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Bodily Maps of Emotions Are Culturally Universal

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Emotions are often felt in the body, and interoceptive feedback is an important component of conscious emotional experiences. Here, we provide support for the cultural universality of bodily sensations associated with 13 emotions in a large international sample (3,954 individuals from 101 countries; age range = 18–90). Participants were presented with 2 silhouettes of bodies alongside emotional words and asked to color the bodily regions whose activity they felt increasing or decreasing while they experienced each given emotion. We tested the effects of various background factors (i.e., age, sex, education, body mass index, nationality, civilization, and language) on the bodily sensation maps. Bodily sensations associated with emotions were concordant across the tested cultures ($r_s > 0.82$) and across the sexes ($r > .80$). Bodily sensations weakened during aging ($M r_s = 0.11$ across emotions). We conclude that universality in experiencing emotions in the body is stronger than the differences due to culture or sex.

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Keywords: emotion, somatosensation, body, culture, universalism, aging






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Emotions prepare us for action. The mechanisms of such survival responses rely on numerous synchronized changes in cardiovascular, skeletomuscular, gastrointestinal, respiratory, endocrine

and exocrine, and autonomic nervous systems (Kreibig, 2010; Levenson, 2003) as well as on distributed neural circuitries in the brain (Kragel, Knodt, Hariri, & LaBar, 2016; Saarimäki et al., 2018; Saarimäki et al., 2016). Interoceptive and somatosensory processes in turn play a major role in the generation of subjectively felt emotion states (Damasio et al., 2000; Kreibig, 2010; Nummenmaa, Glerean, Hari, & Hietanen, 2014). Emotions are physiological survival functions, only modestly influenced by cultural factors and individual differences in genotype and phenotype (Ekman, 1992; Sauter, Eisner, Ekman, & Scott, 2010).

Emotions are inherently social and adaptive and thus are not completely devoid of cultural influence and learning-dependent plasticity. Accordingly, cultural variation is observed in social dimensions of emotions such as facial expression recognition (Jack, Garrod, Yu, Caldara, & Schyns, 2012; Nelson & Russell, 2013), display rules (Matsumoto et al., 2008), and subjective feelings of social emotions (Kitayama, Mesquita, & Karasawa, 2006). There exist also significant differences in how different individuals, particularly men and women, within a given culture process emotions (Fischer, Rodriguez Mosquera, van Vianen, & Manstead, 2004). In general, women recognize emotional expressions better and express emotions more than men do, whereas men respond more strongly to threatening cues (Kret & De Gelder, 2012). Similarly, vocal and facial emotion-recognition ability (Mill, Allik, Realo, & Valk, 2009) and declines in emotional expressivity during aging potentially explain the general impair-

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Lauri Nummenmaa, Riitta Hari, Jari K. Hietanen, and Enrico Glerean designed the experiments; Lauri Nummenmaa and Enrico Glerean acquired data; Sofia Volynets and Enrico Glerean analyzed data; and Lauri Nummenmaa, Riitta Hari, Jari K. Hietanen, Sofia Volynets, and Enrico Glerean wrote the manuscript.

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ments in recognizing older peoples' emotional expressions (Folster et al., 2014).

Recently, it has been shown that bodily "feeling fingerprints" determine the qualia of subjective emotional feelings (Nummenmaa et al., 2014; Nummenmaa, Hari, Hietanen, & Glerean, 2018; Torregrossa et al., 2018). Yet, cultural universalism, sex differences, and age dependency these bodily feelings of emotions remains poorly understood and the existence of emotion-specific, universal psychophysiological signatures of emotions is currently debated (Kreibig, 2010; Siegel et al., 2018). Unlike facial expression recognition tasks or psychophysiological measurements, high-resolution topographical mapping of bodily sensations provides a straightforward measure of one potentially universal component of human emotions. Subjective emotional feelings and their expressions are only modestly correlated with the underlying autonomic activity (Anderson, Monroy, & Keltner, 2018; Mauss, Levenson, McCarter, Wilhelm, & Gross, 2005), potentially due to the fact that these studies typically measure general-level autonomic activity rather than, for example, multichannel cardiovascular, respiratory and endo- and exocrine function as well as bodily region specific skeletomuscular activity. Focusing on specifically at the output layer of these functions—the subjectively felt bodily changes—circumvents this problem even though it sacrifices the physiological specificity.

Furthermore, many facial expressions may be used primarily for affiliative purposes rather than for genuinely communicating one's emotional state (Manninen et al., 2017; Scott, Lavan, Chen, & McGettigan, 2014). They are also oftentimes visible to others, providing ample opportunities for learning cultural and sex-specific display rules. In turn, physiological manifestations of emotions difficult to recognize from others by simple observation: Even though some internal states can be inferred directly from behavior (e.g., an erection indexes sexual arousal and shivering lowered body temperature), internal states are in general less visible than are emotional expressions that are meant to be seen by others. Thus, even though experience-dependent plasticity might lead to culturally distinct expressions of emotions via action-observation-based learning, bodily states and the corresponding subjective bodily sensations associated with distinct emotions could be less likely to be influenced by culture.

We have previously tested concordance of embodied emotions across one West European (Finland) and one East Asian (Taiwan) countries (Nummenmaa et al., 2014). Despite concordant findings across these culturally distant samples, this earlier study did not sample the cultural variation of bodily felt emotions across the world. Finally, developmental studies have shown that understanding of emotions (Thompson & Lagattuta, 2006), emotion recognition skills (Widen, 2013), and the discrete bodily fingerprints of emotions (Hietanen et al., 2015) are tuned to adult-like operation during the childhood. Yet, there exists no data on how the bodily feelings of emotions develop through the adult life span.

