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Universal Patterns in Color-Emotion Associations Are Further Shaped by Linguistic and Geographic Proximity

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Abstract

Many of us "see red," "feel blue," or "turn green with envy." Are such color-emotion associations fundamental to our shared cognitive architecture, or are they cultural creations learned through our languages and traditions? To answer these questions, we tested emotional associations of colors in 4,598 participants from 30 nations speaking 22 native languages. Participants associated 20 emotion concepts with 12 color terms. Pattern-similarity analyses revealed universal color-emotion associations (average similarity coefficient r = .88). However, local differences were also apparent. A machine-learning algorithm revealed that nation predicted color-emotion associations above and beyond those observed universally. Similarity was greater when nations were linguistically or geographically close. This study highlights robust universal color-emotion associations, further modulated by linguistic and geographic factors. These results pose further theoretical and empirical questions about the affective properties of color and may inform practice in applied domains, such as well-being and design.

Keywords

affect, color perception, cross-cultural, universality, cultural relativity, pattern analysis, open data, open materials

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Color–emotion associations are ubiquitous (Adams & Osgood, 1973; Hupka, Zaleski, Otto, Reidl, & Tarabrina, 1997; Madden, Hewett, & Roth, 2000; Major, 1895; Palmer, Schloss, Xu, & Prado-Leon, 2013; Valdez & Mehrabian, 1994; Wexner, 1954; Wilms & Oberfeld, 2018). Common wisdom would suggest that we "feel blue" when sad, "see red" when angry, and are "green with envy." Yet envy can be yellow or red if we come from Germany or Poland, respectively (see Hupka et al., 1997). And although Westerners are likely to wear white to weddings and black to funerals, people from China prefer red for weddings and white for funerals.

Wherever one comes from, such color-emotion associations are intriguing because colors and emotions seem—at face value—to be fundamentally different "things." Colors are visual experiences driven by the wavelength of light. Emotions are subjective feelings, cognitions, and physiological responses that signal value. Are these cross-modal associations cultural creations, laid down in our languages and traditions? Or are they fundamental features of our cognitive architecture? Existing studies have identified both similarities (Adams & Osgood, 1973; D'Andrade & Egan, 1974; Gao et al., 2007; Ou et al., 2018) and differences (Hupka et al., 1997; Madden et al., 2000; Soriano & Valenzuela, 2009) across cultures. However, they have done so among only a small number of individual countries, making it nearly impossible to capture global patterns. In a series of analyses, we examined to what extent color-emotion associations are universal, testing 4,598 participants from 30 nations on six continents in 22 languages.

There are two theoretical explanations for color-emotion associations, which make different predictions about the degree to which the emotional meanings of color should be shared. According to the first view, color-emotion associations arise through environmental experiences. That is, colors may become associated with emotions because they appear in particular emotional situations of evolutionary significance (e.g., red face in anger; Benitez-Quiroz, Srinivasan, & Martinez, 2018). If so, color-emotion associations should be largely universal (in support, see Adams & Osgood, 1973; D'Andrade & Egan, 1974; Gao et al., 2007; Ou et al., 2018). According to the second theoretical explanation, colors and emotions may become arbitrarily associated in the language, history, religion, or folklore of one's culture. If so, color-emotion associations should vary between cultures with different languages, symbolism, and traditions (Evarts, 1919; Soriano & Valenzuela, 2009). Such cross-cultural variations have also been reported (Hupka et al., 1997; Madden et al.,

Statement of Relevance

Why do we "see red," "feel blue," or "turn green with envy"? Are such associations between color and emotion fundamental to our shared cognitive architecture? Or are they cultural creations learned through our languages and traditions? To answer these questions, we tested the emotional meaning of colors in 4,598 participants from 30 nations speaking 22 languages. Overall, participants associated similar emotion concepts with 12 color terms. Moreover, similarity was higher between nations that share borders or languages. Color-emotion associations have universal features, further shaped by a shared language or geography. These results pose further theoretical and empirical questions about the affective properties of color and may inform practice in applied domains, such as well-being and design.

2000; Soriano & Valenzuela, 2009). Although these views are often cast in opposition to each other, they are not mutually exclusive. According to the cross-modal-correspondence framework (Spence, 2011), two unrelated entities (here, colors and emotions) can become cross-modally associated when they regularly appear together in one's perceptual or linguistic environment, whether on a global (shared by all) or local (shared by some) scale.

It is possible, therefore, that universal tendencies to associate certain colors with certain emotions are further modulated by cultural and individual factors. Consider red, an ambivalent color that has been associated with both negative and positive emotions depending on whether one comes from Western countries or China (Jonauskaite, Wicker, et al., 2019). The existence of both associations could be explained in evolutionary terms (e.g., red-blood pairings lead to associations with both danger and sexuality). In countries such as China, however, cultural beliefs that red is a symbol of good fortune might strengthen the link between red and positive emotions and weaken the link between red and negative emotions (see Wang, Shu, & Mo, 2014). In other countries, such as the United States, the strong link between red and danger or red and failure (Pravossoudovitch, Cury, Young, & Elliot, 2014) could strengthen negative associations while weakening positive associations. Such additional variations might be maintained through language and geographic locations (see also Jackson et al., 2019; Jonauskaite, Abdel-Khalek, et al., 2019).

Existing studies provide examples of both similarities and differences across countries. But these studies have focused on just a few countries, languages, or cultures, and so global patterns are still unknown. To test for the degree of universality, we performed a large-scale, cross-cultural survey on color-emotion associations (for our theoretical motivation, see Mohr, Jonauskaite, Dan-Glauser, Uusküla, & Dael, 2018). Participants completed the survey online in their native language. We exceeded previous investigations in terms of the number of tested nations, representativeness of participants, and the number of tested colors and emotions. We collected data from 4,598 participants from 30 nations located on all continents but Antarctica (see Fig. 1). Participants were between the ages of 15 and 87 years and reported having normal color vision. We used 12 color terms representing the most common color categories (Berlin & Kay, 1969; Mylonas & MacDonald, 2015) and an extensive list of 20 emotion concepts varying in valence and potency (Scherer, 2005). Participants chose as many emotion concepts as they thought were associated with a given color term and rated the intensity of the associated emotion from weak to strong.

In a series of analyses, we examined the degree of similarity across the 30 nations in (a) probabilities of color-emotion associations and (b) intensities of associated emotions. We then applied a machine-learning algorithm to quantify the degree of nation specificity in color-emotion associations. Finally, we assessed how color-emotion associations varied as a function of linguistic and geographic distances.

Method

Participants

We extracted our data from the ongoing International Color-Emotion Association Survey (Mohr et al., 2018) performed online. This survey tests participants from a large age range using predefined age categories (15–29 years, 30–49 years, 50 years and older). We started with the largest possible participant pool (4,883 participants) consisting of data sets from countries for which we had at least 20 usable (e.g., without self-reported problems of color vision) participants per age category (see also Simmons, Nelson, & Simonsohn, 2011). We detail additional selection criteria in the Data Preparation section. Our final sample (N = 4,598; 1,114 male) consisted of participants from 30 different nations (see Fig. 1) with a mean age of 35.4 years (SD = 14.5). Counts per nation ranged from 69 to 490 participants. Table S1 in the Supplemental Material available online provides language information, and Table S2 in the Supplemental Material provides demographic information of the participants of each nation. Participation was voluntary. The study was conducted in compliance with the ethical standards described in the Declaration of Helsinki. Parts of the data have been reported previously in relation to different research questions (Jonauskaite, Abdel-Khalek, et al., 2019; Jonauskaite, Parraga, Quiblier, & Mohr, 2020; Jonauskaite, Wicker, et al., 2019).

