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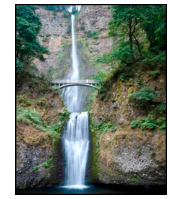

The sun is no fun without rain: Physical environments affect how we feel about yellow across 55 countries

Domicele Jonauskaite[a,*], Ahmed M. Abdel-Khalek[b], Ahmad Abu-Akel[a], Abdulrahman Saud Al-Rasheed[c], Jean-Philippe Antonietti[a], Árni Gunnar Ásgeirsson[d,e], Kokou Amenyona Atitsogbe[a], Marodégueba Barma[f], Daniel Barratt[g], Victoria Bogushevskaya[h], Maliha Khadidja Bouayed Meziane[i], Amer Chamseddine[j], Thammanard Charernboom[k], Eka Chkonia[l], Teofil Ciobanu[a], Violeta Corona[m,n], Allison Creed (艾莉森 克里德)[o], Nele Dael[a,p], Hassan Daouk[q], Nevena Dimitrova[r], Cornelis B. Doorenbos[s], Sergejs Fomins[t], Eduardo Fonseca-Pedrero[u], Augusta Gaspar[v,w,x], Alena Gizdic[y], Yulia A. Griber[z], Gina M. Grimshaw[aa], Aya Ahmed Hasan[b], Jelena Havelka[ab], Marco Hirnstein[ac], Bodil S.A. Karlsson[ad], Stephen Katembu[an,ao], Jejoong Kim[ae], Nikos Konstantinou[af], Eric Laurent[ag,ah], Marjaana Lindeman[ai], Banu Manav[aj], Lynn Marquardt[ac], Philip Mefoh[ak], Aleksandra Mroczko-Wąsowicz[al], Phillip Mutandwa[am], Georgette Ngabolo[ap], Daniel Oberfeld[aq], Marietta Papadatou-Pastou (Μαριέττα Παπαδάτου-Παστού)[ar], Corinna M. Perchtold[as], Alicia Pérez-Albéniz[u], Niloufar Pouyan[a], Tanjir Rashid Soron[at], Maya Roinishvili[au], Lyudmyla Romanyuk[av,aw,ax], Alejandro Salgado Montejo[ay,az,ba], Aygun Sultanova[bb], Ramiro Tau[bc,bd], Mari Uusküla[be], Suvi Vainio[bf], Veronica Vargas-Soto[bg], Eliz Volkan[bh], Grażyna Wąsowicz[bi], Sunčica Zdravković[bj,bk], Meng Zhang (张萌)[bl], Christine Mohr[a]

[a] Institute of Psychology, University of Lausanne, Lausanne, Switzerland
[b] Department of Psychology, Faculty of Arts, Alexandria University, Egypt
[c] Department of Psychology, University of King Saud, Riyadh, Saudi Arabia
[d] Department of Psychology, University of Akureyri, Akureyri, Iceland
[e] Centre for Cognitive Neuroscience, Aalborg University, Aalborg, Denmark
[f] Department of Applied Psychology, University of Lomé, Lomé, Togo
[g] Department of Management, Society and Communication, Copenhagen Business School, Copenhagen, Denmark
[h] Department of Linguistic Sciences and Foreign Literatures, Catholic University of the Sacred Heart, Brescia, Italy
[i] Preparatory School, National Polytechnic School, Algiers, Algeria
[j] School of Computer and Communication Sciences, École polytechnique fédérale de Lausanne (EPFL), Switzerland
[k] Department of Clinical Epidemiology and Department of Psychiatry, Faculty of Medicine, Thammasat University, Pathumthani, Thailand
[l] Department of Psychiatry, Tbilisi State Medical University, Tbilisi, Georgia
[m] Business Management Department, Universidad Panamericana, Zapopan, Mexico
[n] Business Management Department, Universitat Politècnica de València, Valencia, Spain
[o] Faculty of Arts, University of Melbourne, Melbourne, Australia
[p] Department of Organizational Behavior, HEC Lausanne, University of Lausanne, Lausanne, Switzerland
[q] Mar Elias street, Dar Elbayda building, Bayrut, Lebanon
[r] Department of Social Work, University of Applied Sciences in Social Work and Health of Lausanne, HES-SO, Switzerland
[s] Department of Physics, University of Fribourg, Fribourg, Switzerland
[t] Department of Optometry and Vision Science, University of Latvia, Riga, Latvia
[u] Department of Educational Sciences, University of La Rioja, Logroño, Spain
[v] Department of Psychology, School of Human Sciences, Catholic University of Portugal, Lisbon, Portugal
[w] Catolica Research Centre for Psychological, Family and Social Wellbeing (CRC-W), Lisboa, Portugal
[x] Centro de Investigação e Intervenção Social, CIS-IUL, Lisboa, Portugal
[y] Department of Clinical and Health Psychology, Universitat Autònoma de Barcelona (UAB), Barcelona, Spain
[z] Department of Sociology and Philosophy, Smolensk State University, Smolensk, Russia
[aa] School of Psychology, Victoria University of Wellington, Wellington, New Zealand
[ab] School of Psychology, University of Leeds, Leeds, UK

