LETTER

REPLY TO NASH:
Color terms are lost, despite missing data

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David Nash (1) calls into question our findings (2) that color terms are likely lost as well as gained, citing questions about the semantics of certain lexical items, treatment of unattested items, and, crucially, problems with missing (vs. absent) data in Bayesian phylogenetic models.

For ancestral state reconstructions to be correct, several conditions must be satisfied: Sample data must be representative and accurate, the analytical tools should be applicable to the dataset under study, and the analyses must be interpreted correctly. In the case of archival data, there will always be questions of interpretation. We preferred not to introduce a distinction between "missing" and "absent" color terms simply because, in many cases, the judgment would either be arbitrary or would presuppose the very hypotheses under test.

The absence-of-evidence vs. evidence-of-absence issue is a problem for all historical linguistics, for the more general study of cultural evolution, and, indeed, for all studies that rely on recorded observations rather than characters that are measured explicitly. This problem is not specific to our analysis, but the solution is not to introduce arbitrary coding biases.

To assess the impact of our coding decisions, as well as the impact of terms which were missing from Chirila and hence recorded as absent, we reran all analyses with five alternative datasets. (*i*) We corrected errors resulting from data missing from Chirila (3) and (*ii*) applied Nash's alternative judgments about color term presence/absence. The remaining conditions involved missing data: (*iii*) Twenty percent of absent codes were randomly replaced with "missing" codes, (*iv*) 0 codes were replaced with "missing" if they were either incompatible with Berlin and Kay's (4) color term stages or were in a poorly attested language (where a 0 could be due to gaps in documentation), and (*v*) 90% of 0 values were replaced by ambiguous states.

In all cases, our original conclusions from ref. 2 strongly hold; Bayes factors decisively support models which include both gain and loss parameters (Table 1). Color gain predominates, but gain-only models do not capture the dynamics of the data as well as models which also allow loss. Color terms are like other areas of language: subject to change, but constrained (strongly, in this case, but not absolutely) by human perceptual and physiological systems.

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Table 1. Model comparison

Dataset	Unrestricted	Gain only	Bayes factor	Rate q01	Rate q10
i	−584.629	−682.295	−195.332	0.877	0.258
ii	−540.606	−586.339	−91.466	0.895	0.155
iii	−591.194	−704.63	−226.872	1.059	0.324
iv	−387.536	−412.658	−50.244	1.147	$9.054E^{-2}$
v	−167.797	−174.002	−12.41	2.305	$5.739E^{-2}$

For each dataset we compare models where color gain/loss are unrestricted to one where rates are restricted to allow only gains. We give harmonic mean log likelihoods for unrestricted and gain-only models and calculate the Bayes factor support. We also give the mean transition rate estimations for the unrestricted model.

1 Nash D (2017) Loss of color terms not demonstrated. *Proc Natl Acad Sci USA* 114:E8131.

2 Haynie HJ, Bowern C (2016) Phylogenetic approach to the evolution of color term systems. *Proc Natl Acad Sci USA* 113:13666–13671.

3 Bowern C (2016) Chirila: Contemporary and historical resources for the indigenous languages of Australia. *Lang Doc Conserv* 10:1–44. Available at scholarspace.manoa.hawaii.edu/handle/10125/24685. Accessed July 11, 2016.

4 Berlin B, Kay P (1969) *Basic Colour Terms: Their Universality and Evolution* (Univ of California Press, Berkeley, CA).