Material and procedure

Emotion assessment with the Geneva Emotion Wheel. The Geneva Emotion Wheel (Version 3.0; Scherer, 2005; Scherer, Shuman, Fontaine, & Soriano, 2013; see Fig. 2) is a self-report measure designed to assess the feeling component of emotional experiences elicited by particular events. It is based on theoretical categorizations of emotions and validated through research. The Geneva Emotion Wheel represents 20 discrete emotions (e.g., anger, fear, joy) as spokes on a wheel. Emotion concepts that are similar in valence (positive or negative) and power (high or low) are placed close to each other. Each spoke of the wheel contains five circles that extend from a central square, representing increasing intensities of each emotion.

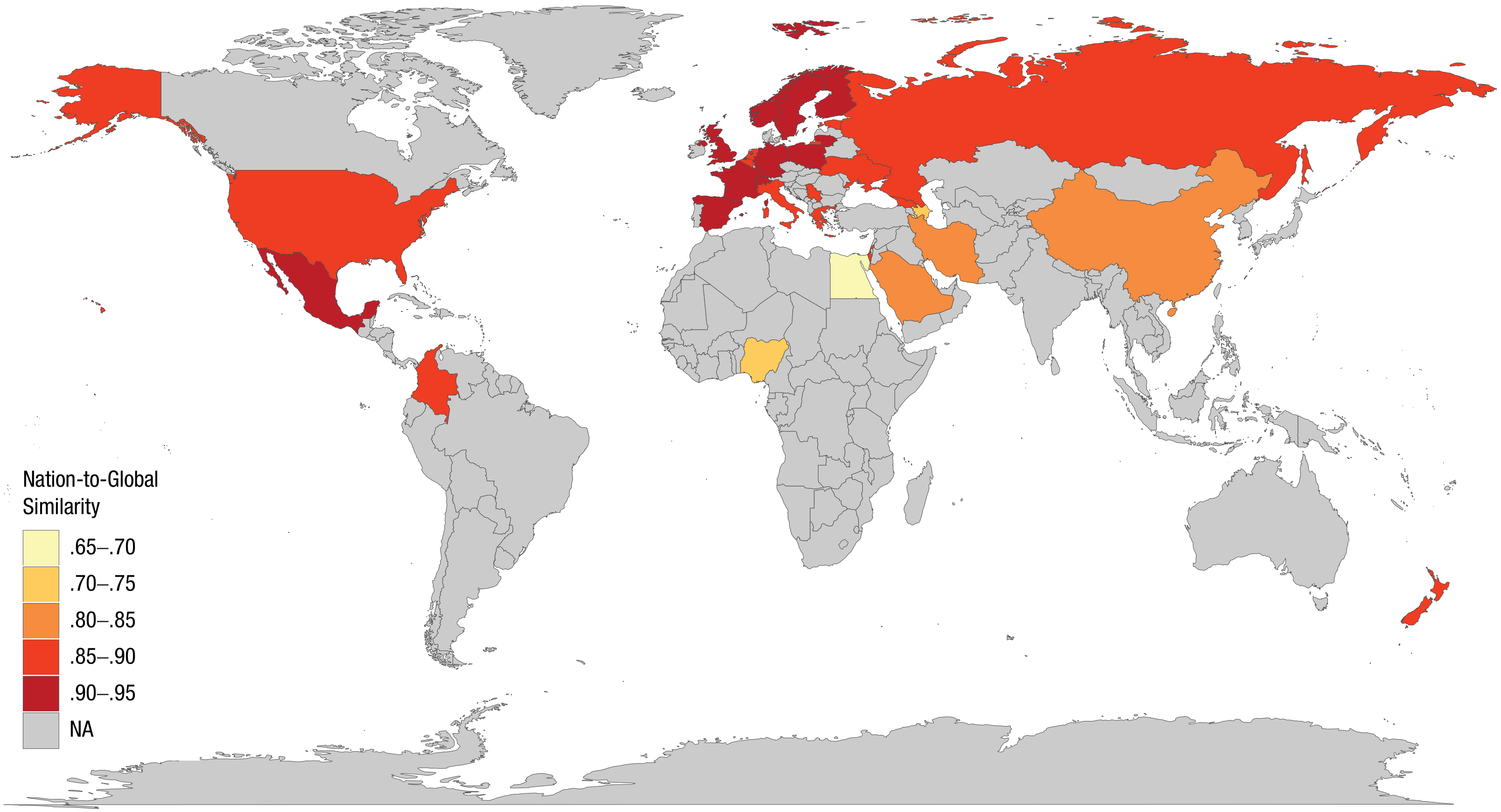

Fig. 1. World map showing the 30 nations included in the study. The colors indicate nations' similarity with the global color-emotion association pattern. Redder nations show color-emotion association patterns more similar to the global mean.

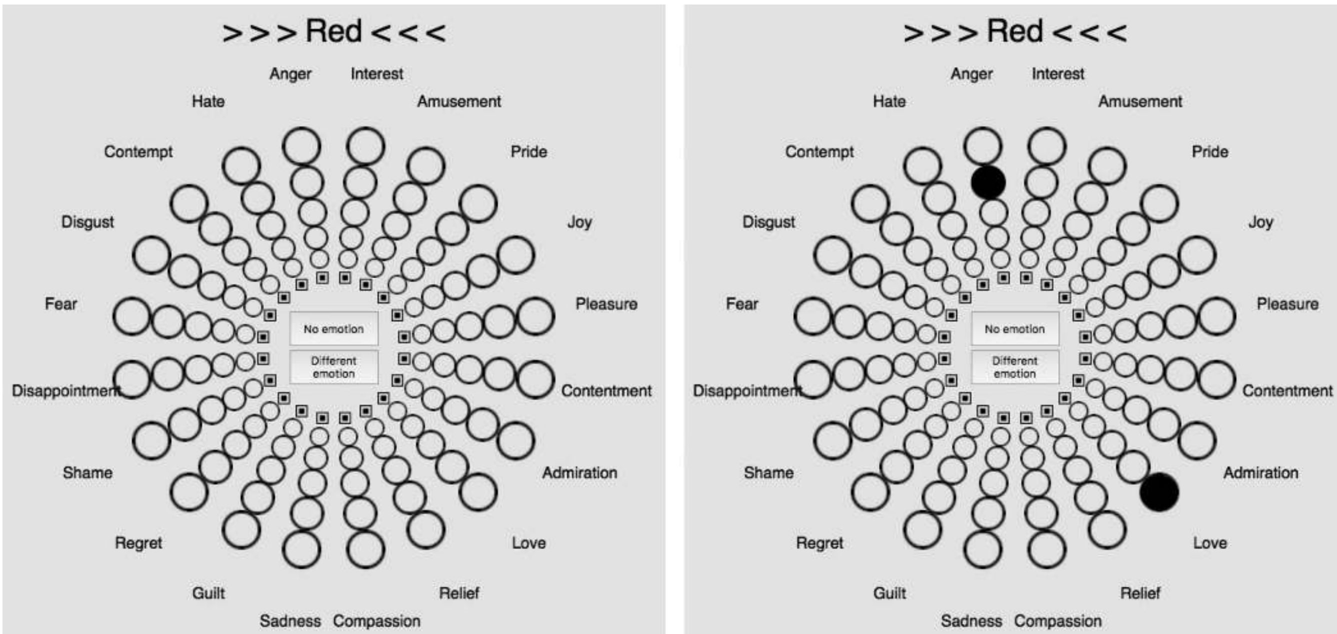

Fig. 2. The Geneva Emotion Wheel with the color term *red* as an example. The wheel was used to assess associations between 20 emotion concepts and 12 color terms. Participants expressed emotion associations by selecting one of the five circles for each associated emotion. At the same time, they chose the intensity of the associated emotion, ranging from weak (smallest circle) to strong (largest circle). Participants could select as many or as few emotions as they thought appropriate. The left panel shows the wheel as it initially appeared. The right panel shows an example of a response from a participant who associated the color term *red* with strong love and relatively strong anger.

