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

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ABSTRACT

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, 2015; 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 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.

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)

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, *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). 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). 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 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 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.

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

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

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 48.3% of our participants endorsed an association between yellow and joy. We observed no comparably compelling associations with any other emotions. Yet, the percentage of participants endorsing this association varied widely, from just 5.8% in Egypt to 87.7% 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 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 association.

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)

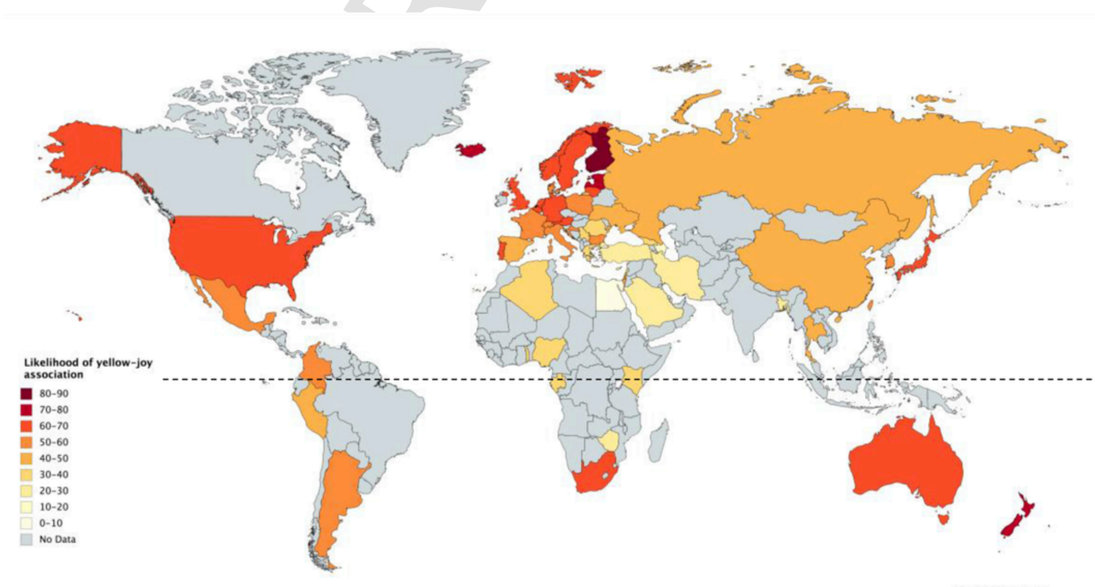

Fig. 1. Likelihood of associating yellow with joy in 55 countries. This map of the world (data not collected in grey countries) shows the likelihood of associating yellow with joy (0%–90%), where darker and redder areas indicate a higher likelihood (i.e., proportion of participants endorsing the yellow-joy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

or semantic pathways (talking about joyful things and sunshine together). Future studies should also investigate whether physical colour exposure impact psychological functions in systematic ways (e.g., yellow being a joy-inducing colour in participants living in warmer 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, JK, NK, EL, ML, BM, LM, PMe, AMW, PMu, SM, 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

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jenvp.2019.101350.

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Supplementary Tables

Table S1. Demographic information of participants by country. Language refers to the language in which the survey was completed.

Country	Language(s) (% of participants)	N (males)	Age (mean, range)
Argentina	Spanish (95.4)	65 (21)	36.98 (17-71)
Algeria	French (50.9) & Arabic (36.8) & English (10.5)	57 (21)	28.47 (18-72)
Australia	English (94.4)	54 (14)	36.13 (19-76)
Austria	German (92.5)	53 (8)	30.74 (20-60)
Azerbaijan	Azerbaijani (99.5)	433 (114)	36.42 (17-70)
Bangladesh	Bengali (95.2)	21 (10)	30.48 (21-62)
Belgium	Dutch (85.4) & English (7.8)	103 (22)	39.06 (19-87)
Bulgaria	Bulgarian (96.9)	32 (13)	39.34 (23-69)
China	Mandarin Chinese (97.8)	181 (52)	34.29 (17-80)
Colombia	Spanish (100)	102 (45)	36.61 (18-74)
Croatia	Croatian (100)	70 (13)	39.64 (18-60)
Cyprus	Greek (79.0) & Turkish (19.8)	324 (88)	30.45 (16-85)
Denmark	Danish (44.8) & English (24.1) & Icelandic (13.8)	29 (12)	44.90 (24-72)
Egypt	Arabic (100)	159 (36)	28.89 (16-65)
Estonia	Estonian (98.5)	131 (16)	38.75 (19-70)
Finland	Finnish (97.8)	138 (17)	32.46 (19-71)
France	French (83.9) & Polish (4.3) & Arabic (3.2)	93 (24)	38.84 (19-75)
Gabon	French (100)	30 (19)	30.70 (24-54)
Georgia	Georgian (97.7)	133 (40)	32.17 (16-73)
Germany	German (85.2) & English (6.0)	250 (36)	33.14 (16-82)
Greece	Greek (100)	499 (84)	30.05 (16-76)
Iceland	Icelandic (97.2)	71 (12)	36.49 (21-62)
Iran	Persian (97.6)	123 (16)	32.74 (16-79)
Israel	Hebrew (92.7)	82 (15)	37.43 (21-67)
Italy	Italian (86.1) & English (2.6)	115 (40)	38.00 (19-80)
Japan	Japanese (96.2)	25 (11)	29.88 (19-48)
Kenya	English (96.0)	26 (11)	29.04 (17-51)
Latvia	Latvian (85.7) & Russian (10.7)	28 (4)	26.11 (19-57)
Lebanon	English (64.9) & Arabic (29.7)	74 (19)	27.32 (17-71)
Lithuania	Lithuanian (81.0) & English (17.5)	126 (19)	34.48 (16-77)

