e.g., *danger*). A likely reason as to why specific black and white tiles were not consistently selected by the Chinese monolingual sample is that this group may be relying on other dimensions of color (e.g., lightness) when making their tile choices. For example, as a whole Chinese monolingual participants made proportionally more associations that were aligned to one of the three lightness categories (91.3%) than the English participants (66.1%) and the Chinese bilingual participants (70%).

Second, we found that particular groups of concepts were associated with particular lightness ranges such that negative concepts were associated with the darker colors whereas positive concepts were associated with the lighter colors. There is considerable evidence to show that one particular dimension of color, namely lightness, has an intrinsic emotional meaning (Palmer et al., 2013). Meier and colleagues showed that in a categorization task positive (vs. negative) words are evaluated faster and more accurately when they are presented in white (vs. black) font (Meier, Robinson, & Clore, 2004). In a large-scale cross-cultural study on affective meanings of color terms (Adams & Osgood, 1973), individuals from 23 cultures rated seven color terms (red, black, gray, yellow, blue, green, or white) using affective adjectives. In all cultures, white was evaluated positively whereas black was evaluated negatively. Other experimental studies confirm these valence-based associations with lightness using adjectives relating to happiness (Dael et al., 2016; Wright & Rainwater, 1962), affective states (Hemphill, 1996) and positive versus negative ratings (Valdez & Mehrabian, 1994) even at an early age (Stabler & Johnson, 1972).

Although our study supports the notion of light-positive and dark-negative associations, previous work suggests that such opposite meanings may also be carried by color categories themselves. For example, given that red is paired with *danger* in daily life, and given the importance of avoiding negative possibilities (Baumeister, Bratslavsky, Finkenauer, & Vohs, 2001), red may carry negative meaning whereas green has more general positive associations and carries positive meaning (Moller et al., 2009). Further, consistent with this notion, red has been shown to enhance memory for negative words, whereas green increases it for positive ones (Kuhbandner & Pekrun, 2013). However, concepts in our study seem to cluster around positive, neutral, and negative themes *within* the color categories green and red suggesting that the picture is not as simple as suggesting red is associated with negative meaning and green positive. For instance, for English concepts, there were positive, neutral, and negative themes associated with green, and positive and negative themes associated with red. Although we found similar positive and negative themes for the color category red in Chinese bilinguals and Chinese monolinguals, green was only associated with a positive theme. Interestingly, the findings for the Chinese sample on these colors correspond with a recent finding on Indian participants. Namely, Bonnardel and colleagues (2014) demonstrated that Indian participants elicited concepts that coincide with red-green opponency. Concepts for the color category red were categorized into positive (e.g., love, euphoria) and negative (e.g., jealousy) emotion words that were high energy, whereas concepts for the color green were categorized into just low energy, positive emotion words (e.g., fresh, peaceful). This suggests that there may be cultural differences between Eastern and Western cultures in patterns of red/green, positive/negative associations.

Additionally, a relationship between lightness and color was found for the color categories red, yellow, green, purple, blue, and pink. For example, while for both English participants and monolingual Chinese participants light green was associated with *fresh*, conversely medium green was associated with *envy*, *jealousy*, *walking*, *running* and *slippery* for English participants but with *hope*, *vitality*, and *sweet and sour* for monolingual Chinese participants. These different patterns of relationship suggest that light, medium, and dark colors can carry specific meaning dependent on the culture. Although there was consistency across culture in that for all language groups concepts were clustered around dark and medium lightness levels for the color category red (dark red was associated with *fighting* [E], *fear* [E], *anger* [CBil], and *danger* [CMon]; medium red was associated with *lust* [E], *passion* [E], *enthusiastic* [CBil], and *fiery* [CMon]), and around light and medium lightness levels for the color categories pink and green, further cultural differences were found in clustering for the color category blue and purple. Concepts were clustered around light, medium, and dark lightness levels for these color categories for the English culture whereas they were clustered around medium and dark lightness levels for the Chinese bilingual culture, and light and medium lightness level for the Chinese monolingual culture. As for the color category purple, only Chinese monolingual participants had concepts around medium and dark lightness level (medium purple – *elegant*; dark purple – *mysterious).*

Overall, our results confirm the particular importance of lightness to positive and negative based associations. Further, they demonstrate that red and green do not necessarily carry opposite meanings but that those colors can carry both positive and negative meaning in a culturally dependent way, and that concepts are not necessarily clustered around the dimension of hue but instead interact with lightness as well.

Implications for Effects of Color on Psychological Functioning

There has been great interest in color among psychologists, reflecting the fact that color is an omnipresent feature of our environment and plays a role in information processing. It has been argued that the influences of color on cognition and behavior are a result of learned associations (Mehta & Zhu, 2009). Thus, we will discuss the psychological effect of the colors red, blue, and green (as have been widely investigated in this area) in the context of the present generic associations and make predictions for future studies in relation to the current findings.