For each color term, participants used a mouse click to indicate the associated emotions and their intensities (i.e., they could indicate that a single color term is associated with more than one emotion concept; see Fig. 2). At the beginning of the trial, the central square was selected, indicating no emotion. Participants were also given the option to select “Different Emotion,” which produced a pop-up window in which they could type the name of a different emotion. These responses were rare, and we did not analyze them.

Participants completed the Geneva Emotion Wheel in their native language. The translation of the Geneva Emotion Wheel was available for some languages on the Swiss Centre for Affective Sciences website. The remaining translations were created using the back-translation technique (for further details, see the Translation of the Geneva Emotion Wheel section in the Supplemental Material; for emotion terms in each language, see Table S3 in the Supplemental Material).

International Color-Emotion Association Survey. We collected the current data online by sharing the survey link (http://www2.unil.ch/onlinepsylab/colour/main.php) with potential participants via university communications, e-mails, social media, and personal contact, mainly through our collaborators (coauthors) in each country. The survey was originally constructed in English and was translated (without back-translation) by coauthors and collaborators (see the Acknowledgments section). We used links that automatically opened in the official language of the country to encourage participants to complete the survey in their native language. However, participants could switch to any other language provided. We analyzed data gathered from only native speakers. Online data collection naturally resulted in literate participants with access to the Internet. Some elderly participants were helped with survey completion.

The first page described the aims of the study and ethical considerations; participants consented by clicking on the “Let’s go” button. The following two instruction pages explained the task and the use of the Geneva Emotion Wheel. We then used a manipulation check to verify that participants understood the task. Participants were presented with a situation and had to identify the correct responses. The situation read,

> Peter thinks that beige strongly represents intense compassion, and believes that beige is also associated with mild relief. Accidentally, he has selected sadness and wants to correct his choice. Look at his response in the emotion wheel below and try to correct it.

Participants saw the largest circle for *sadness* marked (Emotion Intensity 5). They could move to the next page and start the survey only if they successfully corrected Peter’s responses. They had to click on the square for *sadness* (no association, rating 0), the largest circle for *compassion* (Emotion Intensity 5), and the middle circle for *relief* (Emotion Intensity 3). If participants made a mistake and tried to move forward, a pop-up window guided them to the correct responses. This manipulation check ensured that participants understood the task.

In the actual task, participants were presented with 12 color terms (not color patches): *red, orange, yellow, green, blue, turquoise, purple, pink, brown, black, gray*, and *white* (for the color terms in all languages, see Table S4 in the Supplemental Material). Color terms appeared one at a time above the Geneva Emotion Wheel in random order. For each color term, participants could either select any number of the emotion concepts they thought were associated with the given color term or indicate "none." They rated the intensity of each chosen emotion (see Fig. 2). On average, participants associated 3.05 emotion concepts with a color term (95% confidence interval, or CI = [3.03, 3.08], range = 2.25–3.84; see Table S5 in the Supplemental Material).

After evaluating the 12 color terms, participants completed a demographic questionnaire in which they reported the importance of color in their life, along with their age, sex, problems with color vision, country of origin, country of residence, native language, and fluency in the language in which they completed the color-emotion survey. Participants could select the "do not want to answer" option for any of the demographic questions. On the final page, participants were thanked and received results from a previous, related study in graphic form. We provided an e-mail address for future contact. On average, the current sample took 31 min to complete the survey.

Data preparation

We applied the following inclusion and exclusion criteria to clean the data. We included participants (a) who finished the survey, (b) who completed the survey in their native language, and (c) for whom this language was the official language of their country of origin. Taking Norway as an example, we included native Norwegian speakers who completed the survey in Norwegian (Bokmål) and whose country of origin was Norway. An exception was made for participants from Nigeria, who completed the survey in English (the national language). Nigerian participants had high English proficiency levels (M = 7.02, SD = 0.29, out of 8; for other languages and countries, see Table S1 in the Supplemental Material). As stated above, participants who might have had problems with color vision were excluded (i.e., responded "yes," "do not know," or "do not want to answer" to the question "Do you have trouble seeing colors?"). There were 285 (5.8%) participants who potentially had color vision problems across all the nations.

Statistical analyses

With 20 emotion concepts and 12 color terms, we obtained 240 ratings of color-emotion associations per participant. From these associations, we extracted two dependent variables. The first dependent variable was the probability of color-emotion associations. The second dependent variable was emotion intensity (see below). The alpha level was set to .050 for all statistical analyses. Statistical analyses were performed and graphs were created with SPSS Version 25 and R Studio Version 1.1.4 (R Version 3.4.0; R Core Team, 2017).

Global probabilities. To evaluate the probability of color-emotion associations, we assessed which emotions are associated with each color term without considering emotion intensity. To this end, all selected emotion associations were coded as 1 (regardless of intensity), and all nonselected emotion associations were coded as 0. We used a Bayesian method to estimate probabilities of each emotion being associated with each color term (see the Bayesian Probabilities section in the Supplemental Material). We used the mean estimated probabilities of all participants for each color-emotion pair to construct a global matrix of color-emotion association probabilities (12 × 20; see Fig. 3). The same procedure was repeated for each of the 30 nations separately to obtain mean probabilities of associating every emotion with every color term in each of the 30 nations (see 30 nation-specific matrices of color-emotion associations in Table S6 in the Supplemental Material). We used nation-specific matrices for further cross-cultural comparisons.