Mexico	Spanish (98.3)	120 (51)	35.86 (16-78)
Netherlands	Dutch (61.3) & English (36.1)	119 (43)	39.44 (17-71)
New Zealand	English (96.0)	223 (55)	26.22 (18-67)
Nigeria	English (100)	127 (55)	37.92 (19-65)
Norway	Norwegian (96.0)	275 (34)	34.31 (18-79)
Peru	Spanish (100)	22 (4)	48.95 (24-82)
Poland	Polish (98.2)	164 (38)	30.00 (17-70)
Portugal	Portuguese (96.8)	31 (2)	27.06 (18-55)
Romania	Romanian (95.8)	25 (4)	24.04 (17-39)
Russia	Russian (97.4)	115 (46)	36.14 (16-78)
Saudi Arabia	Arabic (98.6)	141 (49)	33.21 (18-85)
Serbia	Serbian (98.2)	109 (28)	41.09 (19-78)
South Africa	English (92.0)	25 (12)	37.60 (26-58)
South Korea	Korean (95.8)	24 (2)	26.50 (20-53)
Spain	Spanish (96.0)	201 (55)	34.41 (19-75)
Sweden	Swedish (93.6)	265 (42)	36.14 (20-82)
Switzerland	French (74.0) & German (7.8) & English (5.5) & Italian (3.8)	346 (102)	30.12 (17-79)
Taiwan	Mandarin Chinese (95.0)	60 (19)	26.37 (18-54)
Thailand	Thai (96.7)	30 (7)	39.83 (25-63)
Togo	French (100)	34 (19)	35.91 (19-69)
Turkey	Turkish (92.3)	91 (26)	30.85 (19-84)
Ukraine	Ukrainian (89.2) & Russian (8.1)	74 (10)	38.15 (18-87)
United Kingdom	English (81.1) & Lithuanian (3.9) & Arabic (2.4)	206 (62)	38.97 (16-71)
USA	English (86.1) & Arabic (3.3) & Spanish (2.6)	151 (43)	36.97 (16-75)
Zimbabwe	English (100)	20 (9)	37.00 (17-63)

Table S2. *Yellow* and *joy* in 40 languages, used in the International Colour-Emotion Association Survey.

Language	"Yellow"	"Joy"
Albanian	E verdhë	Lumturi
Arabic	اصفر	فرح
Arabic (Algeria)	اصفر	فرح
Azerbaijani	Sarı	Sevinc
Bengali	হলুদ	আনন্দ
Bulgarian	Жълт	Радост
Chinese (Mandarin simplified)	黄色	欢乐
Chinese (Mandarin traditional)	黃色	歡樂
Croatian	Zuta	Radost
Danish	Gul	Glæde
Dutch	Geel	Blijheid
English	Yellow	Joy
Estonian	Kollane	Rõõm
Finnish	Keltainen	Ilo
French	Jaune	Joie
Georgian	ყვითელი	სიხარული
German	Gelb	Freude
Greek	Κίτρινο	Χαρά
Hebrew	צהוב	שמחה
Hindi	पीला	मजा
Hungarian	Sárga	Vidámság
Icelandic	Gulur	Gleði
Italian	Giallo	Gioia
Japanese	黄色	喜び
Korean	노란색	기쁨
Latvian	Dzeltena	Prieks
Lithuanian	Geltona	Džiaugsmas
Malay	Kuning	Gembira
Norwegian	Gul	Glede
Persian	زرد	مسرت
Polish	Żółty	Radość
Portuguese	Amarelo	Alegria
Portuguese (Brazilian)	Amarelo	Alegria
Romanian	Galben	Bucurie
Russian	Жёлтый	Радость
Serbian	Žuta	Radost
Slovak	Žltá	Radosť
Spanish	Amarillo	Alegría
Swedish	Gul	Glädje