Red. Previous studies addressing the effect of color on psychological functioning have mainly focused on the color red, showing that red heightens attention (Díaz-Román et al., 2015; Pravossoudovitch, Cury, Young, & Elliot, 2014), undermines performance (Shi, Zhang, & Jiang, 2015), increases aggressiveness and dominance (Bagchi & Cheema, 2013; Fetterman, Liu, & Robinson, 2015; Krenn, 2014), and enhances attraction (Elliot & Niesta, 2008), dependent on its context (see Elliot & Maier, 2014, for a review). It has been suggested that many of these effects are the result of learned color associations. Our findings demonstrated that in the present generic context, red (especially the tiles 3G and 3H) is strongly associated with concepts that represent aggression (*anger*, *fighting*, *rage*), attraction (*lust*, *passion*), and heighten attention (*stop*, *danger*) in English speaking participants.

Interestingly, there are clear cross-cultural differences in associations with red. Although Chinese bilingual speaking participants also associated concepts to do with aggression (*anger*) with the color red, the concept that best represents attraction (*romantic*) was associated with the color pink, and no concepts associated with heightened attention were listed. In contrast, Chinese monolingual speaking participants showed no concepts associated with aggression but one concept associated with heightened attention (*danger*). Like their Chinese bilingual speaking counterparts, Chinese monolingual speaking participants associated the color pink with the concept that best represents attraction (*beautiful*). In addition, there were culturally specific associations with red that were not found in the English culture, *enthusiasm* (CBil) and *excited* (CMon).

Importantly, there was no specific tile that was consistently associated with aggression or attraction in either Chinese bilingual or Chinese monolingual participants. Although English speaking participants associated specific tiles (3G and 3H) with the concepts representing aggression, Chinese bilingual speaking participants associated a particular lightness dimension (dark) with aggression. For the association with attraction, Chinese speaking participants associated the concepts *romantic* and *beautiful* with the color pink. This was not specified to a particular tile but with tiles of medium lightness. English speaking participants on the other hand associated concepts representing attraction with the color red (3G and 3H) and with tiles of medium lightness.

Two concepts relating to heightened attention were strongly associated with the color red for English participants (*stop* and *danger*), but only one concept was found in our Chinese monolingual participants (*danger*) and none was found in our Chinese bilingual participants. The cross-cultural differences for these concepts reflect similar patterns of difference found in previous work (Bergum & Bergum, 1981; Chan & Courtney, 2001; Courtney, 1986) on U.S., Yunnan Chinese, and Hong Kong Chinese population (*stop* – red [U.S. 100%; Yunnan 48.5%; HK 66.4%]; *danger* – red [U.S. 89.8%; Yunnan 64.7%; HK 63%]). S*top* was not strongly associated with the color red in the Chinese speaking population in comparison to the English speaking population. In fact, in both the Chinese bilingual and Chinese monolingual speaking participants from our study, the concept stop was only listed twice in our list task for each population. In addition, the concept *danger* was listed in more than one color category in the Chinese bilingual participants which meant that concepts relating to heightened attention are not as strongly associated with the color red for Chinese speaking participants.

A proposed association between the color red and failure has been consistently considered to be a major contributing factor to poor cognitive performance in achievement contexts when presented with the color red. It has been suggested that these effects (and by implication this association) may be highly specific to this task context as argued by Elliot and Maier (2012), a possibility that we elaborate on in our notes of caution below. In line with a potential context dependence of a red–failure association, in the current generic context we did not find any association between red and failure in either population. Neither failure nor its synonyms (e.g., defeat, unsuccessful) were listed in Experiment 1a. Although previous studies showed evidence indicating poorer test performance when briefly shown the color red (e.g., Elliot et al., 2007; Lichtenfeld, Maier, Elliot, & Pekrun, 2009; Maier, Elliot, & Lichtenfeld, 2008; Shi et al., 2015), null effects have been reported elsewhere in the literature (e.g., Küller, Mikellides, & Janssens, 2009; Larsson & von Stumm, 2015). Other recent literature showed opposite effects (enhanced performance) dependent on profession (Zhang & Han, 2014), type of tasks (Mehta & Zhu, 2009), and task difficulty level (Xia, Song, Wang, Tan, & Mo, 2016). Accordingly, red enhanced performance in a simple proof-reading task as opposed to a difficult proof-reading task or creative tasks (Xia et al., 2016). The inconsistencies regarding the effect of the color red on cognitive performance may well in part be due to subtle contextual differences that change the salient color associations as emphasized by the absence of a red failure association in the present generic context.