Here we tested the (1) cultural universality, (2) sex differences, and (3) age-dependence of bodily sensation maps (BSMs) associated with different emotions; the study was based on unique computer-based, topographical self-report method that we have previously validated (emBODY; Nummenmaa et al., 2014; Nummenmaa, Suvilehto, Glerean, Santtila, & Hietanen, 2016). To provide strong evidence for the cultural universalism of bodily sensations associated with emotions, we employed a cross-cultural

design aiming at maximal geographic and cultural diversity of tested cultures, as statements about universality are strongest when the findings apply to an approximation of the world's database of cultures (Norenzayan & Heine, 2005).

Materials and Method

Participants

The study protocol was approved by the Aalto University Institutional Review Board (21022012v8). A total of 6,559 individuals (5,355 women; 1,204 men) from 105 countries registered. We recruited participants by advertising in English on the laboratory web page, through press releases, and via social media so that individuals could participate from all over the world. The respondents' geographical location (current country of residence) was determined by the IP address used in connecting to the Aalto University servers. A subset (12.5%) of the participants were also directly asked about their nationality; these data showed that IP address and self-reported nationality were, on average, matching on 84% of cases, likely representative of the whole sample. The experiment was presented in English to all participants regardless of their mother-tongue because previous work shows that linguistic factors do not confound the responses in this task. Specifically, the bodily maps of emotions are concordant when participants report bodily feelings associated with verbally presented emotion tokens or when they report their actual bodily feelings resulting from nonverbal emotion induction (Nummenmaa et al., 2014). Upon logging into the experiment and providing informed consent, participants reported background information including age, sex, handedness, education, and height and weight (see Table S-1 in the online supplemental material). Participants under 18 years of age and those completing the body map task for fewer than 10 emotions were removed from the sample. We also filtered participants reporting anomalous weights and heights based on Anthropometric Reference Data for Children and Adults in United States, 2011–2014. We took the lowest 5% and the highest 95% percentiles for values of height and weight for adults from all examined ages and cultural backgrounds as thresholds and excluded participants who reported values outside these limits (43.2–130 kg and 144–176.5 cm for women; 48.5–137.3 kg and 155–188.9 cm for men). We also removed the participants whose reported nationality mismatched their IP address-based geographical location while they completed the experiment. Finally, the data were manually screened for abnormal painting behavior (e.g., drawing symbols or doodling on the bodies). The resulting final sample included data from 3,954 individuals from 101 countries aged between 18 and 90 ($M = 34.9$ years; 3,260 women and 694 men). To reveal potential cultural factors underlying variation in the emotion-specific BSMs, we divided participants into nine groups according to major civilizations (rather than modeling cultural variation as a function of country of residence only) based on their country of residence, as defined by Huntington (1996). Because of the limited number of participants in some groups, we also analyzed the data by collapsing these groups into Western and non-Western cultures.

Data Acquisition

Data were acquired online using the emBODY tool (see Figure 1), developed by our group and freely available at <https://version> F1

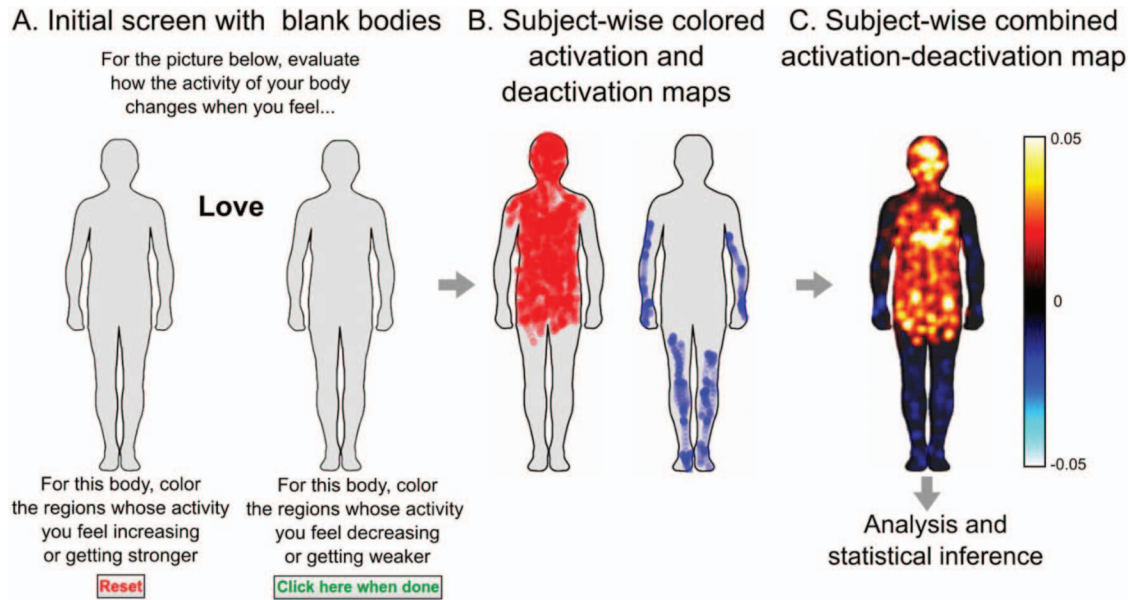


Figure 1. Experimental protocol. Participants were presented with blank body silhouettes (A) and were asked to color the regions whose activity they felt increasing (left body) and decreasing (right body) during a given emotion (B). Activation and deactivation maps were subsequently combined (C) for statistical analysis; the whole body was represented by 50,291 data points and the coloring data were stored as integers. Bodily maps of emotions for the whole sample ($N = 3,954$). The body maps show regions whose activation increased (warm colors) or decreased (cool colors) when the participant was feeling the indicated emotion ($p < .05$, FDR corrected; $t > 2.92$). The color bar indicates the t statistic range. FDR = false discovery rate. See the online article for the color version of this figure.