Turkish	Sarı	Sevinç
Ukrainian	Жовтий	Радість

Table S3. Different language links used in this study

Language	Link
Albanian	http://www2.unil.ch/onlinepsylab/colour_albanian/main.php
Arabic (Egypt & Saudi Arabia)	http://www2.unil.ch/onlinepsylab/colour_arabic/main.php
Arabic (Algeria)	http://www2.unil.ch/onlinepsylab/colour_arabic2/main.php
Armenian	http://www2.unil.ch/onlinepsylab/colour_armenian/main.php
Azerbaijani	http://www2.unil.ch/onlinepsylab/colour_azerbaijani/main.php
Bengali	http://www2.unil.ch/onlinepsylab/colour_bengali/main.php
Bulgarian	http://www2.unil.ch/onlinepsylab/colour_bulgarian/main.php
Chinese (Simplified Mandarin)	http://www2.unil.ch/onlinepsylab/colour_china/main.php
Chinese (Traditional Mandarin)	http://www2.unil.ch/onlinepsylab/colour_trad_chinese/main.php
Croatian	http://www2.unil.ch/onlinepsylab/colour_croatian/main.php
Danish	http://www2.unil.ch/onlinepsylab/colour_danish/main.php
Dutch	http://www2.unil.ch/onlinepsylab/colour_dutch/main.php
English	http://www2.unil.ch/onlinepsylab/colour/main.php
Estonian	http://www2.unil.ch/onlinepsylab/colour_estonian/main.php
Finnish	http://www2.unil.ch/onlinepsylab/colour_finnish/main.php
French	http://www2.unil.ch/onlinepsylab/UNILcouleur/main.php
Georgian	http://www2.unil.ch/onlinepsylab/colour_georgian/main.php
German	http://www2.unil.ch/onlinepsylab/colour_german/main.php
Greek	http://www2.unil.ch/onlinepsylab/colour_greek/main.php
Hebrew	http://www2.unil.ch/onlinepsylab/colour_hebrew/main.php
Hindi	http://www2.unil.ch/onlinepsylab/colour_hindi/main.php
Hungarian	http://www2.unil.ch/onlinepsylab/colour_hungarian/main.php
Icelandic	http://www2.unil.ch/onlinepsylab/colour_icelandic/main.php
Italian	http://www2.unil.ch/onlinepsylab/colour_italian/main.php

Japanese	http://www2.unil.ch/onlinepsylab/colour_japanese/main.php
Korean	http://www2.unil.ch/onlinepsylab/colour_korean/main.php
Latvian	http://www2.unil.ch/onlinepsylab/colour_latvian/main.php
Lithuanian	http://www2.unil.ch/onlinepsylab/colour_lithuanian/main.php
Malay	www2.unil.ch/onlinepsylab/colour_malay/main.php
Norwegian	http://www2.unil.ch/onlinepsylab/colour_norwegian/main.php
Persian	http://www2.unil.ch/onlinepsylab/colour_persian/main.php
Polish	http://www2.unil.ch/onlinepsylab/colour_polish/main.php
Portuguese (Brazilian)	http://www2.unil.ch/onlinepsylab/colour_portuguese/main.php
Portuguese (Portuguese)	http://www2.unil.ch/onlinepsylab/colour_portuguese2/main.php
Romanian	http://www2.unil.ch/onlinepsylab/colour_romanian/main.php
Russian	http://www2.unil.ch/onlinepsylab/colour_russian/main.php
Serbian	http://www2.unil.ch/onlinepsylab/colour_serbian/main.php
Slovak	http://www2.unil.ch/onlinepsylab/colour_slovak/main.php
Spanish	http://www2.unil.ch/onlinepsylab/colour_spanish/main.php
Swedish	http://www2.unil.ch/onlinepsylab/colour_swedish/main.php
Thai	http://www2.unil.ch/onlinepsylab/colour_thai/main.php
Turkish	http://www2.unil.ch/onlinepsylab/colour_turkish/main.php
Ukrainian	http://www2.unil.ch/onlinepsylab/colour_ukrainian/main.php

Table S4. Geographic and climatological variables per country. Latitudes are absolute values relative to the equator, regardless of north/south direction.