Cultural probabilities and their comparisons. We first determined the degrees of similarity between nation-specific patterns of color-emotion associations and the global pattern of color-emotion associations—*nation-to-global pattern similarity*. The underlying values were Bayesian probabilities. The degrees of similarity were calculated by computing Pearson's correlations between the 12 × 20 color-emotion association probabilities of each nation (nation-specific matrix) and the corresponding global 12 × 20 color-emotion association probabilities (global matrix without that nation). The global probabilities were always based on data from 29 nations, that is, all nations but the nation of comparison. These 30 global matrices including the data from 29 nations correlated from .9983 to .9993 with the global matrix including the data from all 30 nations. Hence, no single nation unduly influenced the global pattern. See the full list of nation-specific and global matrices in Table S6 in the Supplemental Material. Next, we estimated *nation-to-nation pattern similarity* by correlating all nation-specific matrices with each other (900 matrix correlations; Table S7 in the Supplemental Material). We also looked at the effects of sex

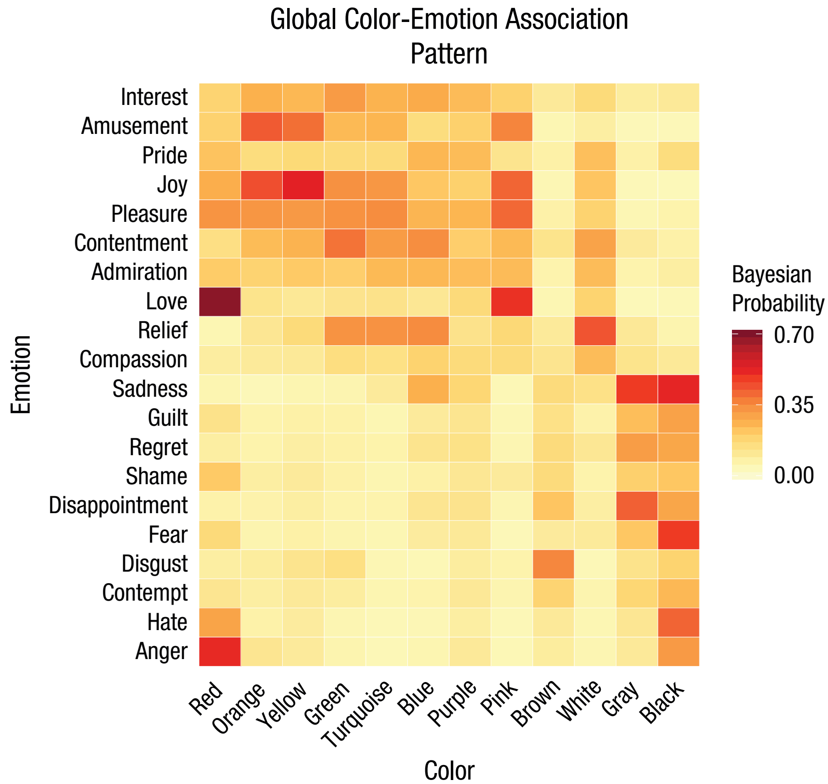

Fig. 3. Heat map showing the unweighted average probabilities of color-emotion associations across the 30 nations. More saturated orange or red indicates a higher probability of a specific color-emotion association. The cells are not exclusive, meaning that the same participant could have contributed to none, one, or several emotion associations for a given color term (many-to-many associations).

and age, which are discussed in the Sociodemographic Factors subsection in Results and reported in full in Tables S8 and S9, respectively, in the Supplemental Material. Finally, we repeated the pattern-similarity analyses per color term. That is, we correlated nation-specific patterns of color-emotion association probabilities with global patterns, excluding that nation for each color term (e.g., nation-specific pattern of *red* vs. global pattern of *red*, excluding that nation; Table S10 in the Supplemental Material). In all of these comparisons, a score of 1.0 indicates perfect similarity in color-emotion association patterns, whereas a score of 0.0 indicates complete dissimilarity in color-emotion association patterns.

In addition to calculating similarity in color-emotion association patterns, we calculated the average probabilities of associating any color with any emotion—*average probability of color-emotion association*. The nation-specific average probability of color-emotion association was calculated by averaging all 240 Bayesian probabilities of color-emotion associations of each nation. The unweighted global average probability of color-emotion association was calculated by averaging all nation-specific average probabilities of color-emotion association (global average-probability score = .161, 95% CI = [.150, .174]). We compared the global average probability of color-emotion association with nation-specific average probabilities of color-emotion association using one-sample t tests. To account for multiple comparisons, we false discovery rate (FDR) corrected the p values, using q = .05 as the threshold. As in the pattern-similarity analyses, we repeated the comparisons per color term as well as for sex and age (see Sociodemographic Factors). An average-probability score of 1.0 for color-emotion association indicates that all color terms were associated with all emotion concepts, whereas a score of 0.0 indicates that no color term was associated with any emotion concept.

The emotion-intensity variable provides information about the average intensity of all emotions associated with each color term. To calculate emotion-intensity similarities, we took all emotion concepts associated with a given color term (previously coded as 1) by a given participant and averaged the intensities assigned to these emotions. Emotion intensities are reported per color term and not per color-emotion association. They varied from 1 (weak) to 5 (intense) unless no emotion was chosen for a given color term (coded as a missing value). We had 12 emotion-intensity scores per participant (one score per color term) and compared these scores across nations. We computed Pearson's correlations between the 12 emotion-intensity scores of each nation and the corresponding global emotion-intensity scores, each time leaving out that nation, when calculating nation-to-global emotion-intensity similarities (see Table S11 in the Supplemental Material). The resulting 29 global emotion-intensity matrices including the data from 29 nations correlated from .9967 to .9999 with the global emotion-intensity matrix including the data from all 30 nations. Hence, no single nation unduly influenced the global pattern. A score of 1.0 for emotion-intensity similarity indicates perfect emotion-intensity pattern similarity, whereas a score of 0.0 indicates complete pattern dissimilarity.

Multivariate pattern classification. We used a supervised machine-learning approach to predict the nation of each participant from his or her set of 240 ratings of color-emotion association (see also Jonauskaite, Wicker, et al., 2019). The accuracy of the classifier provides a quantitative measure of nation specificity in color-emotion associations. If the accuracy is not higher than the chance level, this indicates an absence of nation specificity in the color-emotion associations (i.e., perfect universality). In contrast, high accuracy indicates a high degree of nation specificity. For details of the classifier algorithm, fitting, and evaluation, see the Multivariate Pattern Classification section in the Supplemental Material.

A quantitative measure of the similarity between a pair of nations' color-emotion associations can be readily computed from the classifiers' confusion matrix on the basis of the assumption that nations that are more similar will be more frequently confused by the classifier than nations that are less similar. We used Luce's biased-choice model (Luce, 1963, Equation 5) to estimate similarity values for each pair of nations from the confusion matrix. By convention, a similarity value between a nation and itself is set to 1.0 (representing maximum similarity), whereas a similarity value of 0.0 means that the two nations are completely dissimilar. The estimated similarity values are displayed in Figure S1 in the Supplemental Material.

Linguistic and geographic distances. In addition to assessing cultural similarities, we tested whether two factors—linguistic distance and geographic distance—explained part of the similarity between the color-emotion associations of different nations. We extracted linguistic distances for each nation-nation pair from the study by Jäger (2018; for language codes, see the Linguistic Distances section in the Supplemental Material). These distances are suggested to capture phylogenetic distances that quantify the degree of similarity between the languages of our nation pairs.

The linguistic distances in Jäger's (2018) study range from 0 to 1, with lower linguistic-distance scores indicating higher linguistic similarities. In this data set, the linguistic distances are not evenly spread across this range because there are more unrelated than related language pairs in the world. This was true in our sample of languages as well. In fact, the first 25% of distances fell between 0 and .75, whereas the remaining 75% of distances were concentrated between .75 and .90. To make the spread more homogeneous, we used a power transform of the original distances. At the fourth power, the transformed linguistic distances resulted in a more homogeneous spread (quantiles at 0.00, 0.32, 0.41, 0.53, and 0.65). Jäger proposed that language pairs with distances below .7 should be considered as related. The criterion for related languages became .24 (i.e., $.7^4$), using the transformed linguistic distances (hereinafter referred to simply as *linguistic distances*; see Table S12 in the Supplemental Material).