[.aalto.fi/gitlab/eglerean/embody](https://github.com/eglerean/embody). Via this computerized tool, participants were presented with two silhouettes of a human body and an emotion term displayed between each silhouette. Participants were instructed to read the emotion word and denote in the silhouettes the areas in their bodies where they felt that activation was increased (on the left side of the body) and decreased (on the right side of the body) when experiencing that emotion. Participants evaluated their bodily sensations associated with six basic emotions (anger, fear, disgust, happiness, sadness, and surprise; per Ekman's [1992] original definition), seven nonbasic emotions (anxiety, love, depression, contempt, pride, shame, and jealousy), and the neutral state. Each word was presented once during separate trials in random order. Previous work has suggested that the results from this type of a brief word-cue-based task are concordant with the sensation maps reported during actual experimentally induced emotions (Nummenmaa et al., 2014). The total area for the bodies was 50,365 pixels, and the diameter of the painting tool was 12 pixels. Painting was dynamic, and successive strokes on a region increased the opacity of the paint until the maximum value (arbitrarily set at 255) was reached, shown to the participants as RGB color [255,0,0] for activation and [0,0,255] for deactivation. Finished images were stored in matrices with positive values for activations and negative values for deactivations.¹

Statistical Analysis

Participantwise and emotionwise activation and deactivation maps for each emotion were first combined into BSMs represent-

ing both activations (positive values) and deactivations (negative values). Responses outside the body area were masked. Mass univariate t tests were then used on the participant-wise BSMs to compare pixelwise activations and deactivations of the BSMs for each emotional state against zero. This procedure resulted in statistical t maps, where pixel intensities reflect statistically significant reported bodily changes associated with each emotional state across all the participants. False discovery rate (FDR) correction with an alpha level of 0.05 was applied to the statistical maps to control for false positives due to multiple comparisons here and in all following analyses.

To test whether the bodily sensations associated with each emotion are similar across different cultures, we selected from our sample 15 countries with at least 45 participants in each (see Table S-1 in the online supplemental material; $N = 3,085$). First, we computed the average t maps of each emotion for each country. Because the number of participants varied across countries, we convert the t maps into effect size (ES) maps. To visualize the similarity structure of the emotion-specific BSMs across the selected 15 countries, the emotionwise ES maps were clustered using t -distributed stochastic neighbor embedding (t -SNE; <https://lvdmaaten.github.io/tsne/>). In the resulting multidimensional scaling projection, distance between the elements (i.e., emotions in each country) is related to their similarity. Next, we examined the inter-rater consistency of BSMs by computing a

¹ The full dataset is available on Zenodo (●●●).

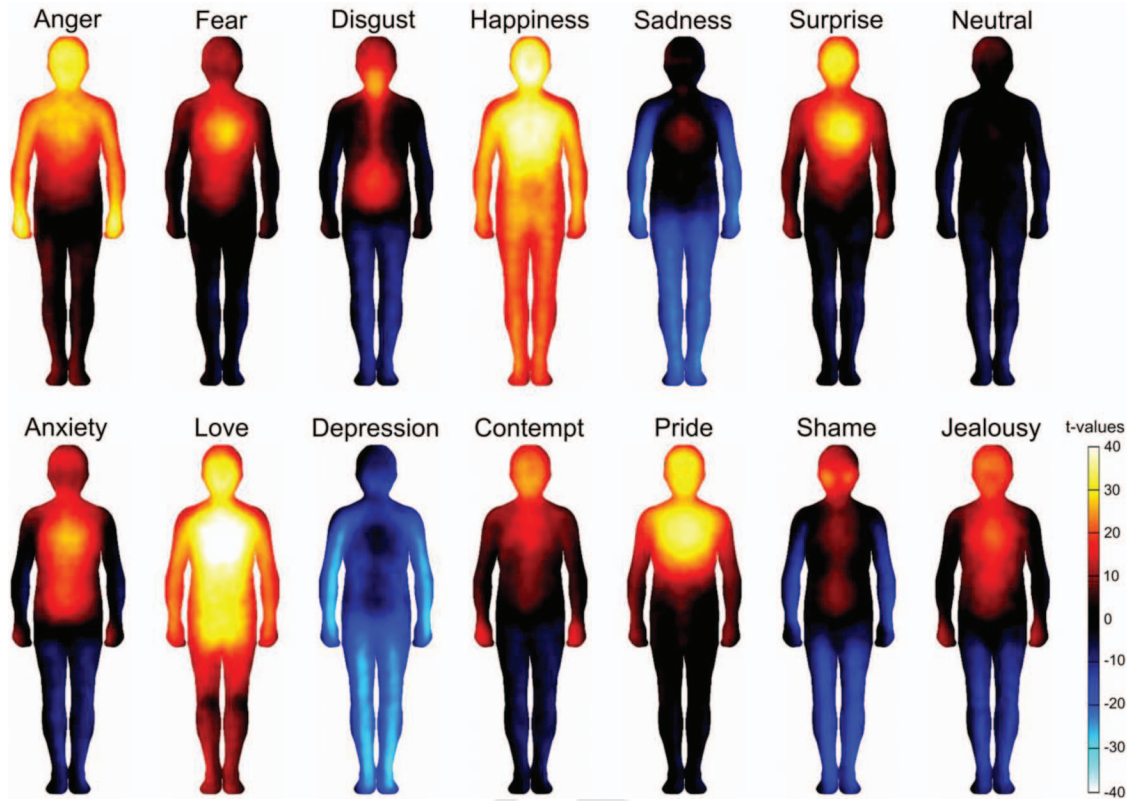


Figure 1. (continued)