[*] Corresponding author. Institute of Psychology, University of Lausanne, Quartier Mouline, Bâtiment Géopolis, CH-1015, Lausanne, Switzerland.
E-mail address: Domicele.Jonauskaite@unil.ch (D. Jonauskaite).

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[ac] Department of Biological and Medical Psychology, University of Bergen, Bergen, Norway
[ad] Division of Built Environment, Research Institutes of Sweden AB (RI.se), Gothenburg, Sweden
[ae] Department of Psychology, Duksung Women's University, Seoul, South Korea
[af] Department of Rehabilitation Sciences, Cyprus University of Technology, Limassol, Cyprus
[ag] Laboratory of Psychology, Bourgogne Franche–Comté University, Besançon, France
[ah] Maison des Sciences de l'Homme et de l'Environnement, CNRS & University of Franche-Comté, Besançon, France
[ai] Department of Psychology and Logopedics, University of Helsinki, Helsinki, Finland
[aj] Department of Interior Architecture and Environmental Design, Faculty of Art Design and Architecture, Istanbul Ayvansaray University, Istanbul, Turkey
[ak] Department of Psychology, University of Nigeria, Nsukka, Nigeria
[al] Institute of Philosophy of Mind and Cognition, National Yang-Ming University, Taipei, Taiwan
[am] Department of Student Affairs, Midlands State University, Gweru, Zimbabwe
[an] Department of Psychology, University of Nairobi, Nairobi, Kenya
[ao] Institut für Psychologie, Humboldt-Universität zu Berlin, Berlin, Germany
[ap] Département de Psychologie, Université Omar-Bongo, Libreville, Gabon
[aq] Institute of Psychology, Johannes Gutenberg-Universitaet Mainz, Germany
[ar] School of Education, National and Kapodistrian University of Athens, Athens, Greece
[as] Department of Psychology, University of Graz, Graz, Austria
[at] Telepsychiatry Research and Innovation Network, Dhaka, Bangladesh
[au] Laboratory of Vision Physiology, I. Beritashvili Center of Experimental Biomedicine, Tbilisi, Georgia
[av] Faculty of Psychology, Taras Shevchenko National University of Kyiv, Kyiv, Ukraine
[aw] Department of Psychology, V.I. Vernadsky National University of Taurida, Kyiv, Ukraine
[ax] Department of Psychology, Kyiv National University of Culture and Arts, Kyiv, Ukraine
[ay] Escuela Internacional de Ciencias Económicas y Administrativas, Universidad de La Sabana, Chía, Colombia
[az] Center for Multisensory Marketing, BI Norwegian Business School, Oslo, Norway
[ba] Neurosketch, Bogotá, Colombia
[bb] National Mental Health Centre of the Ministry of Health, Baku, Azerbaijan
[bc] Faculty of Psychology and Educational Sciences, University of Geneva, Geneva, Switzerland
[bd] Institute of Psychology and Education, University of Neuchâtel, Neuchâtel, Switzerland
[be] School of Humanities, Tallinn University, Tallinn, Estonia
[bf] Faculty of Social Sciences, University of Helsinki, Helsinki, Finland
[bg] Facultad de Psychology, Universidad de Lima, Lima, Peru
[bh] Department of Psychology, Cyprus International University, Nicosia, Cyprus
[bi] Department of Economic Psychology, Kozminski University, Warsaw, Poland
[bj] Department of Psychology, Faculty of Philosophy, University of Novi Sad, Serbia
[bk] Laboratory for Experimental Psychology, University of Belgrade, Serbia
[bl] Department of Psychology and Behavioral Sciences, Zhejiang University, Hangzhou, China

