Perceptual Similarity and the Relationship Between Folk and Scientific Bird Classification

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Abstract

People from every culture observe the natural world in detail and organise it into categories, and Western biology builds on this universal impulse towards classification. Here we provide a quantitative analysis of factors that shape folk and scientific classification of birds from areas associated with three indigenous languages (Anindilyakwa, Tlingit, and Zapotec). We find that traditional Linnaean taxonomies align better with folk categories than do modern phylogenetic classifications, which suggests that human perception is responsible in part for the correspondence between Linnaean and folk taxonomies. Perceptual similarity is difficult to measure at scale, but we use the recently released AVONET database to develop a proxy for the perceptual similarity between pairs of birds and find that traditional Linnaean taxonomies and perceptual similarity both independently predict folk categories. Our results therefore provide quantitative evidence for the view that perceptual similarity influences both scientific and folk classification.

Keywords: categorisation; ethnobiology; TEK (traditional ecological knowledge); cognitive anthropology; bird naming

Introduction

Scientific concepts in many domains are very different from folk concepts. Some (e.g. “quark” and “RNA”) simply have no folk counterparts, while others (e.g. “heat” (Wiser & Carey, 1983) and “momentum” (McCloskey, 1983)) overlap only partially with folk concepts. Anthropologists, however, have documented striking resemblances between folk and scientific classification of living kinds (Yoon, 2009). For example, Diamond (1965) observed a nearly perfect correspondence between lower-level categories in the vertebrate classification system of the Fore people of New Guinea and species in scientific taxonomy.

Two general accounts of the correspondence between folk-biological classification and scientific classification can be distinguished. The *world-centred* view focuses on the environment and proposes that scientific classification resembles folk classification because both reflect the objective structure of the environment. The *human-centered* view focuses on the human observer and proposes that folk and scientific systems are similar because both were created by humans and reflect aspects of human perception. The two views have been extensively discussed by scholars including Malt (1995), who provides a comprehensive review of relevant findings from both psychology and anthropology. Here we present a computational analysis that introduces new data sets to the literature on folk classification and contributes new evidence in favour of the human-centered view.

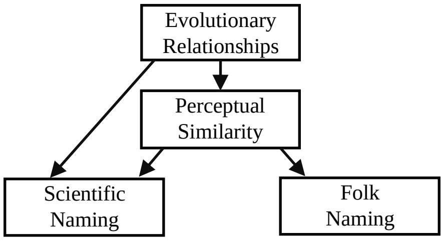

Figure 1: Factors influencing folk and scientific classification.

Our theoretical framework is summarised by Figure 1. Folk and scientific classification lie at the bottom of the diagram and are influenced by two factors. The first is the set of historical evolutionary relationships that provide the ultimate explanation for why animals and plants appear as they do. These evolutionary relationships can be viewed as the best current scientific account of the objective structure of the world. The second factor captures the similarities between living things that are perceivable by humans, bounded by the limits of their perceptual apparatus (Yoon, 2009). Some aspects of perceptual similarity reflect evolutionary relationships (emus and cassowaries are similar because of common descent) but others do not (buttonquails and quails appear similar but are not closely related). Folk classification is also influenced by the cultural and practical significance of organisms and the utility of having labels for them (Hunn, 1982), but we focus here on the variables in Figure 1.

We use the framework in Figure 1 to explore bird naming systems from three indigenous languages, and our work is organised around two core research questions. First, we ask how well different scientific systems account for folk classification. Figure 1 shows “scientific naming” as a single node, but in reality there are two prominent approaches to scientific classification. Traditional classification stems from the work of Linnaeus and uses morphological and behavioural traits to organise living things into hierarchies with ranks such as orders, families, genera, and species. Phylogenetic classification adds methods such as DNA sequencing that provide a more direct characterisation of evolutionary relationships and organises living things into hierarchies without strictly defined ranks. Of the two scientific approaches, we hypothesised that traditional classification would provide the better account of folk classification, because some phylogenetic groupings are dramatically different from folk categories. For example, modern phylogenetics suggests that any category of “reptile”