We also calculated geographic distances for all nation pairs. We used population-weighted geographic centers to reflect the location within each country where participants were most likely to originate. If we could not find population-weighted centers, we used the geographic coordinates of the most populated city of that nation (see Table S13 in the Supplemental Material). Using these centers, we calculated distances (in kilometers) on a sphere between all pairs of nations (see Table S14 in the Supplemental Material). In two linear regression models, we used linguistic and geographic distances to predict (a) nation-to-nation pattern-similarity scores (see the Cultural Probabilities and Their Comparisons section) and (b) Luce's similarity scores (see the Multivariate Pattern Classification section). We argue that comparable results using both approaches provide stronger evidence for the role of linguistic or geographic distance, not least because scores are extracted using very different statistical methods—correlations and multivariate pattern classification.

Results

Global probabilities

We determined the global matrix of the color-emotion association probabilities on the basis of the unweighted means of the estimated Bayesian probabilities for each color-emotion pair across our 30 nations. Prominent color-emotion associations (probabilities ≥ .4 on the basis of our data) were *black* and *sadness, black* and *fear, black* and *hate, red* and *love, red* and *anger, pink* and *love, pink* and *joy, pink* and *pleasure, gray* and *sadness, gray* and *disappointment, yellow* and *joy, orange* and *joy, orange* and *amusement*, and *white* and *relief* (see Fig. 3 & Table S6).

Cultural probabilities

Similarities in color-emotion association patterns. The nation-to-global similarities in color-emotion association patterns were high and significant for all 30 nations. The average nation-to-global pattern similarity (r) was .880 (95% CI = [.857, .903], $p < .001$). All nation-to-global pattern similarities ranged from .684 (Egypt vs. global) to .941 (Spain vs. global; all ps < .001, FDR corrected; see Figs. 1 and 4a). The high pattern similarity indicates that all individual nations associated color terms with emotion concepts similarly to the global pattern. Nation-to-nation pattern similarities were also high and significant (ps < .001). They had a mean of .781 (95% CI = [.773, .789]) and ranged from .501 (The Netherlands vs. Azerbaijan) to .951 (Switzerland vs. France; all ps < .001, FDR corrected; see Fig. S2 and Table S7 in the Supplemental Material). Half of all nation-to-nation correlations fell between .738 and .839, with a median correlation of .799. Figure 4b shows distributions of nation-to-global and nation-to-nation pattern similarities.

Nation-to-global pattern similarities per color term were also high. Average similarities ranged from .659 (95% CI = [.548, .769]; *purple*) to .925 (95% CI = [.910, .940]; *pink*; see Fig. S3 and Table S10 in the Supplemental Material). Across all nations, *purple* and *yellow* had the highest variance in similarities, and *pink*, *green*, *turquoise*, and *black* had the lowest variance in similarities, suggesting that associations with the former colors were the least similar and associations with the latter colors were the most similar across the 30 nations. We also observed certain nation-specific color-emotion associations (see Table S6 and Fig. S3). For instance, Nigerians associated *red* with *fear* in addition to *love* and *anger*; Chinese associated *white* with *sadness* in addition to *relief*. Unlike other nations, Egyptians did not associate *joy* and other positive emotions with *yellow*. Greeks associated *purple* with *sadness*, whereas other nations, on average, associated *purple* with positive emotions.

Average probabilities of color-emotion associations. One-sample t tests showed that the average probabilities of color-emotion association were not significantly different from the global average probability of color-emotion association in 25 out of 30 nations (see Fig. 4c; ps > .604). Only five nations differed significantly from the global average probability of color-emotion association. Relative to the global average probability, participants from Finland, Lithuania, and New Zealand were significantly more likely to associate color terms with emotion concepts, and participants from Azerbaijan and Egypt were significantly less likely (ps < .005, FDR corrected; see Fig. 4c, nations in green). When visually inspecting average probabilities of color-emotion association per color term (see Fig. S4 in the Supplemental Material), we found that, in every nation, *red* and *black* had the highest average probability of being associated with any emotion concept, and *brown* had the lowest.

Emotion-intensity pattern similarities. Emotion-intensity pattern similarities were high and significant for all 30 nations. The average nation-to-global emotion-intensity similarity was .709 (95% CI = [.666, .752], $p < .001$) and ranged from .693 (Azerbaijan vs. global) to .970 (Serbia vs. global; ps ≤ .012, FDR corrected; see Fig. 4d).

Multivariate pattern classification

The machine-learning classifier correctly predicted the nation for 34.4% of the participants (area under the receiver-operating-characteristic curve, or AUC = .85). This proportion of correctly classified instances is well above the random guessing rate of 9.7% that can be obtained by always choosing the nation contained most frequently in our data set (Azerbaijan). The AUC of .85 was also considerably higher than the AUC for the randomly permuted data sets (.51). Thus, the classifier performance demonstrates a systematic amount of nation specificity in color-emotion associations. The confusion matrix (see Fig. 5) shows that participants from Nigeria were the easiest to predict (true positive rate, or TPR = .811), whereas participants from Spain were the most difficult to predict (TPR = .071).

Linguistic and geographic distances

We fitted a linear regression model with measures of linguistic and geographic distance as predictors of nation-to-nation pattern-similarity scores for color-emotion associations, once with and once without the interaction between the two distance measures. The inclusion of the interaction did not improve the model ($p = .389$). Therefore, we report the model without the interaction term. The model was significant overall, $F(2, 432) = 39.9$, $p < .001$, and explained 15.2% of the variance (adjusted R^2). A shorter linguistic distance ($\beta = -0.37$, $p < .001$) and a shorter geographic distance ($\beta = -0.13$, $p = .003$) both predicted higher nation-to-nation pattern-similarity scores for color-emotion associations (see Figs. 6a and 6b).

The analogous linear regression model with linguistic and geographic distances as predictors of Luce's similarity scores in multivariate pattern classification was also significant, $F(2, 432) = 37.4$, $p < .001$. The model explained 14.4% of the variance (adjusted R^2). Again, shorter linguistic ($\beta = -0.36$, $p < .001$) and