A R T I C L E I N F O

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A B S T R A C T

Across cultures, people associate colours with emotions. Here, we test the hypothesis that one driver of this cross-modal correspondence is the physical environment we live in. We focus on a prime example – the association of yellow with joy, – which conceivably arises because yellow is reminiscent of life-sustaining sunshine and pleasant weather. If so, this association should be especially strong in countries where sunny weather is a rare occurrence. We analysed yellow-joy associations of 6625 participants from 55 countries to investigate how yellow-joy associations varied geographically, climatologically, and seasonally. We assessed the distance to the equator, sunshine, precipitation, and daytime hours. Consistent with our hypotheses, participants who live further away from the equator and in rainier countries are more likely to associate yellow with joy. We did not find associations with seasonal variations. Our findings support a role for the physical environment in shaping the affective meaning of colour.

1. Introduction

Across cultures, people associate colours with emotions (Adams & Osgood, 1973). These associations may be attributed to linguistic and cultural factors. If so, one's built and natural environments need to be considered too, because one's environment interacts with one's psychological functioning. In this context, colour is an obvious descriptor of one's physical environment, and is thought to directly influence our psychological functioning (Jalil, Yunus, & Said, 2012). For instance, pink rooms were proposed to reduce aggressiveness in prisoners (Schauss, 1979; but see; Genschow, Noll, Wänke, & Gersbach, 2015). Others suggested that green reduces stress in hospital environments (Dijkstra, Pieterse, & Pruyn, 2008). We focus on natural variations in our physical environments to test whether these variations can predict how people associate colours with emotions. We chose yellow, because yellow is commonly, although not exclusively, associated with joy (Burkitt & Sheppard, 2014; Dael, Perseguers, Marchand, Antonietti, & Mohr, 2016; Jonauskaite, Althaus, Dael, Dan-Glauser, & Mohr, 2019; Kaya & Epps, 2004; Lindborg & Friberg, 2015; Sutton & Altarriba, 2016). This affective association might originate from saturated yellow co-occurring with positive climatological experiences like sunshine (Griber, Mylonas, & Paramei, 2018; Palmer & Schloss, 2010) and warmth (Ou, Luo, Woodcock, & Wright, 2004).

Sunshine, and pleasant weather more generally, have been related to better mood in French and American participants (Guéguen, 2013; Keller et al., 2005). However, since research is primarily focused on individuals from Western countries (Henrich, Heine, & Norenzayan, 2010), this positive evaluation of sunshine might not hold globally. Rather, the association of joy with sunshine might be further modulated by warmth and rainfall. Sunshine, warmth, and sufficient rain are necessities for life and growth whereas sunshine alone might lead to drought and death. Thus, people in the Sahara Desert, where yellow is the colour of sand and the burning sun, might rate yellow as less joyful than Norwegians. Joyfulness of yellow might be further reduced when daylight is plentiful (i.e., midsummer) compared to when daylight is scarce (i.e., midwinter). Hence, geographic, climatological, and seasonal factors may modulate one's affective associations with yellow.

We tested these putative associations with data gathered from our ongoing International Colour-Emotion Survey (Mohr, Jonauskaite, Dan-Glauser, Uusküla, & Dael, 2018). We tested whether sunshine, distance to the equator, precipitation, and number of daytime hours, when the survey was completed, predict the strength of the association of yellow with joy in over 6500 participants living in 55 different countries. We hypothesised that participants living in less sunny countries, further away from the equator and/or with heavier rainfall would endorse the yellow-joy association to a greater extent than people living in sunnier countries, located closer to the equator and/or with lighter rainfall. Furthermore, we expected stronger associations when daylight was scarce compared to when daylight was plentiful.

2. Method

2.1. Participants

We extracted responses on yellow-joy associations from a larger data set (see the ongoing International Colour-Emotion Survey (Mohr et al., 2018) (http://www2.unil.ch/onlinepsylab/colour/main.php). This survey aims to evaluate colour-emotion associations in as many countries as possible. To include a wide range of geographic locations, we included countries for which we had at least 20 useable participants (see Simmons, Nelson, & Simonsohn, 2011 for choice of minimum sample size; see "Data preparation" for inclusion criteria). This procedure left us with 6625 participants (1669 males) living in one of 55 countries (Table 1).