Country	Latitude (°)	Longitude (°)	Precipitation (mm/year)	Sunshine (average % of sunny hours per daytime hours across a year)
Algeria	28.00	3.00	89	65.00
Argentina	-34.00	-64.00	591	57.83
Australia	-27.00	133.00	534	63.14
Austria	47.33	13.33	1110	43.01
Azerbaijan	40.50	47.50	447	50.40
Bangladesh	24.00	90.00	2666	47.17
Belgium	50.83	4.00	847	35.30
China	35.00	105.00	645	40.54
Bulgaria	43.00	25.00	608	49.70
Colombia	4.00	-72.00	3240	39.04
Croatia	45.17	15.50	1113	43.68
Cyprus	35.00	33.00	498	76.76
Denmark	56.00	10.00	703	35.14
Egypt	27.00	30.00	51	80.86
Estonia	59.00	26.00	626	40.02
Finland	64.00	26.00	536	42.42
France	46.00	2.00	867	37.95
Gabon	-1.00	11.75	1831	39.36
Georgia	42.00	43.50	1026	48.22
Germany	51.00	9.00	700	37.12
Greece	39.00	22.00	652	65.02
Iceland	65.00	-18.00	1940	30.27
Iran	32.00	53.00	228	68.40
Israel	31.50	34.75	435	75.59
Italy	42.83	12.83	832	43.72
Japan	36.00	138.00	1668	42.85
Kenya	1.00	38.00	630	56.89
Latvia	57.00	25.00	641	41.37
Lebanon	33.83	35.83	661	67.12
Lithuania	56.00	24.00	656	41.10
Mexico	23.00	-102.00	758	58.33
Netherlands	52.50	5.75	778	37.95
New Zealand	-41.00	174.00	1732	47.00
Nigeria	10.00	8.00	1150	63.20
Norway	62.00	10.00	1414	38.08

Peru	-10.00	-76.00	1738	28.08
Poland	52.00	20.00	600	35.87
Portugal	39.50	-8.00	854	64.06
Romania	46.00	25.00	637	48.29
Russia	60.00	100.00	460	39.52
Saudi Arabia	25.00	45.00	59	74.16
Serbia	44.00	21.00	686	48.22
South Africa	-29.00	24.00	495	85.20
South Korea	37.00	127.50	1274	47.17
Spain	40.00	-4.00	636	59.16
Sweden	62.00	15.00	624	41.58
Switzerland	47.00	8.00	1537	35.75
Taiwan	23.50	121.00	2090	32.08
Thailand	15.00	100.00	1622	60.03
Togo	8.00	1.17	1168	53.29
Turkey	39.00	35.00	593	50.64
Ukraine	49.00	32.00	565	44.63
United Kingdom	54.00	-2.00	1220	37.28
USA (excluding Alaska and Hawaii)	38.00	-97.00	715	57.87
Zimbabwe	-20.00	30.00	657	68.74

Table S5. Participant count at each stage of exclusion until the final sample was reached.
Complete data are available here: https://forsbase.unil.ch/project/study-public-overview/15126/1672/

Sample size	Description
N = 8934	Extracted data from the online International Colour-Emotion Survey in February 2019
N = 8857	Excluding incomplete responses
N = 8507	Excluding participants who were not fluent in the language of the survey (leaving responses 5-8 only) or did not provide an answer
N = 7618	Excluding colour-blind participants by self-report (leaving participants who responded "no") or those who did not provide an answer
N = 7219	Excluding participants who were too slow or too quick in completing the survey (leaving those who completed the survey between 3 and 90 min)
N = 7081	Excluding younger than 16 years old participants or those who had missing age information
N = 6945	Excluding participants who were too quick when responding to the first four colour terms (took less than 20 seconds on all four colour terms)
N = 6929	Excluding participants who had missing responses for *yellow*
N = 6625	Excluding participants from the countries, which had fewer than 20 responses in total. This is the final sample

Table S6. Correlation matrix between the predictors performed by taking each country as an individual data point.

	Absolute latitude	**Precipitation**	**Sunshine**
Absolute latitude	1.000	-0.283*	-0.405**
Precipitation	-0.283*	1.000	-0.478***
Sunshine	-0.405**	-0.478***	1.000

*$p < .050$, **$p < .010$, ***$p < .001$

Table S7. The likelihood of yellow-joy associations in per cent with 95% confidence intervals (CI) per country.