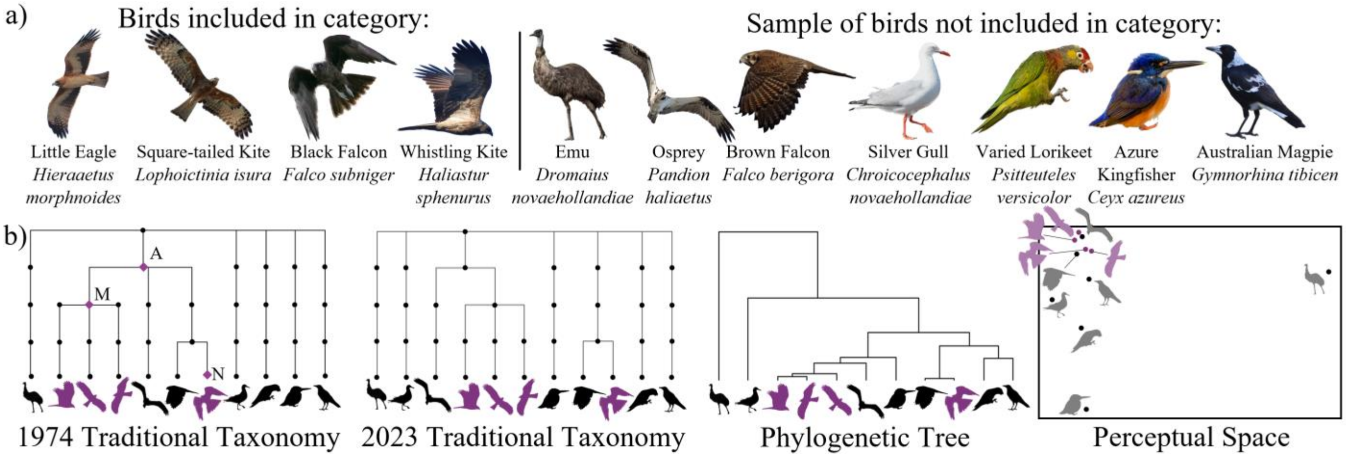

Figure 2: Tree-structured and spatial representations of the Anindilyakwa folk taxon *yukwurrijija/yiburrilya*. (a) Waddy records *yukwurrijija* and *yiburrilya* as alternative names for the folk category that includes four raptor species shown on the left. (b) Traditional taxonomies (Clements 1974 and Clements 2023), a phylogenetic tree, and a spatial representation of perceptual distance. All trees are subsets of the full trees that include only the species shown in (a). The top nodes in the traditional taxonomies correspond to the class Aves and the remaining nodes (from top to bottom) show families, orders, genera, and species. The perceptual space was constructed by applying multidimensional scaling to distances based on AVONET features. Images used with permission from the Cornell Lab of Ornithology/Macaulay Library.

that includes both lizards and crocodiles should also include birds. Our hypothesis needs to be tested, however, because there are competing cases in which folk categories are more consistent with phylogenetic systems than with traditional systems. For example, the Iban people of Borneo have long distinguished between two kinds of Marang trees, but Western science made no such distinction until a recent genetic study was carried out (Gardner et al., 2022).

As expected, we find that folk systems are better predicted by traditional systems than by phylogenetic systems, even though phylogenetic systems come closer to the underlying generative structure of the world. This result highlights the importance of the “perceptual similarity” node in Figure 1, and our second research question asks how well perceptual similarity accounts for folk classification. We build on the perceptual model of Hunn (1976), which proposes that organisms are grouped into folk categories based on their proximity in a perceptual space. Hunn's model therefore departs from most other contributions to the literature on folk biology, which emphasise hierarchical tree structures rather than spatial representations. Although theoretically intriguing, Hunn's model has been difficult to test in the absence of an independent measure of perceptual similarity. Here we draw on the recently released AVONET data set (Tobias et al, 2022), which specifies morphological variables (e.g. mass and beak length) for all extant species of birds, and take proximity in this morphological space as a proxy for perceptual similarity. We use this measure to show that perceptual similarity contributes predictive information about folk categories that goes beyond the information contained in scientific classification systems (traditional or phylogenetic).

We begin in the next section by introducing the data sets that we consider, and then present two kinds of computational analyses. The first set of analyses directly compares folk taxonomies with traditional scientific taxonomies. The second set of analyses uses a regression framework to explore how well different factors predict whether two birds are given the same folk label. We conclude by discussing implications of our results for the factors that shape folk and scientific categories.