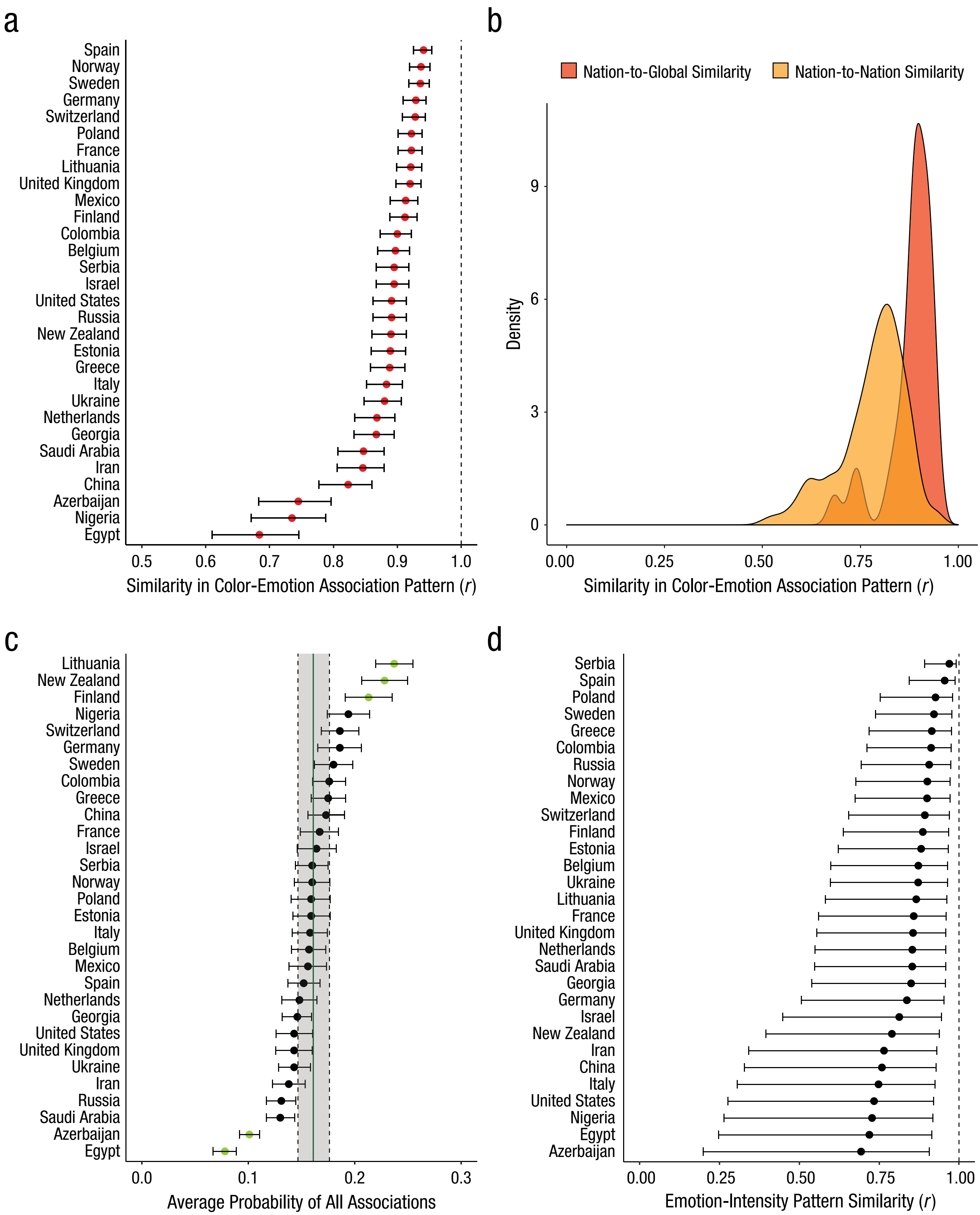

Fig. 4. *(continued on next page)*

Fig. 4. Nation comparisons. Nation-to-global similarity in color-emotion association patterns (a) is shown for each of the 30 nations. The dotted line marks perfect pattern similarity ($r = 1$). Density plots (b) show nation-to-global and nation-to-nation similarity in color-emotion association patterns. Average probabilities of all color-emotion associations (c) are shown for each nation. The average probability of each nation was compared with the global average probability, which is the unweighted average of all average probabilities (dark green line; gray area = 95% confidence interval, or CI). Nations marked in green are significantly different from the global average probability after false-discovery-rate correction. A higher score indicates a higher probability of associating any color term with any emotion concept. Nation-to-global emotion-intensity pattern similarity (d) is shown for each nation. The dotted line marks perfect pattern similarity ($r = 1$). Error bars in (a), (c), and (d) represent 95% CIs.

geographic ($\beta = -0.13$, $p = .003$) distances predicted higher Luce's similarity scores (see Figs. 6c and 6d).

Sociodemographic factors

We examined the influence of two key sociodemographic factors—sex and age—on similarities in color-emotion association patterns and on average probabilities of color-emotion associations. Color-emotion association patterns of men and women were almost identical ($r = .987$, $p < .001$; see Table S8) and were very similar across age groups ($r = .901$–$.991$; ps $< .001$; see Table S9). Men and women also did not differ in their average probability of color-emotion associations, $t(478) = 0.49$, $p = .624$ (see Fig. S5a in the Supplemental Material). Notably, however, age was nonlinearly related with average probabilities of color-emotion associations. A curve-estimation analysis revealed that the association of age with average probabilities followed a U-shaped pattern; the average probability gradually decreased from early adulthood, that is, from 15 to 20 years of age to 50 to 60 years of age, and then started increasing from 50 to 60 years of age onward, $F(2, 1677) = 55.22$, $p < .001$, adjusted $R^2 = .061$ (see Fig. S5b in the Supplemental Material). In other words, 50- to 60-year-old participants were the least likely to associate any color term with any emotion concept.

Discussion

The cross-modal association of color with emotion is a universal phenomenon. Moreover, there is global similarity in how specific emotion concepts are associated with specific color terms, although these universal associations are modulated by geographic and linguistic factors. Across 30 nations and 22 languages on six continents, the pattern of color-emotion associations in each country highly coincided with the global pattern (mean $r = .88$). In other words, participants from different nations shared the relative tendencies to favor certain color-emotion associations (e.g., love and anger with red) over others (e.g., shame with red). Furthermore, participants from different nations agreed on which colors were the most (i.e., black and red) and the least (i.e., brown) emotional. Finally, they rated emotion intensities in a similar manner. Hence, we demonstrated robust agreement across 30 nations in color-emotion associations, providing strong evidence that such associations might represent a human psychological universal (in agreement with Adams & Osgood, 1973; D'Andrade & Egan, 1974; Gao et al., 2007; Ou et al., 2018). Potential mechanisms for these universal associations may be found in a lasting shared human history, regularities in human languages and environments, and shared cognitive biases.

But beyond these global similarities, certain color-emotion associations additionally varied locally (see also Hupka et al., 1997; Madden et al., 2000; Soriano & Valenzuela, 2009). In particular, nations that were linguistically or geographically closer had more similar color-emotion association patterns. Such nations were predicted with lower accuracy by the machine-learning algorithm, even though the algorithm could still predict any participant's nation from the ratings of color-emotion associations above chance level (see also Jonauskaite, Wicker, et al., 2019). These variations might originate from cultural or linguistic differences in how emotion terms or color terms are understood across nations (Jackson et al., 2019). But these variations might also stem from differences in the physical environments themselves. For instance, we recently reported that exposure to sunshine modulated the degree to which yellow was perceived as a color of joy (Jonauskaite, Abdel-Khalek, et al., 2019).

Although the majority of nations did not vary in the extent to which color-emotion associations were endorsed, specific variations were nevertheless observed. Finns, Lithuanians, and New Zealanders endorsed color-emotion associations to a greater extent, whereas Azerbaijanis and Egyptians did so to a lesser extent than the global average. The source of these differences requires further study. Moreover, some nations exhibited idiosyncratic color-emotion associations. For instance, although sadness was universally associated with black, Greeks also associated it with purple, and Chinese also associated it with white. Likely, these divergent color-emotion associations reflect different cultural traditions. White is commonly worn at funerals in China, whereas Greeks occasionally wear darker shades of purple during mourning periods.