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Spearman-correlation-based similarity matrix of the aforementioned ES maps (see Figure 4). We compared all the available Country + Emotion ES maps ($14 \text{ emotions} \times 15 \text{ countries} = 210 \text{ maps}$, e.g., happiness in Finland, disgust in the United States, and so on), and the resulting matrix was sorted by emotions. We then computed the mean similarity score separately for each emotion across all countries to assess the international consistency of BSMs for the given emotion (e.g., the mean similarity of “pride” maps across all countries). To test the statistical significance of those mean emotionwise international similarity scores (reported in Figure 4), we shuffled the columns and the rows of the initial similarity matrix 5,000 times to compute a surrogate distribution of similarity scores for each emotion.

To deal with multicollinearity of the predictors, we used ridge regression to evaluate the influence of emotion and demographic, anthropometric (age, sex, education, body mass index [BMI]), and cultural (country of residence, civilization, and language family) characteristics on the BSMs (see Figure S1 in the online supplemental material). This approach allows nonorthogonal regressors while quantifying how much variance emotions explain in the body maps relative to cultural and subject-specific factors by adding a degree of bias to the regression estimates. For each pixel, the participantwise and emotionwise values were regressed against a model containing the regressors of interest: 14 emotions, 15 countries (with $N > 45$ plus “other” category), nine major civilizations (Western, Orthodox, Islamic, Buddhist, Hindu, African, Latin American, Sinic, Japanese; see Huntington, 1996), eight

language families according to the first official language of the country of the participant’s IP address and “other” category, plus education, age, BMI, and sex. We used Huntington’s classification of cultures because the conventions stemming from national ideologies, politics, and religion could presumably have long-term and consistent impact on the way emotions are potentially shaped in the culture. We tested a logarithmic lambda parameter in the range of 10^{-3} to 10^9 and chose $\lambda = 10^7$ as it provided stable beta values across all pixels. To assess statistical significance and control for multiple comparisons, we shuffled the rows of the model matrix and considered the biggest beta value to obtain the maximum statistical distribution.

Finally, we applied a two-sample t test to compare BSMs of Western participants against those of the others (Western group: $n = 3,069$; non-Western group: $n = 885$). A similar test was performed to compare BSMs between men and women. The relationship between BSMs and participants’ geographical location (longitude and absolute latitude), anthropometric parameters (height, weight, BMI), and age were assessed by pixelwise Spearman correlation separately for each emotion.

Results

Figure 1 shows BSMs associated with the 13 emotions and the neutral state reported by the whole sample ($N = 3,954$), with distinct bodily “fingerprints” for each emotion (see Figure S-1 in the online supplemental material for standard deviation maps). The similarity space for the emotions across different countries derived

F2 by *t*-SNE (see Figure 2) revealed that the 13 examined emotions plus neutral state formed distinctive clusters, with clear concordance across tested countries. For example, BSMs for “love” are remarkably similar across all countries but are also distinct from both closely related (e.g., “happiness”) and more distant (e.g., “depression”) emotions. This concordance of BSMs across cultures was corroborated by similarity analyses of the BSMs for the 15 countries with $N > 45$. Despite some variability across the countries, the mean similarity of BSMs for each emotion was considerable across tested countries (emotionwise intercultural similarities indexed by $r_s > 0.82$, $p_s < 0.001$; see Figure 3).

F3

Ridge regression analysis confirmed that emotions themselves were the major source of variation in the BSMs, with factors relating to sociodemographics, anthropometrics, and culture contributing to the variance only modestly (see Figure S2 in the online supplemental material). The only major exception was age: the BSMs showed an age-dependent decline in intensity (see Figure 4). Age correlated negatively with pixelwise values of BSMs for anger, fear, disgust, happiness, surprise, anxiety, love, contempt, pride, shame and jealousy, and positively with BSMs for depression and sadness (for all BSMs, $r > .036$, $p < .05$, FDR corrected) because depression and sadness were associated with sensations of deactivation (negative values), the positive correlation thus implies dampening of the sensations of decreasing activity for these emotions. Accordingly, participantwise mean absolute intensity scores (across all the pixels and emotions) were negatively associated with age ($r_s = 0.11$, $p < .001$). No significant correlations were found between the participants’ BSMs and their geographical

location (longitude and absolute latitude) and body parameters (height, weight, BMI). Two-sample *t* test comparison however revealed some differences between BSMs of Western and non-Western groups ($t > 2.65$, $p < .05$, FDR corrected; see Figure S3 in the supplemental material). Western participants reported more activation in various regions of their bodies when feeling fear, anxiety, disgust, happiness, love, pride, contempt, jealousy, anger, and while being neutral. On the contrary, non-Western participants reported less deactivation for depression, sadness, and shame. Differences between male and female participants were modest ($t > 2.65$, $p < .05$, FDR corrected; see Figure S4 in the online supplemental material). Compared with men, women reported more activation in their “guts” during anger, jealousy, anxiety and shame, and in their throat during anxiety, shame, fear, contempt, and sadness (more activation in the heart area as well). Women also reported less activation in their legs when feeling surprised, depressed and neutral. Men reported stronger activation in their genital area when experiencing love.