Data

Bird Naming Data

Our analyses focused on three unrelated languages for which the names of birds had been comprehensively documented: Anindilyakwa from Groote Eylandt, Australia (Waddy, 1988), Tlingit from South-East Alaska (Hunn & Thornton, 2010), and Zapotec from Oaxaca, Mexico (Hunn, 2008). Each dataset was compiled by Western anthropologists working with native speakers, and the names in these datasets pick out natural categories formed over thousands of years by speakers of the languages. The taxonomies include categories at different ranks, and our analyses focus on folk generic categories, which correspond to such categories as “pigeon” and “duck” in English. Folk generic categories are the smallest categories into which organisms can be placed without close examination and are typically considered the most salient categories in folk taxonomies (Berlin, 1992). When people are asked to name an organism, their first response is typically a folk generic label. One Anindilyakwa category is “*yukwurrijija*” (Figure 2), which includes two local species of kite, the little eagle, and the black falcon (but not the brown falcon).

Traditional Taxonomies

Several traditional avian taxonomies have been developed and we used the Clements checklist, a mainstream taxonomy described as "less contentious" than the alternatives because of its agreement with other taxonomies and its conservatism in including disputed species (Tomer, 2019). The Clements checklist has changed over time, and we used both the first (Clements, 1974) and current versions (Clements et al., 2023) of the taxonomy. Comparing these editions is valuable because the 2023 version is influenced by modern phylogenetic methods, but the 1974 version is based primarily on observable morphological and behavioural differences between birds. Of the two versions, we expected that the 1974 version would align more closely with folk classification.

Each version of the checklist provides the species, genus, family, and order of each member of Class Aves. We used Avibase (https://avibase.bsc-eoc.org/) to assist with aligning the 1974 names of the birds with their names in the 2023 taxonomy. Our analyses considered only species represented in the bird naming data, and we created different subsets of the traditional taxonomies for each of the three languages. Figure 2 includes examples of the 1974 and 2023 taxonomies based on species named in Anindilyakwa.

Phylogenies

Phylogenetic trees for the species in the three naming data sets were derived from BirdTree, a large-scale analysis of evolutionary relationships between birds (Jetz et al., 2012; Jetz et al., 2014). BirdTree provides samples from a posterior distribution over phylogenies, and we worked with a sample including 250 trees. A consensus tree based on samples for the Anindilyakwa species is shown in Figure 2.

Perceptual Similarity

Perceptual spaces for the three languages were constructed using all eleven morphological traits included in AVONET (Tobias et al., 2022). These traits include body mass, measures of beak length, width and depth, leg length, three measures of flight feathers on the wing, tail length, and hand-wing index. Other morphological traits such as colour are important for folk classification but not included in AVONET, which includes only traits that can be reliably measured for both museum and living specimens. AVONET also includes several categorical variables related to bird behaviour, including dietary information and predominant foraging mode (e.g. aquatic, aerial, or terrestrial), but we did not include these variables in our analyses. We log-transformed all positively skewed measurements, then took the resulting 11-dimensional space as a proxy for perceptual space. Figure 2b shows a low-dimensional projection of the 11-dimensional space for the Anindilyakwa species.

The individual dimensions of our perceptual space are likely to align poorly with many of the dimensions people consider when assessing similarities between birds. Our working hypothesis, however, is that proximity in the AVONET-derived space is a reliable guide to perceptual similarity. Previous scholars suggest that biological species correspond to bundles of correlated features (Rosch, 1978; Boyd, 1999), and this correlational structure suggests that two observers can attend to different subsets of features but arrive at near-identical judgments about the overall perceptual similarity between pairs of organisms.

Analysis 1: Correspondence Between Folk and Traditional Taxonomies

Our first analysis aimed to quantify the correspondence between folk and traditional taxonomies, and to test the hypothesis that folk names are better captured by the 1974 taxonomy than the 2023 taxonomy. Several methods have been proposed for comparing folk and traditional taxonomies (Holman, 1992; Malt, 1995), and we followed the approach of Hunn (1977), which computes a dissimilarity for each folk category with respect to a traditional scientific taxonomy. Categories that map perfectly on to a node in the traditional taxonomy are assigned a dissimilarity of zero, and dissimilarities above zero indicate departures from the taxonomy of increasing severity.