Country	Likelihood	95% lower CI of likelihood	95% higher CI of likelihood
Algeria	29.82	17.58	42.07
Argentina	50.77	38.28	63.25
Australia	62.96	49.66	76.27
Austria	62.26	48.78	75.75
Azerbaijan	10.62	7.71	13.54
Bangladesh	28.57	7.50	49.64
Belgium	62.14	52.61	71.66
Bulgaria	53.13	34.85	71.40
China	44.20	36.89	51.50
Colombia	58.82	49.11	68.54
Croatia	57.14	45.26	69.03
Cyprus	28.09	23.17	33.01
Denmark	51.72	32.38	71.07
Egypt	5.66	2.03	9.29
Estonia	70.99	63.12	78.87
Finland	87.68	82.13	93.23
France	59.14	48.96	69.32
Gabon	36.67	18.36	54.97
Georgia	33.83	25.69	41.98
Germany	64.00	58.01	69.99
Greece	34.87	30.67	39.07
Iceland	78.87	69.14	88.60
Iran	28.46	20.37	36.54
Israel	43.90	32.93	54.87
Italy	53.04	43.78	62.30
Japan	69.23	50.22	88.24
Kenya	36.00	15.78	56.22
Latvia	75.00	57.90	92.10
Lebanon	35.14	24.00	46.27
Lithuania	64.29	55.80	72.77
Mexico	55.00	45.97	64.03
Netherlands	62.18	53.34	71.03
New Zealand	73.54	67.71	79.38
Nigeria	35.43	27.00	43.87
Norway	67.64	62.07	73.20
Peru	45.45	22.86	68.05
Poland	57.32	49.67	64.97
Portugal	64.52	46.68	82.36
Romania	32.00	12.35	51.65

Russia	47.83	38.56	57.09
Saudi Arabia	24.11	16.97	31.26
Serbia	36.70	27.50	45.89
South Africa	60.00	39.36	80.64
South Korea	50.00	28.43	71.57
Spain	48.76	41.79	55.73
Sweden	66.04	60.30	71.78
Switzerland	56.36	51.11	61.61
Taiwan	55.00	42.04	67.96
Thailand	46.67	27.72	65.61
Togo	32.35	15.78	48.92
Turkey	25.27	16.17	34.38
UK	65.05	58.48	71.61
Ukraine	45.95	34.32	57.57
USA	60.93	53.06	68.80
Zimbabwe	25.00	4.21	45.79

Table S8. The likelihood (in per cent) of the associations between yellow and 10 positive emotions in the 55 studied countries.

	Admiration	Amusement	Compassion	Contentment	Interest	Joy	Love	Pleasure	Pride	Relief
Algeria	10.53	33.33	5.26	10.53	10.53	29.82	1.75	26.32	8.77	8.77
Argentina	21.54	36.92	16.92	26.15	30.77	50.77	18.46	26.15	18.46	20.00
Australia	14.81	31.48	20.37	31.48	29.63	62.96	18.52	33.33	12.96	12.96
Austria	18.87	18.87	9.43	39.62	33.96	62.26	9.43	39.62	16.98	32.08
Azerbaijan	8.78	15.01	5.31	8.08	10.62	10.62	4.85	8.78	4.85	6.24
Bangladesh	14.29	19.05	9.52	19.05	9.52	28.57	23.81	9.52	14.29	14.29
Belgium	16.50	46.60	6.80	34.95	17.48	62.14	9.71	57.28	23.30	20.39
Bulgaria	12.50	56.25	3.13	28.13	18.75	53.13	15.63	28.13	12.50	12.50
China	30.39	42.54	14.92	35.91	27.62	44.20	17.13	41.99	27.07	10.50
Colombia	31.37	39.22	13.73	35.29	20.59	58.82	8.82	16.67	25.49	17.65
Croatia	15.71	38.57	8.57	31.43	27.14	57.14	18.57	37.14	11.43	14.29
Cyprus	16.67	25.00	10.80	16.36	19.75	28.09	12.35	18.52	10.80	13.27
Denmark	10.34	31.03	0.00	13.79	17.24	51.72	0.00	24.14	6.90	20.69
Egypt	4.40	8.18	5.03	3.14	5.66	5.66	2.52	5.03	4.40	1.89
Estonia	16.79	54.96	4.58	29.01	24.43	70.99	14.50	24.43	17.56	20.61
Finland	26.81	55.80	13.77	42.75	37.68	87.68	12.32	42.75	17.39	28.99
France	29.03	45.16	9.68	26.88	21.51	59.14	8.60	34.41	22.58	10.75
Gabon	36.67	13.33	6.67	10.00	16.67	36.67	6.67	16.67	16.67	16.67
Georgia	25.56	46.62	8.27	18.05	20.30	33.83	8.27	20.30	12.78	9.77
Germany	15.20	31.20	9.60	35.20	31.20	64.00	8.40	48.40	18.40	26.40
Greece	13.63	24.45	7.82	14.63	20.84	34.87	6.81	22.24	14.03	11.22