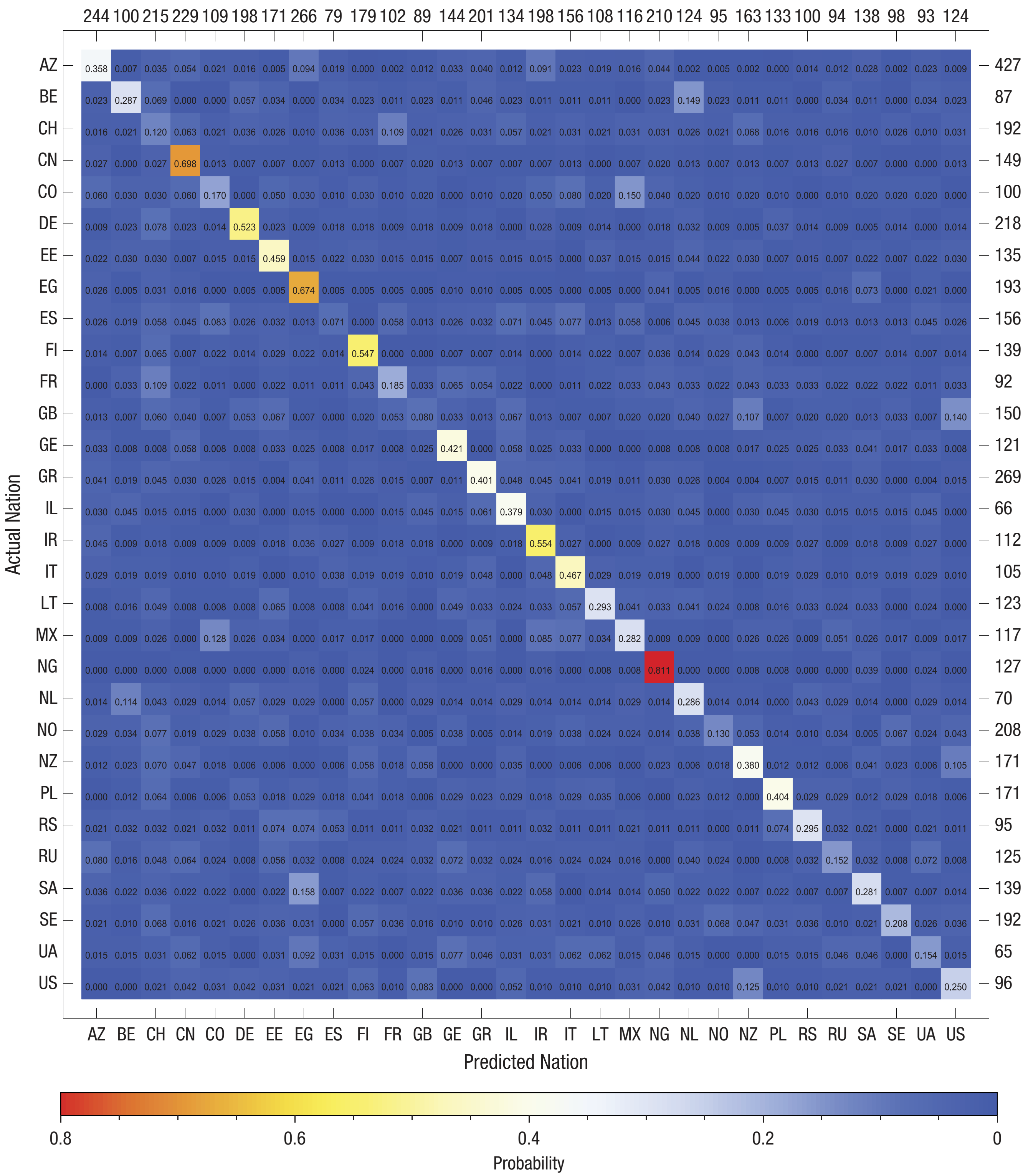

Fig. 5. Confusion matrix for the prediction of the participants' nation (machine-learning multivariate-pattern-classification approach). Rows represent the actual nation that participants were from, and columns represent the predicted nation. Cells represent the probability that participants originating from the nations specified in rows were classified by the machine-learning algorithm as originating from the nations specified in columns, on the basis of their 240 individual color-emotion associations. Thus, probabilities on the main diagonal represent the true positive rate, or recall. The numbers to the right of the matrix represent the absolute frequency of participants originating from a given nation. The numbers above the matrix represent the absolute frequency of participants predicted to originate from a given nation. AZ = Azerbaijan, BE = Belgium, CN = China, CO = Colombia, EG = Egypt, EE = Estonia, FI = Finland, FR = France, GE = Georgia, DE = Germany, GR = Greece, IR = Iran, IL = Israel, IT = Italy, LT = Lithuania, MX = Mexico, NL = The Netherlands, NZ = New Zealand, NG = Nigeria, NO = Norway, PL = Poland, RU = Russia, SA = Saudi Arabia, RS = Serbia, ES = Spain, SE = Sweden, CH = Switzerland, UA = Ukraine, GB = United Kingdom, US = United States.