To compute the dissimilarity of "yukwurrijija" with respect to the 1974 taxonomy, the first step is to mark all nodes that include only examples of "yukwurrijija" as descendants. If there is only one such node, the category receives a dissimilarity score of zero. In Figure 2 there are two such nodes, marked M and N. If there are multiple marked nodes, we identify the most recent common ancestor A of these nodes, and the dissimilarity of "yukwurrijija" is defined as the maximum number of steps required to reach A from any of the marked nodes. In Figure 3 node A is one step away from M and three steps away from N, so the dissimilarity of "yukwurrijija" is 3.[1] For the 2023 taxonomy, there is no single order that includes all species named "yukwurrijija," and the dissimilarity assigned to this category is 4. Hunn's method therefore reflects the intuition that "yukwurrijija" is better captured by the 1974 than the 2023 taxonomy.

Results

Results of the correspondence analysis for all three languages are shown in Table 1. *n* is the number of folk generic categories included in the analyses, and n_0 indicates the number of categories that match the scientific taxonomy perfectly and have a dissimilarity of zero. For each of the three languages, at least 70% of the folk categories are perfectly captured by the scientific taxonomies, which supports previous claims of a high level of correspondence between folk and scientific classification.

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[1] Our description of Hunn's method omits some important details, including how the taxonomy is reduced by removing nodes with a single child, and how dissimilarity is defined for folk categories that divide (or "overdifferentiate") a single species. A complete specification of the method is provided by Hunn (1974).

Table 1: Comparison between folk taxonomies and 1974 and 2023 Clements taxonomies. n is the number of folk categories, n_0 is the number that match the scientific taxonomy perfectly, D is the average dissimilarity, and *Improved* is the number of categories that match one taxonomy better than the other.

	Language					
	Anindilyakwa		Tlingit		Zapotec	
Taxonomy	74	23	74	23	74	23
n	77	77	86	86	68	68
n_0	55	55	76	74	51	52
D	.58	.60	.16	.20	.41	.40
Improved	5	4	3	0	1	2

D is the "weighted coefficient of dissimilarity" (Hunn, 1976), which is defined as the average dissimilarity (lower is better) across all folk categories for a language. Table 1 shows that Anindilyakwa and Tlingit categories are better captured by the 1974 than the 2023 taxonomy, but that Zapotec categories are better captured by the 2023 taxonomy. These differences, however, reflect a handful of categories only. The final row in Table 1 shows, for example, that 5 Anindilyakwa categories are better captured by the 1974 taxonomy, 4 are better captured by the 2023 taxonomy, and the remaining 68 are equally well captured by both taxonomies. The differences in correspondence scores across the 1974 and 2023 taxonomies are therefore not statistically robust, and bootstrapped confidence intervals on D are broad and heavily overlapping for the two taxonomies.[2]

Hunn's correspondence measure is a useful starting point but cannot address all of our research questions. As defined, the measure cannot be used to compute the correspondence between folk taxonomies and phylogenetic trees, and it is unclear how to extend the measure so that folk categories can be compared with both traditional and phylogenetic trees on equal terms. An even more fundamental limitation is that the measure considers tree structures only and cannot be used to compute the correspondence between folk categories and our spatial measure of perceptual distance. We therefore turned to regression analyses in order to compare traditional taxonomies, phylogenetic trees, and perceptual distances as predictors of folk classification.

Analysis 2: Scientific And Perceptual Similarity as Predictors of Naming

Given a set of folk categories that apply to a set of species, we assign a binary variable to each pair of species that indicates whether the species in each pair are given the same category label. In Figure 2a, Brown Falcon and Whistling Kite share a name (*yukwurrijija*), but Brown and Black Falcon do not. We take this *shared_name* variable as the dependent variable for our regression analyses, and consider predictors based on traditional, phylogenetic, and perceptual distance. All predictors were scaled to have zero mean and unit variance.

Table 2: Correlations between all four distance measures.