Discussion

Our main finding was that bodily sensations associated with different emotions are strikingly concordant across a wide range of cultures spanning the northern (e.g., Finland, Poland, Romania, Canada) and southern (Brazil, Mexico, Indonesia, Australia) hemispheres, as well as Western (e.g., United States, Canada), Latin American (e.g., Brazil, Mexico), Hindu (e.g., Indian), Orthodox (Romania), and Islamic (e.g., Turkey) cultures per the standard

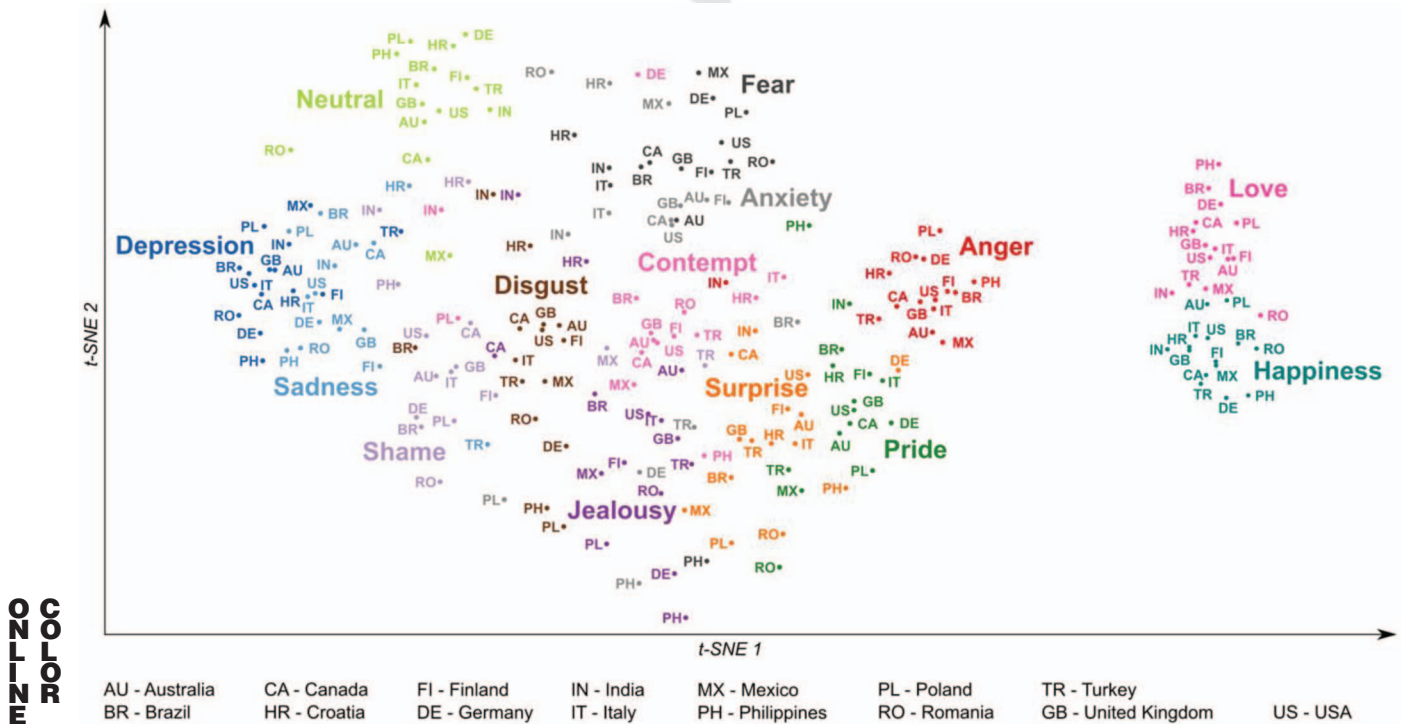


Figure 2. The *t*-distributed stochastic neighbor embedding (*t*-SNE) multidimensional scaling projection of the bodily sensation map BSM data for each emotion in 15 countries with $N > 45$. Body maps that are similar are closer in the *t*-SNE space. Color coding indicates the a priori emotional categories denoted with larger words inside the clusters. See the online article for the color version of this figure.