Finally, it is widely accepted that the color red has positive connotations in the Chinese culture as it represents celebrations, joyful occasions (He, 2011), and fortune (Huang, 2011). Therefore, it is no surprise the concepts *enthusiastic* and *excited* were listed in our study for Chinese bilingual and monolingual participants. However, the concept *prosperity*, which is commonly associated with red in the Chinese culture, was not evident in the list of concepts elicited in Experiment 1a. Even its synonyms (*wealth*, *success*, *fortune*) were not found in our list. Because the participants in our study were young adults, it is plausible that the lack of association with prosperity and fortune meant that these associations are not as salient to young student participants as compared with those that are older and have their own wealth.

Based on the current findings and previous studies, we can predict that (a) the effect of red on aggression and dominance is stronger than its effect on cognitive performance in English and Chinese speaking adults, (b) the effect of red on attraction and heightened attention should be more enhanced in English than Chinese speaking adults, and (c) there may be an effect of red on feeling joy, which is more enhanced in Chinese than English speaking adults.

Blue. In contrast to red, studies have yielded evidence suggesting that viewing blue enhances creative performance (Mehta & Zhu, 2009) and, more recently, is beneficial for detail-oriented tasks that are difficult (Xia et al., 2016). It has been argued that red and blue have different associations within the cognitive domain such that they induce alternative motivations (Mehta & Zhu, 2009). Accordingly, because red is often associated with danger, it should activate an avoidance motivation in achievement contexts. On the other hand, it is argued that blue is associated with openness, peace, calm, sad, and concepts related to ocean and sky (Kaya & Epps, 2004; Mehta & Zhu, 2009; Palmer et al., 2013; Wexner, 1954) and therefore should activate an approach motivation thus making people behave in a more explorative, risky manner (Friedman & Förster, 2010 for a review). Across both experiments, these passive concepts under the themes water/sky related and relaxed were also consistently associated with the color category blue in our study by English (e.g., *cool*, *wet*, *relaxed*, etc.) Chinese bilingual (e.g., *fly*, *broad*, *deep*, etc.), and Chinese monolingual (e.g., *fly*, *broad*, *swim*, *peaceful*, etc.) participants. We found a specific blue tile (28E) that was associated with passivity across all cultures. However, there seem to be cross-cultural differences in the range of lightness selected. While Chinese bilingual participants choose tiles ranging from medium lightness to dark and Chinese monolingual participants choose tiles ranging from light to medium lightness, English participants chose tiles ranging from light to medium and dark to represent concepts associated with passivity. Thus, although passive concepts are consistently associated with the color blue (28E) across culture and experiments, the present finding suggests that passivity in the English culture encompasses a larger lightness range than in the Chinese culture.

Green. Recently, green has also been found to facilitate creative performance. Lichtenfeld and colleagues (2012) suggested that green is associated with growth (physical and psychological) and may serve as a cue that evokes a mastery-approach in a creative context. In the current study the color green was associated with concepts such as *fresh* and *health,* but there was no direct association related to growth. As was the case for red and failure associations between green and growth may be context specific. The association observed with health supports previous research on green being associated with increased perceived health (Schuldt, 2013) and positive exercise outcomes (Akers et al., 2012). Conventional associations with green were not as strong as expected. For example, green is conventionally conceived to signal safety. However, in a study on red versus green (Pravossoudovitch et al., 2014), there was strong evidence of an association between red and danger, but weak evidence of an association between green and safety. In support of Pravossoudovitch and colleague's findings, the green-safety association was not found in our study or in previous work (Chan & Courtney, 2001). In addition, we did not find any specific (green) tile that was strongly associated with any concepts in comparison with red and blue. Previous research has shown that green may also at times serve as an implicit cue that exerts a subtle influence on affect, cognition, and behavior (Akers et al., 2012; Lichtenfeld et al., 2012; Schuldt, 2013). However, we suspect that the power, breadth, and applicability of green's meaning and influence will be far less than that of red and blue.

Notes of Caution

Although we are the first to carry out a cross-cultural conceptual color association study using both open-ended and closed-ended tasks and a full array of actual color stimuli specified in a colorimetric space, we are also cautious about the interpretation of our findings.

First, although we showed that given a general context, people make consistent associations to color categories, to specific color tiles and to specific lightness ranges that support some of the color effects within the literature, there are a number of concepts featured in other relevant literature that were not generated by our participants. For example, the concepts failure and prosperity were not given in response to the color category red, and the concepts growth and safe did not arise in response to the color category green. Although these concepts were not listed, this does not necessarily mean that they are never associated with the respective colors; rather, this finding might imply that these associations are highly context sensitive in contrast to, say, the association between red and danger, which emerges even in the present general context. According to Elliot and Maiers' (2012) color-in-context theory, the physical and psychological context in which a color is perceived is thought to influence its meaning and, accordingly, responses to it. Consequently, the general context in which our participants were listing associations might not have encouraged those associations to become salient in comparison to a specific context such as taking an exam or opening a new business. Thus, presenting red in the context of taking an exam might evoke the concept failure but not in the context of opening a new shop. The potential context sensitivity of some color associations underlines the importance for future work to explore color associations on a context by context basis using the same kind of systematic approach developed in the present work.