The mean age (always in years) of participants was 33.87 (*95% CI* = [33.87, 34.21], range: 16–87). Table S1 displays information regarding the language of the survey, age, and gender composition, separately for each country. The included participants were not colour-blind according to self-report. The survey was conducted in accordance with the principles expressed in the Declaration of Helsinki. No formal ethics approval was received in Switzerland since the law of the Canton of Vaud, Switzerland, does not require it for behavioural studies.

2.2. Material and procedure

2.2.1. Geneva Emotion Wheel (GEW version 3.0; Scherer, Shuman, Fontaine, & Soriano, 2013)

GEW is a self-report measure to assess the subjective feeling component of emotions. GEW presents 20 discrete emotions *(interest, amusement, pride, joy, pleasure, contentment, admiration, love, relief, compassion, sadness, guilt, regret, shame, disappointment, fear, disgust, contempt, hate,* and *anger*) organised in a circular fashion, with similar emotions being placed close to each other (see Table S2 for *joy* in all the languages). For each emotion, five radially aligned circles and a square are used to rate the intensity of the emotion. Selecting the square located the closest to the centre of the wheel means that the emotion intensity is zero (i.e., the given emotion is not perceived as associated with the given colour term). Selecting one of the five circles of increasing size means that the emotion is perceived as being associated with the colour term; the larger the selected circle, the more intense the emotion. Thus, a six-point ordinal rating scale (0–5) was used, with the lowest scale category representing the absence of a colour-emotion association.

2.2.2. International colour-emotion association survey (http://www2.unil.ch/onlinepsylab/colour/main.php)

The co-authors and collaborators were responsible for data collection in their respective countries. Participants were invited to complete the survey online, in their native language. Here, they were included regardless of which language they chose (see "Data preparation"). We facilitated local data collection by using links that directly opened in the target language (see Table S3). At the time of data extraction (February 2019), our survey was available in 40 different languages. Native speakers, many of whom co-author this article, had translated the survey and the GEW emotion terms into their respective languages (see complete list of translators in the Acknowledgments section). Bilingual speakers back-translated the emotion terms to ensure compatibility between languages.

The survey started by stating its main goal, providing ethical information (i.e., participation is anonymous and strictly confidential, responses are to be used for research purposes and its dissemination, participants can stop the survey at any time with no consequences) and collecting informed consent – participants knowingly consented by clicking on the "Let's go" button. The next two pages explained the task and how to use the GEW. To ensure that participants had understood the task, they performed a practice trial for "beige", a colour term not used in the actual survey. Participants had to correct the choices made by Peter, a fictional character. Once corrected, participants could continue to the experiment, in which they associated emotions with 12 colour terms (*red, orange, yellow, green, blue, turquoise, purple, pink, brown, black, grey,* and *white;* see Table S2 for *yellow* in all the languages) and evaluated emotion intensities. The colour terms were presented above the GEW display, and colour order was randomised. Participants could select one, several, or none of the GEW emotions. Participants rated the emotion intensities by clicking on the corresponding circle. Colour terms were chosen instead of colour patches because accurate colour presentation cannot be ensured when showing colour patches online.

After rating the 12 colour terms, participants reported age, gender, colour blindness ("*Do you have any trouble seeing certain colours?*"), colour importance in their life, country of origin and country of residence ("*What is your country of residence? The most recent country you have been living in for at least 2 years*"), native language, and fluency of the language they used to complete the colour-emotion survey. A "*do not want to answer*" option was available for all questions. On the final page, participants were thanked and graphically presented with the results from a previous, related study. Participants were further able to contact us via an e-mail address. On average, our participants took 13.9 min to complete the survey.

2.2.3. Geographic, climatological, and seasonal factors

We extracted three measures for each country of residence. First,

Table 1
The number of participants (n) from each of the 55 countries included in the current study. See Table S1 for further demographic information.