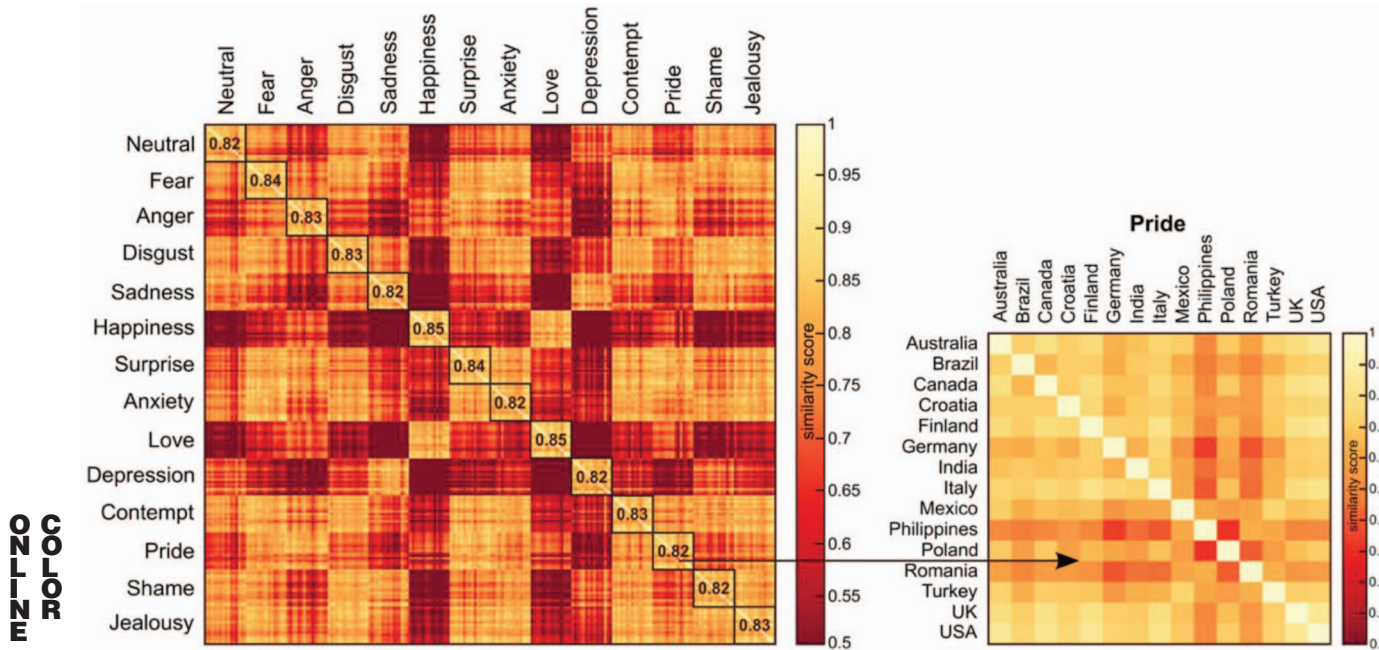


Figure 3. Similarity of effect size bodily maps for each Emotion + Country pair (across 15 countries with $N > 45$). Average similarity across countries per emotion is marked in the larger diagonal squares ($ps < 0.001$). The color scale shows similarity values (Spearman correlations). The matrix on the right illustrates the order of the countries in the full similarity matrix. See the online article for the color version of this figure.

definition by [Huntington \(1996\)](#). Remarkably, the BSMs were also invariant across sexes and various sociodemographic factors. Altogether these results provide support for the view that subjectively felt emotions strongly reflect interoceptive processes ([Damasio et al., 2000](#); [Nummenmaa et al., 2014](#)) and that emotions are experienced in the body in predominantly culture-independent, discrete fashion, lending support to the basic emotion view ([Ekman, 1992](#)). However, despite cultural and sex invariance, we found significant age-dependent reduction in the intensities of the bodily felt emotions, reflected in decreasing sensations of both bodily activation and deactivation.

Across cultures, each emotion was associated with a unique and discernible “bodily fingerprint” (see [Figure 2](#)), in agreement with those reported in previous studies ([Nummenmaa et al., 2014](#)). Despite the minor differences in BSMs across countries (see [Figure 3](#)), the examined emotions form distinctive clusters with BSMs from different countries clustering together in the a priori emotion categories. This is further supported by the correlation-based similarity analysis (see [Figure 4](#)), highlighting clear concordance ($rs > 0.82$) for BSMs of each emotion across countries. The ridge regression analysis confirmed that the emotions themselves explained most variation in the BSMs, with cultural and anthropometric variables contributing only weakly (see [Figure S2](#) in the online supplemental material). These data accord with the view that emotions have a strong biological basis and they are only modestly influenced by cultural factors ([Ekman, 1992](#); [Sauter et al., 2010](#)). This suggests that on the subjectively experienced level, universalism extends beyond the Ekman’s canonical six basic emotions to a variety of nonbasic or social emotions known to have discrete neural and expressive bases ([Cowen & Keltner, 2017](#); [Saarimäki et al., 2018](#); [Shaw et al., 2005](#)).

Previous research has found that cultural factors influence how people express and perceive emotions particularly on the face, questioning the universality of human emotions ([Jack et al., 2012](#); [Nelson & Russell, 2013](#)). However, recent investigations suggest that cultural similarity of a broad array of facial expressions (i.e., 22) is more similar than different across cultures ([Cordaro et al., 2018](#)) and that even building blocks of socially complex emotions such as pride are culturally universal ([Sznycer et al., 2017](#)). Our results reconcile these diverging lines of evidence: Although the nonverbal expressions of emotions may be malleable to cultural influences and learning-dependent plasticity, the embodied experience of emotions is universal (although, see [Russell, 1991](#)). Because facial and vocal expressions, as well as gestures, can be seen and heard by other individuals, it is understandable that they may be more strongly influenced by sociocultural experiences than the bodily states associated with emotions. The latter—such as heart and breathing rate, muscle tension, and so forth ([Kreibig, 2010](#))—go most of the time unnoticed by observers and are thus less likely to be transmitted from one individual to another. This dovetails nicely with recent findings suggesting that affective communication via body—particularly via social touching—is culturally universal ([Suvilehto et al., 2019](#); [Suvilehto, Glerean, Dunbar, Hari, & Nummenmaa, 2015](#)).