Second, our strict criteria to only include words that are strongly defined as one of the abstract concepts (emotion, action, quality of things, symbolic) meant that we could have missed out on certain words that had high consensus and specificity to a particular color. For example, the same word listed by Chinese monolingual participants *lovely* (*cute*) (可爱) was not included in the final list of words in Chinese bilingual participants even when it met the consensus and specificity criterion under the color category pink (consensus = 71%; specificity = 86%). This was because Chinese bilingual participants did not define the word *lovely* (*cute*) (可爱) as an abstract concept.

Third, our sample sizes for the studies, especially the English and bilingual Chinese samples are relatively small. This could result in some associations that are present in the population being missed in our sample and in associations that appear robust in our sample failing to generalize to the population.

Fourth, we should be careful not to overgeneralize effects to a whole culture. Jiang and colleagues (2014) found red and green conveying different meanings based on cultural environment such that mainland Chinese participants tended to associate red with up and green with down, whereas Hong Kong Chinese participants associated green with up and red with down suggesting that culturally specific environmental cues could influence behavior. Similarly, using nine to 16 concepts (Bergum & Bergum, 1981; Chan & Courtney, 2001; Courtney, 1986) such as *safe*, *danger*, *caution*, *cold*, *hot*, *go*, *stop*, *on*, *off*, *potential hazard*, *radiation hazard*, *soft*, *hard*, *weak*, *strong*, and *normal*, it was found that Chinese participants from Yunnan and Hong Kong did not yield such clear-cut associations as those found with US participants. Our samples of Chinese participants residing in the U.K. and China consisted of undergraduate university students from different regions of China. In addition, while the Chinese bilingual participants knew Chinese and English, they also spoke in Cantonese and/or Mandarin whereas the Chinese monolinguals only spoke Mandarin. These differences in dialect and region may have impacted on our findings such that they are specific to particular dialects and regions. Future work should seek to compare across dialects and speakers of the same dialect from different regions to explore these possibilities.

Fifth, we acknowledge that the themes we generated were subjective and that others might interpret them differently as words can have more than one meaning (e.g., *running* and *walking* can be either a positive, neutral or negative word).

Finally, although we were able to identify whether it is any color category, lightness, or specific tile (with a specific hue, lightness, and saturation) that evokes a particular association, we acknowledge a limitation of using the WCS stimulus grid. We were not able to evoke any association based on saturation as the standardized Munsell color chips in this array consist of chromatic color chips at only high levels of saturation.

Conclusions

We have created a large dataset of conceptual associations in English- and bilingual and monolingual Chinese-speaking populations through first identifying concepts that were strongly associated with a color category and then reversing the process to identify colors that were associated with those concepts. The integration of both methods using the WCS stimulus grid meant that we were able to identify concepts that have the strongest association with a specific color category, exemplar, and lightness range to accurately predict the effects of color on cognition and behavior. It is clear that color associations vary with culture, and this fact should be borne in mind when trying to generalize findings of the current paper to other groups of people. Our findings suggest that using the right colors and lightness in a culturally nuanced way in contexts such as product marketing, education, web development, information visualization (e.g., food labeling, medical information, road signs), urban design, and the visual arts may not only improve semantic coherence, but may also better inspire the desired psychological response.

Context of the Research

At the time that this work was conceived the body of research being published in experimental, cognitive, social, and educational psychology reporting that color could influence a range of aspects of cognition, affect, and behaviour was growing significantly. The explanations of these effects were often couched in terms of symbolic associations with color priming aspects of cognition that then shaped behaviour. But explanations were typically post hoc. We (Sowden, Grandison, and Franklin) were conducting similar work at the time and became aware that, like others, we lacked a systematic analysis of symbolic (as opposed to object) word–color associations to draw upon to be able to make strong a priori predictions about how exposure to color would influence cognition and behaviour. Thus, we embarked on the present work to provide this foundation for future work in the field. Because most work was being conducted with English language speakers, we chose to map English symbolic associations with color. But we also felt that stronger work would be possible if authors approached research into the effects of color on behaviour cross-culturally because different symbolic word–color associations across languages would lead to different predicted effects on behaviour, as a function of those different associations. We selected Chinese because it is the world's other most spoken language and one that preliminary work suggested would have a rich range of contrasting color associations compared with English and hence the program of work was born.

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