Country (n)	Country (n)	Country (n)	Country (n)	Country (n)
Algeria (57)	Cyprus (324)	Iran (123)	Nigeria (127)	Spain (201)
Argentina (65)	Denmark (29)	Israel (82)	Norway (275)	Sweden (265)
Australia (54)	Egypt (159)	Italy (115)	Peru (22)	Switzerland (346)
Austria (53)	Estonia (131)	Japan (26)	Poland (164)	Taiwan (60)
Azerbaijan (433)	Finland (138)	Kenya (25)	Portugal (31)	Thailand (30)
Bangladesh (21)	France (93)	Latvia (28)	Romania (24)	Togo (34)
Belgium (103)	Gabon (30)	Lebanon (74)	Russia (115)	Turkey (91)
Bulgaria (32)	Georgia (133)	Lithuania (126)	Saudi Arabia (141)	United Kingdom (206)
China (181)	Germany (250)	Mexico (120)	Serbia (109)	Ukraine (74)
Colombia (102)	Greece (499)	Netherlands (119)	South Africa (25)	USA (151)
Croatia (70)	Iceland (71)	New Zealand (223)	South Korea (24)	Zimbabwe (20)

sunshine – percentage of sunny hours per year, calculated by dividing the number of sunshine hours per year (https://en.wikipedia.org/wiki/List_of_cities_by_sunshine_duration) by the total number of daytime hours in a year (i.e., 12 h × 365 days = 4,380 h). This number was then multiplied by 100. Second, *absolute latitude* – distance to the equator of each country (central point) expressed in absolute latitude degrees (https://developers.google.com/public-data/docs/canonical/countries_csv; we ignored the ± sign). Higher absolute latitude degrees indicate that a country is located further away from the equator and is colder. Third, *precipitation* – annual precipitation levels measured as millimetres (mm) of rainfall per year (https://data.worldbank.org/indicator/AG.LND.PRCP.MM), see Table S4 for data of each country. This precipitation variable was chosen to complement the sunshine variable for two reasons. Firstly, few sunshine hours indicate more clouded hours, which may or may not be accompanied by rain/snow. Second, precipitation provides information about the amount of rainfall/snowfall that reached the ground. However, one could imagine situations when weak rainfall lasts all day (i.e., low sunshine and low rainfall) or when heavy rainfall lasts for a short period of time (i.e., high sunshine and high rainfall). Thus, we considered sunshine, latitude, and precipitation as complementary predictor variables.

The sunshine, precipitation, and latitude measures were calculated per country and represent values that were based on averages extracted from assessments over several years (sunshine and precipitation). To account for individual, seasonal factors, we further calculated for each participant the number of *daytime hours* on the day the participant completed the survey. We defined daytime hours as the number of hours between the country-specific sunrise and sunset time. To make the calculation, we took into account the day of the year when the survey was completed and the latitude of participants' country of residence (see *Supplementary Material* for derivation and R code). A greater number of daytime hours occur during local summer and fewer daytime hours during local winter, especially in countries further away from the equator.

2.3. Data preparation

Our exclusion criteria are the same used before (e.g., Jonauskaite, Dael, et al., 2019; Jonauskaite, Wicker, et al., 2019). We excluded participants who were too quick (i.e., took < 3 min to complete the main task) or too slow (took > 90 min to complete the main task). We also excluded participants who seemed not to engage with the task (i.e., spent < 20 s rating the first four colour terms). We did not exclude participants even if they did not complete the survey in their indicated native language, as long as their fluency of the survey language was sufficiently high (i.e., scored at least 5 on 1–8 scale, 8 indicating highest fluency). This criterion allowed the inclusion of immigrants and accounted for native languages in formerly colonised countries (e.g., Swahili speakers in Kenya who completed the survey in English). Finally, we excluded participants who had missing data on the yellow-joy association (i.e., provided no association, not even 0). The dataset contained the occasional missing data, because of technical problems when recording answers. See Table S5 for the count of excluded participants at each step of the data cleaning procedure. Cleaned data are available here: https://forsbase.unil.ch/project/study-public-overview/15126/1672/

2.4. Design and statistical analyses

All data were analysed and graphs were created using R (v. 3.4.0) statistical programming language. We started by assessing the correlations between the geographical and climatological predictors. None of the predictors seemed redundant as shown by average correlation coefficients (all $|r| \leq .478$; Table S6). Also, the variance inflation factor in the regression model was acceptable (VIF ≤ 2.35) indicating no issue of multicollinearity. Thus, we kept all predictor variables to compute our models. These models were run on the *intensity* of yellow-joy associations (scores of 0–5). For descriptive purposes, we also calculated the percentage of participants associating yellow with joy (*likelihood of association*) by dividing the number of participants who associated *joy* of any intensity (1–5) with *yellow* by the total number of participants in each country and multiplying this outcome by 100%.