		23	Phy	Per
74	Anindilyakwa	.96	.77	.33
	Tlingit	.99	.85	.29
	Zapotec	.98	.86	.52
23	Anindilyakwa		.79	.32
	Tlingit		.85	.28
	Zapotec		.86	.52
Phy	Anindilyakwa			.26
	Tlingit			.21
	Zapotec			.49

Predictors

Traditional distance was calculated by counting the steps up a traditional taxonomic tree before a pair of birds shared a taxon. For example, the Black Falcon's (*Falco subniger*) taxonomic distance from the Brown Falcon (*F. berigora*) is 1, as they share the same genus, and its distance from the Azure Kingfisher (*Ceyx azureus*) is 4, as the first taxon they share is Class Aves.

Phylogenetic distance was based on the sample of phylogenies downloaded from BirdTree. Given a single tree, phylogenetic distance between a pair of species is defined as the cophenetic distance, or the height of the phylogenetic tree where the branches connecting two species meet. We created a distance matrix for each tree then averaged these matrices across the sample of phylogenies to create a single measure of phylogenetic distance.

Finally, perceptual distance was defined as the Euclidean distance between points in the 11-dimensional perceptual space derived from AVONET.

Results

Table 2 shows correlation coefficients for all pairs of variables. As expected, the 1974 and 2023 taxonomic distances show extremely strong correlations, and we therefore included only one of these measures in some of our subsequent analyses. 1974 distance also shows relatively high correlations with phylogenetic distance, but both 1974 distance and phylogenetic distance show relatively weak correlations with perceptual distance. Our predictors therefore allow us to ask whether perceptual similarity captures information about naming that goes beyond the information captured by 1974 and phylogenetic distance. Figure 3 shows separate distance distributions for bird pairs that share and do not share a name. As expected, across all languages and predictors, distances between birds with the

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[2] 95% confidence intervals on D based on 10,000 bootstrap samples are [0.36,0.82] (Anindilyakwa, 1974), [0.38, 0.84] (Anindilyakwa, 2023), [0.07, 0.28] (Tlingit, 1974), [0.09, 0.33] (Tlingit, 2023), [0.24, 0.62] (Zapotec, 1974), and [0.22, 0.60] (Zapotec, 1974).

