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**A commentary: The sun is no fun without rain: Reply to “The sun and how do we feel
about the color yellow? Methodological concerns”**

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Studying the link between colour and emotion, or colour and affect more widely, attracts interest and criticism from two major study domains that naturally speak little to each other, namely vision science and linguistics. In both domains, researchers represent their respective study domain frequently expressing strong opinions about the importance, if not sole importance, of their research fields and methodologies. Cognitive psychologists working on the affective meaning of colour will touch upon both domains; or rather find themselves right in-between. Thus, we are not surprised by the current comments, welcoming the interest and criticisms. We consider the commentary a valuable opportunity to communicate differences and highlight opportunities for inter-disciplinary attempts to answer shared questions using different methodologies.

In our study (Jonauskaite, Abdel-Khalek, et al., 2019), we replicated that yellow and joy are associated. Yellow-joy associations were previously detected with a variety of methods (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). We further reported that this association varied as a function of climatological factors in 55 countries. Participants living in countries farther away from the equator and/or with higher annual precipitation levels associated yellow with joy to a greater extent. We concluded that environmental experiences contribute to the affective meaning of colour. Here, we reply to the two concerns raised by Azer in his commentary (Azer, 2019), i) the variability in sample sizes and ii) the importance of colour metaphors.

Sample size

The author highlighted that our sample sizes varied substantially (i.e., from 20 Zimbabwean to 499 Greek participants). The question is whether this variability is a hazard to our conclusions. Our data come from an ongoing survey (Mohr, Jonauskaite, Dan-Glauser, Uusküla, & Dael, 2018). Thus, whatever the study question, sample sizes will differ between countries (e.g., (Jonauskaite, Wicker,

et al., 2019). In the actual study, we included as many countries as possible in order to have a large spread in our predictor variables, which were fixed per country. Based on a previous recommendation, we included a country if it had at least 20 participants (Simmons, Nelson, & Simonsohn, 2011) and accounted for uneven population sizes using the hierarchical cumulative link mixed model (Christensen, 2018). Alternatively, we could have included fewer countries of larger sample sizes, or randomly chosen 20 participants from each of the 55 countries. Both options would lead to lower accuracy due to a reduced number of participants.

To test if certain countries or participants were determinant for our results, we supplemented our original analyses with bootstrapping (Efron, 1979). Bootstrapping provides information about the reliability of our predictive model by simulating what the model could have been if a different subsample of countries or participants had been studied. We created an algorithm that randomly resampled the original data 10'000 times in a two-step procedure. The two-step procedure simulated our recruitment strategy. We first drew 55 countries with replacement, and then we drew 6625 participants with replacement. To each new resampled dataset, we fitted the model that best explained our data (Jonauskaite, Abdel-Khalek, et al., 2019, pages 4-5, Block 3). This bootstrapping estimated the distribution of the coefficients for each predictor variable and their respective 95% confidence intervals (*95%CI*). The *95%CI* for absolute latitude was [0.012, 0.042] and for precipitation was [0.033, 1.020]. Since the confidence intervals do not include 0, these variables significantly predict the yellow-joy associations. The *95%CI* for sunshine was [-0.031, 0.015] and includes 0. Therefore, sunshine is not a significant predictor of yellow-joy associations. Overall, the same predictors were significant in bootstrapping and in our study.

Colour metaphors

The author also highlighted a lack of culture-specific explanations referring to colour metaphors. True, many languages have metaphors involving colour terms. Thus, we are not surprised to learn

about two Egyptian metaphors – *yellow as a lemon* and *yellow-eyed*, which have negative connotations. The justified question is whether such metaphors would explain our findings that yellow is less joyful in some countries (e.g. Egypt) than others.

In our article, we described how climatological factors predicted yellow-joy associations. The mechanisms through which climatological factors impact these cognitive associations are unknown. The causality question was outside the scope of our study. In the discussion, we suggested that “yellow-joy associations [could] 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)” (page 5). Colour metaphors could be another mechanism linking climatological experiences with colour-emotion associations. The author mentioned two Egyptian examples and claimed that “these idiomatic expressions are unique to the Egyptian culture”. While we can follow the overall argument, we do not agree that such metaphorical connotations of yellow are unique to the Egyptian language. We are aware of metaphors that include the term yellow and carry negative connotations such as *yellow-bellied* (to be cowardly) in English, *Gelb vor Neid sein* (to be envious) in German, or *rire jaune* (to laugh out of embarrassment) in French. In English, there seem to be no positive metaphors with yellow (Allan, 2009). Despite these negative metaphorical connotations, 55-75% of English, French and German speakers associated yellow with joy. Participants from any country, including Egypt, did not associate yellow with negative emotions (see Table S9 in Jonauskaite, Abdel-Khalek, et al., 2019). Therefore, speakers of different languages may possess negatively charged colour metaphors and still endorse positive emotion associations with respective colours.

To definitively understand the role of colour metaphors in yellow-joy associations, we would have needed to systematically analyse colour metaphors in 40 languages and 55 countries. Nonetheless, understanding the explanatory power of colour metaphors for colour-emotion associations is an

important future direction (e.g., see Barchard, Grob, & Roe, 2017). We provide our data for further use (<https://forsbase.unil.ch/project/study-public-overview/15126/1672/>) and hope that researchers from different backgrounds would take up the task to further explain inter-individual and inter-national variance(s) using other methodologies.

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