For the main analysis, we computed the hierarchical cumulative link mixed models with a random effect via Laplace approximation (*clmm* function in R package *ordinal;* Christensen, 2018). This analysis is a hierarchical nested regression model for ordinal data. We estimated the amount of explained variance in the intensity of yellow-joy associations (range of scores from 0 to 5) by the geographical, climatological, and seasonal predictors. We chose a hierarchical regression model to assess the explained variance of each predictor variable in this order: from sunshine, which seemed an obvious variable according to our hypotheses, to absolute latitude, precipitation, and, finally, daytime hours. We chose a cumulative link model to account for the ordinal nature of the dependent variable (discrete responses measured on a six-point ordinal scale from 0 to 5). We chose a mixed-effects model because geographical and climatological variables varied by country and not by individual participants; therefore, within country variance was of little interest here. Fixed effects were sunshine, absolute latitude, precipitation, and daytime hours. Country was a random effect. To prevent numerical issues in model estimations, we rescaled the

Table 2
The table displays unstandardized coefficients (B), standard errors of unstandardized coefficients (SE), standardized coefficients (β), odds ratios with 95% confidence intervals (CI), and z-values associated with each predictor in each block of the hierarchical regression predicting the intensity of yellow-joy associations. The best model is marked in bold.

	B (SE)	β	Odds ratio (95% CI)	*z*-value
Block 1				
sunshine	−0.031 (0.007)	−0.435	0.969 [0.956, 0.982]	−4.67***
Block 2				
sunshine	−0.024 (0.007)	−0.335	0.976 [0.962, 0.990]	−3.38***
absolute latitude	0.014 (0.006)	0.198	1.015 [1.003, 1.027]	2.37*
Block 3				
sunshine	−0.009 (0.009)	−0.119	0.991 [0.973, 1.009]	−0.93
absolute latitude	0.025 (0.007)	0.346	1.026 [1.011, 1.040]	3.51***
precipitation (scaled)	0.485 (0.194)	0.263	1.625 [1.244, 2.005]	2.50*
Block 4				
sunshine	−0.008 (0.009)	−0.116	0.992 [0.974, 1.010]	−0.90
absolute latitude	0.025 (0.007)	0.347	1.026 [1.012, 1.040]	3.51***
precipitation (scaled)	0.492 (0.195)	0.266	1.636 [1.254, 2.018]	2.52*
daytime hours	−0.008 (0.012)	−0.023	0.991 [0.968, 1.015]	−0.73

*p < .050, ***p < .001.

precipitation variable by dividing all precipitation values by 1000.

In block 0, we entered no predictors. In the next block (block 1; see Table 2), we added sunshine. In the following blocks, we assessed, in this order, sunshine and latitude (block 2), then sunshine, latitude, and precipitation (block 3), and finally sunshine, latitude, precipitation, and daytime hours (block 4). We used likelihood ratio tests (R function *anova*), because these tests sequentially compared every block to establish whether each new predictor changed the amount of explained variance in the intensity of yellow-joy associations. We determined the best model based on the significant change in the overall goodness-of-fit of the model as well as based on the Akaike Information Criterion (AIC), where lower values indicate a better fit.

3. Results

The likelihood of yellow-joy associations varied across our 55 countries, ranging from just 5.7% in Egypt to 87.7% in Finland (Fig. 1; Table S7). The global average of the likelihood of yellow-joy associations was 48.26% (*95% CI* = [46.86, 49.26]). We present associations between yellow and other positive and negative emotions in Tables S8 and S9 respectively.