Japan	53.85	61.54	3.85	46.15	30.77	69.23	11.54	46.15	38.46	23.08
Kenya	28.00	28.00	4.00	12.00	16.00	36.00	0.00	24.00	20.00	8.00
Latvia	28.57	50.00	14.29	21.43	17.86	75.00	17.86	35.71	21.43	17.86
Lebanon	13.51	31.08	13.51	12.16	13.51	35.14	5.41	17.57	10.81	10.81
Lithuania	29.37	64.29	12.70	33.33	28.57	64.29	19.05	40.48	20.63	26.98
Mexico	26.67	45.83	9.17	16.67	20.00	55.00	5.00	13.33	18.33	14.17
Netherlands	15.97	32.77	9.24	18.49	22.69	62.18	9.24	54.62	12.61	16.81
New Zealand	31.84	52.47	27.35	36.32	36.77	73.54	14.80	52.47	28.70	21.97
Nigeria	35.43	34.65	12.60	7.87	33.86	35.43	25.98	38.58	12.60	19.69
Norway	16.00	38.18	13.09	30.18	29.09	67.64	14.91	26.91	23.27	24.73
Peru	27.27	40.91	9.09	9.09	27.27	45.45	9.09	9.09	31.82	4.55
Poland	10.37	39.02	3.66	34.76	19.51	57.32	6.10	36.59	8.54	11.59
Portugal	29.03	45.16	19.35	45.16	29.03	64.52	12.90	25.81	16.13	16.13
Romania	12.00	28.00	0.00	8.00	12.00	32.00	8.00	28.00	20.00	4.00
Russia	25.22	40.00	2.61	14.78	13.91	47.83	8.70	24.35	8.70	6.96
Saudi Arabia	17.73	26.95	6.38	7.09	12.77	24.11	4.26	25.53	14.18	7.80
Serbia	14.68	33.94	4.59	24.77	28.44	36.70	8.26	27.52	11.93	13.76
South Africa	32.00	52.00	28.00	24.00	32.00	60.00	24.00	44.00	20.00	20.00
South Korea	37.50	58.33	12.50	50.00	50.00	50.00	20.83	70.83	41.67	41.67
Spain	18.41	39.30	7.96	20.40	23.88	48.76	6.47	9.95	16.92	9.45
Sweden	18.87	35.85	15.47	27.17	36.60	66.04	8.68	27.17	19.25	23.77
Switzerland	23.12	35.26	12.72	26.88	23.41	56.36	8.67	35.26	19.94	17.34
Taiwan	30.00	51.67	11.67	45.00	35.00	55.00	23.33	56.67	33.33	13.33
Thailand	36.67	46.67	13.33	16.67	20.00	46.67	0.00	33.33	13.33	10.00
Togo	35.29	26.47	38.24	23.53	26.47	32.35	14.71	20.59	35.29	14.71
Turkey	9.89	32.97	5.49	12.09	15.38	25.27	12.09	14.29	7.69	13.19
Ukraine	22.97	54.05	5.41	18.92	29.73	45.95	6.76	27.03	16.22	10.81
United Kingdom	14.56	36.89	10.68	25.24	23.79	65.05	9.71	33.01	11.17	11.65

United States	16.56	40.40	13.25	28.48	32.45	60.93	11.26	37.75	17.88	17.22
Zimbabwe	15.00	15.00	5.00	5.00	25.00	25.00	10.00	10.00	15.00	10.00
All countries	18.97	35.55	10.22	23.40	23.59	48.06	10.04	28.53	16.09	15.61

Table S9. The likelihood (in per cent) of the associations between yellow and 10 negative emotions in the 55 studied countries.