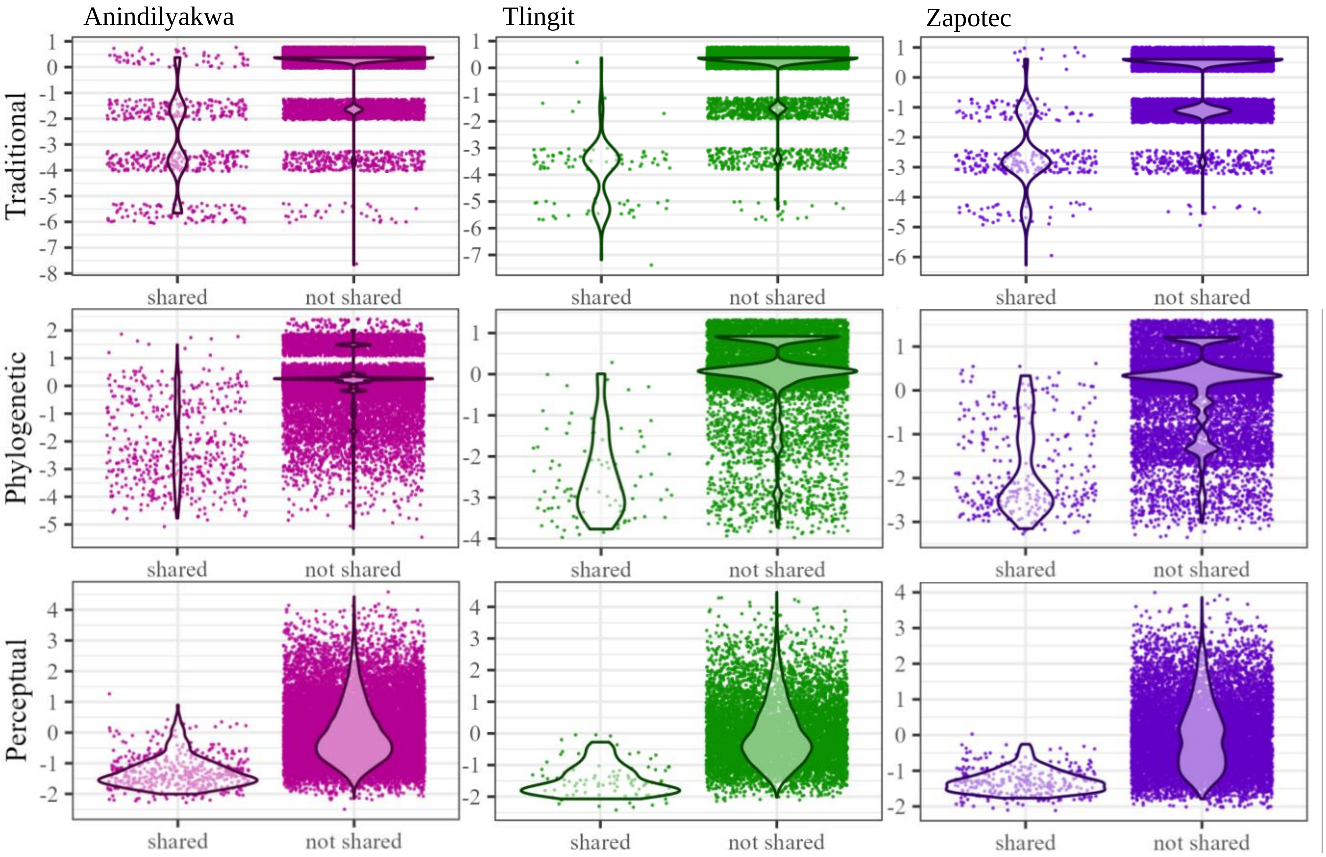

Figure 3: Distribution of each distance variable for pairs of birds that do and do not share names in each language. Each data point represents a pair of birds. All variables are scaled to have a mean of 0 and a standard deviation of 1.

same name tend to be smaller than distances between birds with different names.

Table 3 shows results for logistic regression models with name sharing as the outcome variable and traditional, phylogenetic, and perceptual distance as predictors. The table includes regression weights along with Bayesian Information Criterion (BIC) scores for each model considered. Among all four models with a single predictor, the best-performing model uses 1974 traditional distance. Of the three scientific distance measures, 1974 distance reflects the generative structure of the world less accurately than do 2023 distance and phylogenetic distance. Our results therefore suggest that scientific progress over the last 50 years has reduced the correspondence between folk and scientific classification.

The finding that 1974 distance is superior to 2023 distance is consistent with our results based on Hunn's correspondence measure (Table 1). The difference in BIC scores for the 1974 and 2023 models exceeds 10 for all three languages, which suggests that there is strong evidence in favour of the 1974 model in all three cases. We therefore dropped 2023 distance and used 1974 distance as a single measure of traditional distance for all remaining analyses in Table 3.

Before considering models with two and three predictors, we computed Variance Inflation Factors (VIFs) to identify cases where coefficients may be unreliable because of multicollinearity. The largest VIF was 2.8, which is smaller than thresholds commonly used (3, 4, 5 and 10) to identify problematic cases, and suggests that our regression models can be interpreted without allowing for inflation.

Although 1974 distance is the best single predictor, Table 3 suggests that perceptual distance captures information about naming that goes beyond 1974 distance alone. The best models overall for Anindilyakwa and Zapotec (shown in bold) include both 1974 and perceptual distances, and the best model for Tlingit includes 1974, perceptual and phylogenetic distances. For all three languages, adding perceptual distance to the model that includes 1974 distance alone produces a BIC improvement of at least 45, indicating strong evidence in favour of the two-predictor model.

The contribution of perceptual distance reflects cases in which two birds with the same name are separated by a relatively large 1974 distance but are relatively close in perceptual space. One example involves the Little Eagle (*Hieraaetus morphnoides*) and Whistling Kite (*Haliastur sphenurus*) in Figure 1. The two belong to different families in the 1974 taxonomy but are relatively close in perceptual space. The model with 1974 distance alone gives a probability of 0.39 that the two belong to the same category, but this probability increases to 0.66 when perceptual similarity is added as a predictor.

Table 3: Results of logistic regressions with name-sharing as the outcome variable.