We found no clear sex differences in the bodily felt emotion, even though it has been previously suggested that men would be more internally focused with respect to their emotions. ([Pennebaker & Roberts, 1992](#)). This overall sex-invariance however seems to contrast prior work showing sex differences in nonverbal emotional expressions and in the processing of emotional signals ([Kret & De Gelder, 2012](#)). Yet, sex differences in subjectively felt emotions, as well as in autonomic nervous system responses dur-

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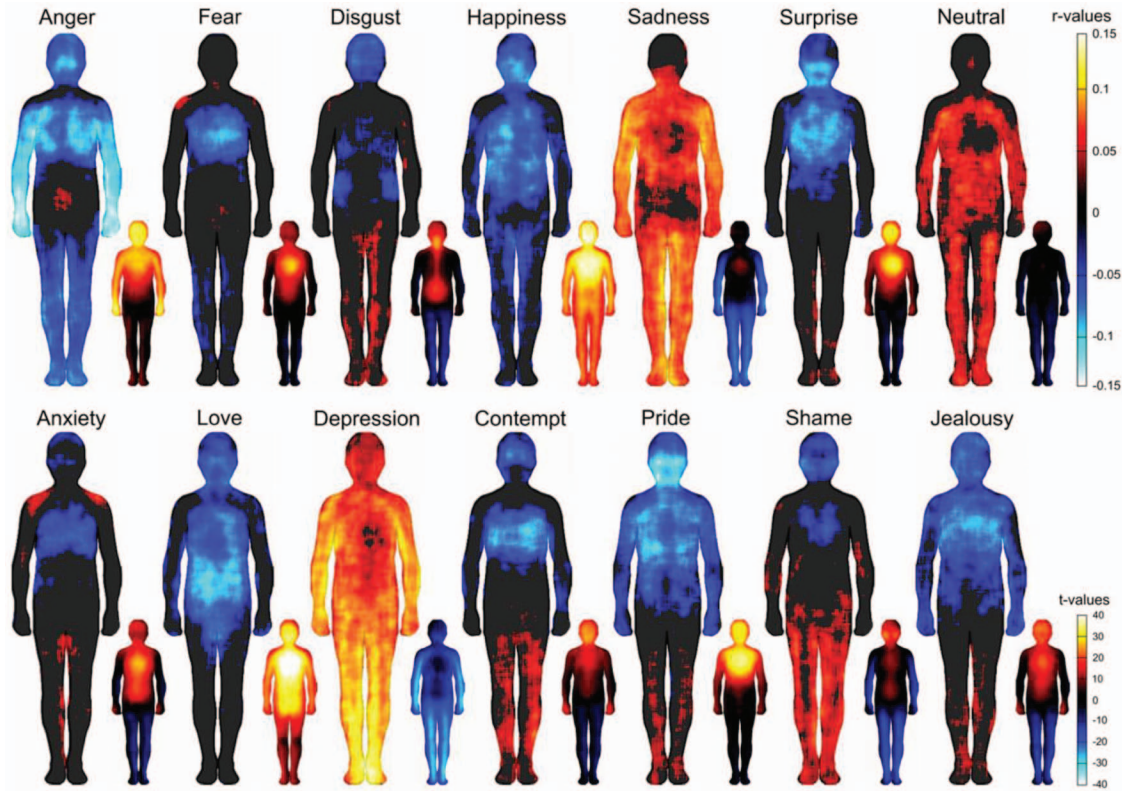


Figure 4. Age-dependent changes in bodily sensations for basic (upper row) and nonbasic (lower row) emotions. On the large bodies, hot colors indicate positive and cool colors indicate negative correlations with age ($r > 0.036$, $p < .05$, false discovery rate corrected). The small bodies show the mean bodily sensation maps for each emotion in the whole sample for the sake of reference. Note that age-dependent dampening is seen for all emotions: the emotion-related deactivations (e.g., for sadness and depression) have negative values in the mean body maps, thus their positive correlation with age reflects dampening of these sensations. The upper color bar indicates the r -statistic range for large bodies, the lower color bar indicates the t -statistic range for small bodies. See the online article for the color version of this figure.

ing emotions, are less well established. Again, our results suggest that the expressive dimension might show more experience-dependent plasticity than do the bodily felt emotions. This suggests that both sexes feel emotions in their bodies similarly, even though they might express those emotions differently. A recent review on emotional expressions in childhood and adolescence shows that the sex differences in expression of various emotions only begin to emerge through school-age and adolescence (Chaplin & Aldao, 2013). These differences are influenced by contextual factors; for example, differences between boys and girls are almost absent when the children interact with parents but become significant during interaction with unfamiliar adults or peers (Chaplin & Aldao, 2013). Thus, the sex differences in emotional expressions observed in adulthood may arise more from social learning and internalizing the sex-appropriate emotional display rules rather than from biological factors affecting the bodily feelings. If that were true, the physiology of emotions and related bodily sensations would indeed remain alike in men and women—as was observed in the present study—even when their expression patterns diverge.

Bodily sensations waned with aging for all emotions. Alongside with our previous developmental work, showing that bodily feel-

ings of emotions becoming more and more discrete from childhood toward early adulthood (Hietanen et al., 2015), these data reveal a dynamic developmental time course of emotional bodily feelings: After becoming discrete toward adulthood, these sensations slowly weaken toward the old age. Our data cannot provide a direct causal explanation for this effect, but multiple feasible possibilities exist. Basal metabolism and various physiological processes slow down during aging (Schofield, 1985) and increased age is also coupled with decreased reactivity of the limbic system, increased activity of prefrontal cortex, slower cardiovascular response, and prolonged neuroendocrine response. These age-dependent physiological changes could explain our finding of the dampened bodily sensations of emotions during aging, and altogether these data could explain why subjective and physiological responses to emotional stimuli become decoupled during aging (Scheibe & Carstensen, 2010). Furthermore, our data could also explain why older people are in general better in emotion regulation (Urry & Gross, 2010): Because of weakened interoceptive awareness, they may become less connected to the bodily components of emotions, and this shift of emotions toward “cognitive” as opposed to embodied processes might make the emotions easier to regulate. Altogether these alterations might explain why aging is

generally associated with increased life satisfaction and emotional well-being.