The likelihood ratio test showed that the model with sunshine (block 1) was significant; $LR(4) = 17.98$, $p < .001$, $AIC = 17{,}116$, ${}_{pseudo}R^2 = .139$ (Cox & Snell), .149 (Nagelkerke). The model with sunshine and absolute latitude (block 2) was superior to the model with sunshine alone (block 1) in explaining the intensity of yellow-joy associations; $LR(5) = 5.43$, $p = .020$, $AIC = 17{,}112$, ${}_{pseudo}R^2 = .140$ (Cox & Snell), .150 (Nagelkerke). The model accounting for sunshine, absolute latitude, and precipitation (block 3) was superior again to the model accounting for sunshine and absolute latitude alone (block 2); $LR(6) = 5.78$, $p = .016$, $AIC = 17{,}109$, ${}_{pseudo}R^2 = .141$ (Cox & Snell), .151 (Nagelkerke). Finally, the goodness-of-fit of the model including sunshine, absolute latitude, precipitation, and daytime hours (block 4) was not superior to the model including just sunshine, absolute latitude, and precipitation (block 3); $LR(7) = 0.53$, $p = .46$, $AIC = 17{,}110$, ${}_{pseudo}R^2 = .141$ (Cox & Snell), .151 (Nagelkerke). Therefore, this hierarchical regression approach showed that the variation in the intensity of yellow-joy associations can be best explained when accounting for sunshine, absolute latitude, and precipitation (block 3). Parameter estimates of individual predictors of block 3 showed that higher absolute latitude and higher precipitation significantly predicted a higher intensity of yellow-joy associations, while sunshine was not a significant predictor when these other variables were included (Table 2).

4. Discussion

We tested whether one's physical environment might influence how one attaches emotional meaning to colours. More precisely, we tested the hypothesis that geographic, climatological, and seasonal factors might impact yellow-joy associations in 55 countries. We replicated previous findings showing that yellow is predominantly associated with joy (e.g., Jonauskaite, Althaus, et al., 2019; Kaya & Epps, 2004; Lindborg & Friberg, 2015). About half of our participants endorsed an association between yellow and joy. We observed no comparably compelling associations with any other emotion. Yet, the percentage of participants endorsing this association varied widely, from about 6% in Egypt to about 88% in Finland (see also Barchard, Grob, & Roe, 2017). Overall, participants rated yellow as more joyful if they lived in rainier countries located further away from the equator. This conclusion is based on an analysis in which we used the centre of each country as the point of reference. Although this provides a good estimate of a country's latitude, it will be less reflective of the participant's latitude in large countries.

We initially hypothesised that scarcity of sunshine is a key contributor to yellow-joy associations (Guéguen, 2013; Palmer & Schloss, 2010). Yet, after having accounted for the distance to the equator and rainfall, the factor of sunshine became redundant. Our correlational data indicate that joyful connotations of yellow are stronger when