Model	Variable	Statistic	Language		
			Anindilyakwa	Tlingit	Zapotec
		n	190	130	152
Null Model					
Null		BIC	4426.62	986.12	2852.82
Single Predictor Models					
74		BIC	*2678.15*	*484.76*	*1593.10*
	74	β	-1.14	-1.47	-1.72
23		BIC	2773.97	527.59	1603.80
	23	β	-1.11	-1.39	-1.71
Phy		BIC	3084.74	685.86	2059.60
	Phy	β	-1.22	-1.35	-1.46
Per		BIC	2983.89	608.88	1938.32
	Per	β	-3.54	-4.56	-3.87
Two Predictor Models					
74+Phy		BIC	2682.7	485.19	1597.66
	74	β	-1.04	-1.76	-1.9
	Phy	β	-0.16	0.50	0.24
74+Per		BIC	***2395.69***	*438.55*	***1478.16***
	74	β	-0.82	-1.09	-1.36
	Per	β	-1.83	-2.13	-1.94
Per+Phy		BIC	2593.26	548.54	1770.77
	Per	β	-2.28	-3.22	-2.76
	Phy	β	-0.77	-0.72	-0.86
Full Model					
74+Phy+Per		BIC	2405.13	***431.41***	1470.91
	74	β	-0.79	-1.49	-1.66
	Per	β	-1.83	-2.34	-2.07
	Phy	β	-0.04	0.70	0.46

Discussion

We compared three different scientific classifications as predictors of folk classification and found that a traditional taxonomy published in 1974 accounted better for folk categories than both the 2023 version of the same taxonomy and a modern phylogenetic tree. Our results are broadly consistent with previous evidence of a high degree of correspondence between folk and scientific classification but suggest that this correspondence has declined over time as the basis for scientific classification has shifted towards genetic features and away from morphological features.

The world-centred view of classification emphasises ways in which categories are constrained by the objective structure of the world, and the human-centred view emphasises ways in which categories reflect the human mind. The correspondence between scientific and folk classification is often taken to support the world-centred view, but our results seem better explained by the human-centered view. One reason why traditional taxonomic categories often correspond with folk categories is that Linnaeus (and other Western scientists) relied on the same perceptual apparatus used by people all around the world. The human-centered view therefore explains not only the initial correspondence between scientific and folk classification, but also why this correspondence has declined as scientists have placed greater emphasis on features that are imperceptible to humans.

A human-centred approach suggests that characterising perceived similarity between organisms is the key step towards accounting for folk categories. Perceptual similarity has been emphasised by previous accounts of folk classification (Hunn 1976) but comprehensive measures of perceptual similarity have been lacking. We proposed that morphological traits from the AVONET data set can be used to construct a rough measure of perceptual similarity between birds and showed that this measure of perceptual similarity contributes information about folk classification that goes beyond the information captured by scientific classification systems. The traditional scientific taxonomies used in our analyses already reflect perceptual similarity to some extent, and our result therefore suggests that perceptual similarity contributes more strongly to folk classification than to traditional scientific classification.

A significant strength of our approach is that the morphological data from which our similarity measure is derived are available for every bird species on the planet. Our approach can therefore be used to analyse any collection of bird names published in the literature on folk biology. Here we analysed bird names for three languages, and future studies can ask whether our findings generalise across a larger set of languages.

A second direction for future work is to consider folk categories above and below the level of folk generic categories. Previous work suggests that folk generic categories align more closely with scientific categories than do folk categories at other levels, and methods similar to ours can potentially be used to quantify variation in naming strategies over levels. For example, Anindilyakwa has no word that corresponds to English "bird" or the scientific class Aves --- birds are classified as *wurrajija*, glossed as "winged creatures and others", along with bats and most kinds of insects. Examples such as this suggest that a comprehensive account of folk classification will need to account for differential weighting of features (both perceptual and functional) across cultures.

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We acknowledge that the datasets we used for our analyses are derived from living languages that are deeply intertwined with the identities and traditions of the people who speak them. The existence of these datasets is a tribute to the resilience of the cultures and the generosity of the local knowledge keepers.

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From left to right, the photographs in Figure 2 were taken by Wayne Sladek, Anthony Katon, Andreas Heikaus, David Tytherleigh, Beata Matysiokova, Ben Milbourne, Dennis Devers, Peter Bennet, Adrian Boyle, Joel Poyitt, Jill Duncan, and Ken Bissett.

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