	Anger	Contempt	Disappointment	Disgust	Fear	Guilt	Hate	Regret	Sadness	Shame
Algeria	3.51	7.02	5.26	17.54	7.02	12.28	7.02	12.28	8.77	5.26
Argentina	13.85	18.46	18.46	18.46	15.38	12.31	20.00	13.85	10.77	15.38
Australia	5.56	5.56	1.85	11.11	7.41	5.56	1.85	3.70	0.00	5.56
Austria	9.43	16.98	9.43	28.30	3.77	7.55	9.43	3.77	0.00	13.21
Azerbaijan	8.08	11.32	8.78	13.86	4.16	7.39	11.78	12.01	5.08	11.78
Bangladesh	9.52	14.29	19.05	23.81	4.76	4.76	19.05	4.76	14.29	23.81
Belgium	5.83	7.77	6.80	9.71	6.80	5.83	6.80	4.85	3.88	10.68
Bulgaria	6.25	9.38	0.00	3.13	6.25	6.25	9.38	3.13	3.13	6.25
China	9.39	11.05	7.73	9.39	6.63	8.84	6.08	6.63	8.84	8.29
Colombia	11.76	4.90	3.92	9.80	5.88	7.84	3.92	8.82	9.80	7.84
Croatia	8.57	7.14	4.29	4.29	7.14	5.71	10.00	5.71	5.71	8.57
Cyprus	11.11	12.35	10.19	15.74	7.41	9.88	22.22	7.41	10.49	13.89
Denmark	3.45	3.45	6.90	3.45	6.90	13.79	6.90	3.45	0.00	13.79
Egypt	3.77	13.84	7.55	13.21	6.29	8.81	15.09	6.92	1.26	5.66
Estonia	10.69	2.29	3.82	5.34	2.29	3.05	3.82	3.05	2.29	7.63
Finland	7.25	10.14	5.80	16.67	5.07	6.52	6.52	8.70	2.90	7.25
France	8.60	10.75	6.45	10.75	3.23	1.08	3.23	4.30	1.08	5.38
Gabon	3.33	6.67	6.67	10.00	3.33	10.00	3.33	3.33	3.33	6.67
Georgia	8.27	13.53	15.79	13.53	4.51	2.26	9.77	6.02	8.27	9.77
Germany	8.80	17.20	8.00	18.40	9.20	6.40	9.20	5.20	4.00	9.60
Greece	16.43	16.63	10.22	17.03	10.42	16.83	33.67	7.21	6.01	13.83
Iceland	2.82	1.41	1.41	2.82	2.82	7.04	1.41	4.23	2.82	2.82
Iran	4.88	4.88	8.94	13.82	8.94	2.44	14.63	4.07	5.69	9.76
Israel	14.63	18.29	9.76	18.29	9.76	10.98	25.61	7.32	4.88	9.76
Italy	9.57	5.22	5.22	8.70	3.48	6.09	6.09	6.09	5.22	6.96

Japan	15.38	11.54	3.85	3.85	3.85	3.85	3.85	3.85	3.85	11.54
Kenya	0.00	0.00	0.00	4.00	4.00	0.00	0.00	0.00	0.00	0.00
Latvia	7.14	7.14	10.71	14.29	7.14	7.14	7.14	14.29	7.14	10.71
Lebanon	6.76	8.11	10.81	21.62	8.11	17.57	5.41	13.51	5.41	13.51
Lithuania	13.49	11.90	8.73	12.70	9.52	11.90	12.70	10.32	8.73	14.29
Mexico	13.33	10.00	6.67	10.83	2.50	7.50	5.83	6.67	4.17	10.00
Netherlands	10.92	6.72	8.40	6.72	7.56	8.40	10.92	6.72	4.20	4.20
New Zealand	8.52	12.11	4.93	12.56	8.52	5.83	5.38	4.93	6.73	10.31
Nigeria	7.87	3.94	11.02	11.02	3.94	4.72	10.24	11.02	1.57	7.09
Norway	6.91	7.27	6.55	12.00	6.55	6.91	6.18	7.27	4.73	6.91
Peru	9.09	9.09	4.55	9.09	4.55	9.09	4.55	0.00	4.55	9.09
Poland	21.34	10.98	6.10	14.02	4.88	4.88	4.88	6.71	2.44	8.54
Portugal	0.00	6.45	0.00	16.13	3.23	6.45	0.00	9.68	0.00	12.90
Romania	16.00	12.00	12.00	8.00	0.00	12.00	16.00	4.00	0.00	4.00
Russia	1.74	5.22	3.48	5.22	2.61	3.48	2.61	8.70	3.48	6.09
Saudi Arabia	9.22	7.09	10.64	8.51	4.96	7.80	9.93	7.09	4.96	6.38
Serbia	10.09	11.93	6.42	10.09	6.42	6.42	7.34	7.34	4.59	10.09
South Africa	16.00	16.00	16.00	20.00	20.00	16.00	16.00	16.00	28.00	16.00
South Korea	20.83	12.50	8.33	25.00	8.33	12.50	20.83	12.50	12.50	12.50
Spain	9.95	9.45	9.45	6.47	6.47	5.97	7.46	5.97	4.98	13.93
Sweden	9.06	7.17	7.17	12.08	7.17	3.40	3.02	4.91	2.64	4.15
Switzerland	10.12	13.01	9.25	19.36	9.25	13.29	6.65	9.54	5.20	10.98
Taiwan	3.33	15.00	5.00	5.00	3.33	5.00	3.33	5.00	3.33	3.33
Thailand	3.33	3.33	0.00	6.67	0.00	0.00	6.67	0.00	0.00	0.00
Togo	5.88	2.94	0.00	2.94	5.88	5.88	2.94	2.94	2.94	2.94
Turkey	7.69	15.38	9.89	13.19	7.69	4.40	9.89	8.79	10.99	10.99
Ukraine	2.70	9.46	12.16	8.11	8.11	4.05	2.70	10.81	4.05	8.11
United Kingdom	4.85	7.28	3.88	9.71	6.80	4.37	3.88	5.34	1.94	5.83

United States	7.28	6.62	4.64	8.61	11.26	6.62	5.96	4.64	3.31	9.27
Zimbabwe	10.00	5.00	0.00	5.00	10.00	0.00	10.00	0.00	0.00	0.00
All countries	9.33	10.34	7.74	12.59	6.81	7.77	10.42	7.15	5.07	9.37

Derivation for the number of daytime hours

We defined daytime hours as the number of hours between sunrise and sunset. We define sunrise and sunset as the moments that the centre of the sun crosses the horizon.