How Universal Are the Bodily Maps of Emotions?

Focus on null hypothesis testing is an inherent problem in cross-cultural research. As long as scientists are looking for differences between cultures, the null hypothesis easily becomes “no differences between cultures,” which is impossible to prove using Fisherian statistics. This is particularly problematic, as cross-cultural research requires large samples, where trivially small differences may become statistically significant, even though the corresponding variables would not meaningfully increase the predictive accuracy of the model. This may bias scientists toward seeing small differences across cultures even when consistencies would dominate (see, e.g., Hanel, Maio, & Manstead, 2019). In cross-cultural studies, it is thus better to focus on (1) quantifying the de facto degree of similarity across cultures and (2) testing whether there is evidence for cross-cultural consistency based on some predefined criterion favoring universality, rather than testing if there is just any potentially trivial cultural variation. Unfortunately, there is no clear definition of how large “meaningful” cultural similarity in psychological studies should be. From practical viewpoint we can contemplate the presently observed ES for cross-cultural consistency ($r = .82$) against ES with practical significance. For example, mean typical ES for common medications considered effective in the general population (levodopa treatment for Parkinson’s disease, antipsychotics for schizophrenia, or antidepressants for major depressive disorder and so forth) are typically well below $r = .40$ (Leucht, Helfer, Gartlehner, & Davis, 2015). This is less than half than that of the ES for the consistency of bodily maps across cultures. Against such baseline, we would argue that the present data clearly favor universalism at least in the tested populations.

A second common problem in cross-cultural work pertains to the sampling of the high-dimensional cultural space separated by national and geographic boundaries. We note that the present data did not cover all the world’s cultures (defined as nations). For example, the sample lacked a sufficient number of East Asian and African respondents, which limits the generalizability of the findings to these populations. These cultures need to be sampled in detail in future studies. Although we have previously demonstrated that West European and East Asian BSMs are concordant (Nummenmaa et al., 2014), it is possible that in some (e.g., African) cultures tested in the future, the bodily maps would somehow differ from what was observed in the present sample. But how should such a potential discrepancy be interpreted if it was observed? One approach would be to consider this as proof by contradiction and take it as evidence against the universality of the bodily maps. This might be applicable if *psychology universality* meant strictly that a phenomenon is observed in exactly the same fashion in all individuals and in all cultures. Yet, our view of psychological universality refers to the degree of consistency of psychological phenomena across cultures, rather than naïve all-or-nothing conceptualization. Accordingly, the question is not whether the bodily maps of emotions are different in some culture, but instead how similar they are across the world’s population. In line with this reasoning, the question of cultural universality should not be treated as a yes-or-no phenomenon, but a continuum

of cultural influences on the human nature, ranging from universal homeostatic and defensive responses to flexible and malleable social processes. This obviously calls for Bayesian reasoning in these types of studies, where the accumulation of evidence favoring different cultural universals versus discrepancies could be quantified.

Our data were based on self-reports. Even though humans are capable of sensing changes in their bodily states, interoceptive accuracy is far from perfect (Critchley, Wiens, Rotshtein, Ohman, & Dolan, 2004) and bodily changes are not strongly coupled with subjective feelings of emotions (Mauss et al., 2005; Nummenmaa & Saarikmaki, 2017). Thus, the present data do not reflect a detailed description of emotion-specific physiological changes but only the net consciously felt changes occurring in the body during emotions, thus the BSMs are subjective feeling maps. The Internet-based data acquisition was relatively uncontrolled and might have led to response bias due to uneven access to Internet across the targeted populations, attrition, and selection bias (e.g., the sample was biased toward women and highly educated participants). However this approach has been used successfully previously in mapping various interoceptive and somatosensory processes (Suvilehto et al., 2015) and the presently observed mean BSMs accord well with previous reports (Hietanen et al., 2015; Nummenmaa et al., 2014). Countries of residence were assessed based on the IP address; however, sampling in a subset of the data showed that IP address and self-reported nationality match on average on 85% of the cases. The task was presented in English to all participants, which could potentially bias the results toward English-speaking immigrants in each country. Yet, using single language in the task circumvented confounds arising from translation. All in all, these are unlikely severe confounds, given that the overall bodily topographies of emotions match closely with those reported earlier and that any effects of culture on the body maps were minimal to begin with.

Conclusions

Emotions are associated with unique and discernible “bodily fingerprints” which are to large extent culturally universal. The intensity of these fingerprints however diminished during aging. In turn, sex, anthropometric and sociodemographic variables affected the BSMs only weakly. These data support the view that emotions have a strong biological basis and that they are only modestly influenced by cultural factors. The results also suggest that, at bodily level, the universalism extends beyond the canonical basic emotions. Even though we found minor differences between Western and Non-Western groups, as well as between men and women, these effects were small in comparison with the typical intercultural consistency of the BSMs. We conclude that although the nonverbal expressions of emotions may be malleable to cultural influences, the embodied experience of emotions is likely more universal, because it cannot be directly observed and copied from others and likely reflects underlying physiological changes and interoceptive awareness.

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