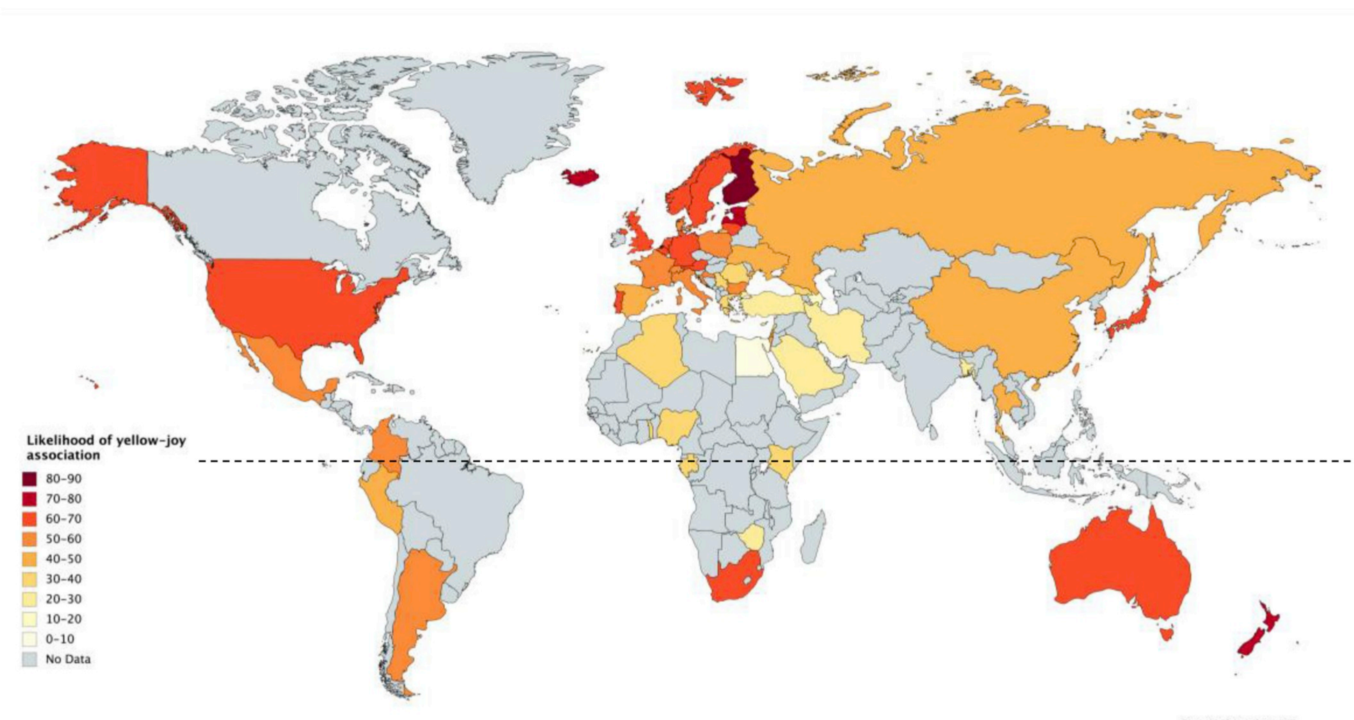

Fig. 1. Likelihood of associating yellow with joy in 55 countries. This map of the world (data not collected in grey countries) shows the likelihood of associating yellow with joy (0%–90%), where darker and redder areas indicate a higher likelihood (i.e., proportion of participants endorsing the yellow-joy association). The dotted line shows the equator. Map created with the free software on https://mapchart.net/.

temperatures are moderate and rainfall is ample. While sunshine might be positive, ample rainfall reduces otherwise harmful effects of heat and too much sunshine (e.g., droughts). These associations were driven by a country's typical annual climate and were not modulated by transient changes. We found that the number of daytime hours on the day of completing the survey did not influence the intensity of yellow-joy associations, suggesting minor seasonal effects on yellow-joy associations.

The stability across seasons contrasts with previous studies on colour preferences, which vary systematically between autumn and the other seasons (Schloss, Nelson, Parker, Heck, & Palmer, 2017). Potentially, colour preferences are more dynamic than colour-emotion associations, since preferences are shaped by one's personal and shared past affective experiences (Palmer & Schloss, 2010). This would explain why we found that yellow-joy associations varied with global climatological factors, but not with seasonal fluctuations.

Our results invite future research testing mechanisms by which climatological and geographical factors may impact colour-emotion associations. One could imagine that yellow-joy associations emerge because of an individual's experience (sunshine makes all colours more vibrant), physical sensations (the positive feeling of skin warmed by the sun), embodied experience (doing joyful things in the sunshine) or semantic pathways (talking about joyful things and sunshine together). Future studies should also investigate whether physical colour exposure impacts psychological functions in systematic ways (e.g., yellow being a joy-inducing colour in participants living in colder and rainier countries). While we acknowledge that many questions remain, our global study lays the groundwork for a better understanding of how the physical environment comes to shape the human mind.

Authors' contributions

Conceptualisation: DJ, CM.
Formal analysis: DJ, JPA, CBD.
Funding acquisition: DJ, NDa, CM.
Investigation: DJ, AAK, AAA, ASAR, ÁGÁ, KAA, MB, DB, VB, MKBM, ACh, TCh, EC, TCi, VC, ACr, NDa, HD, NDi, CBD, SF, EFP, AGa, AGi, YAG, GG, AAH, JH, MH, BSAK, SK, JK, NK, EL, ML, BM, LM, PMe, AMW, PMu, GN, DO, MPP, CMP, APAI, NP, TRS, MR, LR, ASM, AS, RT, MU, SV, VV, EV, GW, SZ, MZ, CM.
Methodology: DJ, CM.
Supervision: CM.
Visualization: DJ.
Writing – original draft: DJ, CM.
Writing – review & editing: DJ, AAK, AAA, ASAR, JPA, ÁGÁ, KAA, MB, DB, VB, MKBM, ACh, TCh, EC, TCi, VC, ACr, NDa, HD, NDi, CBD, SF, EFP, AGa, AGi, YAG, GG, AAH, JH, MH, BSAK, SK, JK, NK, EL, ML, BM, LM, PMe, AMW, PMu, GN, DO, MPP, CMP, APAI, NP, TRS, MR, LR, ASM, AS, RT, MU, SV, VV, EV, GW, SZ, MZ, CM.

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Appendix A. Supplementary data

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