To calculate the number of daytime hours, we define a geocentric coordinate system. The z-axis is the rotation axis of the Earth (the North South axis). The x-axis is chosen to be perpendicular to the z-axis, and so that the sun always moves in the x-z plane. In spherical coordinates, the θ coordinate is the angle from the positive z-axis (from the North Pole). The ϕ coordinate describes the angle from the positive x-axis, in the x-y plane.

The relationship between Cartesian and Spherical coordinates is as follows:

$$x = rsin\theta cos\phi$$
$$y = rsin\theta sin\phi$$
$$z = rcos\theta$$

For the Sun, ϕ is zero (by construction) and θ varies sinusoidally throughout the year. At the spring and autumn equinoctes, the angle is 90°. At the summer and winter solstices, the angle is respectively 66.5° and 113.5° (90° plus or minus the axial tilt of the earth, T = 23.5°). The θ coordinate is then:
$\theta_s = 90^o - Tsin(2\pi\,(t-79)/365)$, where *t* is the day of the year.

A point on Earth, $\vec{p}$, describes a circle in the x-y plane. Its ϕ coordinate varies throughout the day – it is 0° at noon and 180° at midnight. Its θ coordinate is fixed by the latitude, $\theta_p = 90^o - latitude$ The points on this circle where $\vec{p}$ crosses into and out of the half of the Earth lit by the Sun are sunrise and sunset. The number of daytime hours is therefore proportional to the part of this circle that is inside the lit area.

Given the latitude of a point, we can calculate the coordinates where sunrise and sunset occur. At sunrise and sunset, the angle of the sun with the zenith is 90°. Since the inner product of two vectors $\vec{p}$ and $\vec{q}$ is equal to $|\vec{p}||\vec{q}|cos\alpha$, where α is the angle between p and q, at sunrise and sunset the inner product of the vectors representing our point ($\vec{p}$) and the sun ($\vec{q}$) is zero.

Using the fact that the Sun is in the x-z plane, so that it's ϕ coordinate is zero, we transform the position of the sun from spherical into Cartesian coordinates:

$$\vec{s} = r_s(sin\theta_s cos\phi_s, sin\theta_s sin\phi_s, cos\theta_s) = r_s(sin\theta_s, 0, cos\theta_s)$$

We use the fact that the cross product of $\vec{p}$ and $\vec{s}$ is zero to calculate the ϕ coordinate of the sunrise and sunset:

$$\vec{p}\cdot\vec{s} = r_p r_s\left(sin\theta_p cos\phi_p sin\theta_s + cos\theta_p cos\theta_s\right) = 0$$
$$sin\theta_p cos\phi_p sin\theta_s = -cos\theta_p cos\theta_s$$
$$cos\phi_p = \frac{-cos\phi_p cos\phi_s}{sinphi_p sinphi_s} = -cot\phi_p cot\phi_s$$
$$\phi_p = \pm acos\left(-cot\phi_p cot\phi_s\right)$$

The angle ϕ_p of sunrise or sunset is directly related to the number of daytime hours, since it is proportional to the fraction of the circle described by point that has sun:

$$daylighthours = \phi_p \cdot 24\,hours/180\,degrees$$

R code to calculate the daytime hours for each participant at the time of survey completion.
To make the calculation, the day of the year (1st – 365th) when the survey was completed and the latitude of the country of residence are fed to the function. The function assumes that spring equinox is on 20th March (i.e., 79th day of the year).

```
hours_daytime <- function (day_of_year, latitude) {
 earth_axial_tilt = 23.5*pi/180 # in radians
  theta = 0.5*pi - latitude*pi/180  # theta = angle from the
north pole in radians
  theta_s = 0.5*pi - earth_axial_tilt * sin(2*pi*(day_of_year -
79)/365)  #theta_s = angle of the sun from the north pole in
radians on that day
  x = max(-1/(tan(theta)*tan(theta_s)), -1)
  x = min(x, 1)
  phi = acos(x) #phi angle
  result = 24 * abs(phi)/pi
  return(result)
}
```