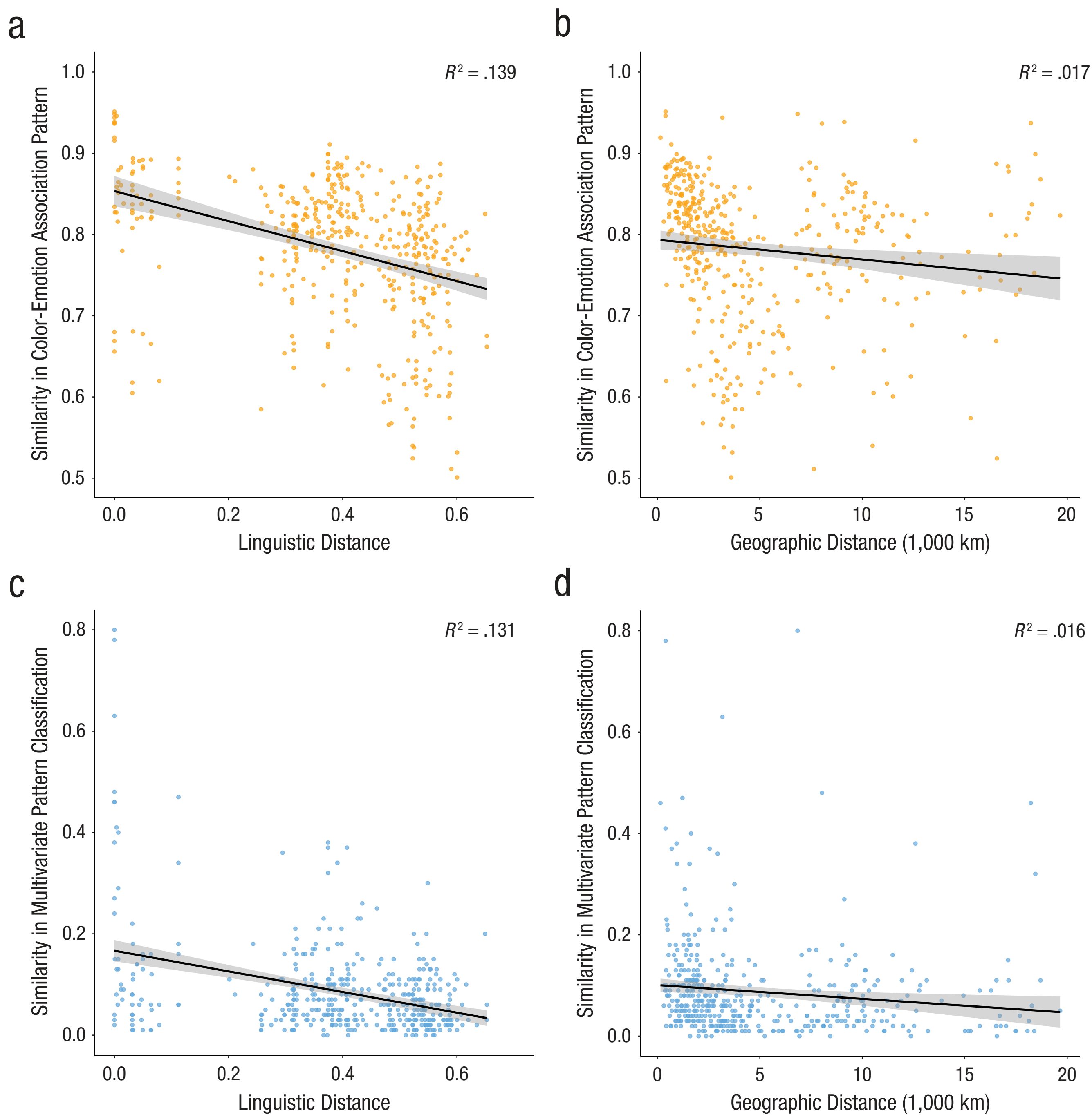

Fig. 6. Scatterplots showing linguistic and geographic distance as predictors of nation-to-nation similarities. The top row shows similarity between color-emotion association patterns and both (a) linguistic distance and (b) geographic distance (see also Fig. S2 in the Supplemental Material available online and Fig. 4b). The bottom row shows similarity between multivariate pattern classifications and both (c) linguistic distance and (d) geographic distance according to Luce's biased-choice model applied to the classifier confusion matrix (see also Fig. S1 in the Supplemental Material). In all the plots, solid lines indicate best-fitting regressions, and shaded areas indicate 95% confidence intervals.

Hence, cultural pairings of white, purple, or black with funerals may explain why specific colors are associated with sadness in some nations but not others.

In this study, we asked participants about their associations between color terms and emotion terms, allowing us to capture the conceptual relationship between them (see also Hupka et al., 1997; Ou et al., 2018; Palmer et al., 2013; Wexner, 1954). However, we do not know whether that relationship also plays out in emotional experiences associated with color perception. That is, people may universally associate the concepts of red and anger but may not universally feel angry when seeing red objects. Within cultures, colors do induce specific subjective and physiological emotional responses (e.g., Wilms & Oberfeld, 2018), and similar emotion concepts are associated with color terms and their best perceptual examples (Jonauskaite et al., 2020). It remains to be seen whether the direct association between color and emotion shows the same patterns of linguistic and geographic modulation that we have described here.

Our results suggest that there is a universal basis for color-emotion associations that is shared by everyone. Numerous other human universals exist (Brown, 1991). In the domains of color and affect, such universals include the shared understanding of facial emotion expressions (Ekman, Sorenson, & Friesen, 1969, but see Gendron, Roberson, van der Vyver, & Barrett, 2014), of emotions perceived in music (Cowen, Fang, Sauter, & Keltner, 2020), and of emotions expressed in human songs (Mehr et al., 2019) as well as the shared loci of focal colors (Regier, Kay, & Cook, 2005, but see Uusküla & Bimler, 2016). This universal foundation of color-emotion association is further modulated by language, geography, and culture.

Some researchers might understand the modulation as evidence against universality because color-emotion associations were not shared at 100%. Yet no human psychological universal is shared at 100% (Mehr et al., 2019; Norenzayan & Heine, 2005; Regier et al., 2005). Luckily, they are not. The scope for dissimilarities seems essential for dynamic adaptations to immediate and lasting changes in one's environment (Lupyan & Dale, 2016). Other researchers might interpret our overall conclusions as evidence of a globalized world. This concern might be justified because we mainly tested computer-literate participants who completed the survey online. Potentially, our color-emotion associations become increasingly similar as we share more and more information globally via the Internet and other communication channels. To test the generalizability of our results, we would need further data from small-scale societies (e.g., Davidoff, Davies, & Roberson, 1999; Groyecka, Witzel, Butovskaya, & Sorokowski, 2019).

Given our current knowledge, we suggest that color-emotion associations represent a human psychological universal that likely contributes to shared communication and comprehension. Thus, the next time you feel blue or see red, know that the world is with you.

Transparency

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Editor: D. Stephen Lindsay
Author Contributions

A. Abu-Akel, N. Dael, and D. Oberfeld contributed equally to this study and share joint second authorship. The study was conceptualized by D. Jonauskaite, N. Dael, and C. Mohr. Data were curated by D. Jonauskaite, A. Chamseddine, and Y. Schrag. Data were analyzed by D. Jonauskaite, A. Abu-Akel, D. Oberfeld, and J.-P. Antonietti. Data were collected by D. Jonauskaite, A. Abu-Akel, N. Dael, D. Oberfeld, A. M. Abdel-Khalek, A. S. Al-Rasheed, V. Bogushevskaya, E. Chkonia, V. Corona, E. Fonseca-Pedrero, Y. A. Griber, G. Grimshaw, A. A. Hasan, J. Havelka, M. Hirnstein, B. S. A. Karlsson, E. Laurent, M. Lindeman, L. Marquardt, P. Mefoh, M. Papadatou-Pastou, A. Pérez-Albéniz, N. Pouyan, M. Roinishvili, L. Romanyuk, A. Salgado Montejo, Y. Schrag, A. Sultanova, M. Uusküla, S. Vainio, G. Wąsowicz, S. Zdravković, M. Zhang, and C. Mohr. D. Jonauskaite, N. Dael, and C. Mohr served as project administers. Software was developed by A. Chamseddine. Translation of the survey was overseen by D. Jonauskaite and implemented by D. Jonauskaite and Y. Schrag. The study was supervised by C. Mohr. The figures were created by D. Jonauskaite, A. Abu-Akel, and D. Oberfeld. The original draft of the manuscript was written by D. Jonauskaite, A. Abu-Akel, D. Oberfeld, and C. Mohr. The manuscript was reviewed and edited by all of the authors, and all the authors approved the final version for submission.

Declaration of Conflicting Interests

The author(s) declared that there were no conflicts of interest with respect to the authorship or the publication of this article.

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Open Practices

All data and materials have been made publicly available and can be accessed at https://forsbase.unil.ch/datasets/dataset-public-detail/15126/2060/ and https://forsbase.unil.ch/project/study-public-overview/15126/1474/, respectively. The complete Open Practices Disclosure for this article can be found at http://journals.sagepub.com/doi/suppl/10.1177/0956797620948810. The design and analysis plans for this study were not preregistered. The complete Open Practices Disclosure for this article can be found at http://journals.sagepub.com/doi/suppl/10.1177/0956797620948810. This article has received the badges for Open Data and Open Materials. More information about the Open Practices badges can be found at http://www.psychologicalscience.org/publications/badges.

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Supplemental Material

Additional supporting information can be found at http://journals.sagepub.com/doi/suppl/10.1177/0956797620948810

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