**Folktale transmission in the Arctic provides evidence for high bandwidth social learning among hunter-gatherer groups**

There exist striking resemblances in the stories of ethnolinguistic groups separated by vast geographic distances, with nearby groups having the most in common. The causes of these geographic associations are uncertain. Here we use method and theory from population genetics to examine cultural transmission in folktale inventories of 18 hunter-gatherer groups spread across 6000 km of Siberia, Alaska, Canada, and Greenland. We find that linguistic relatedness and geographic proximity independently predict overlap in folktale inventories, which provides evidence for both vertical transmission down cultural lineages and horizontal transmission between groups. These results suggest that high-bandwidth social learning across group boundaries is a feature of traditional hunter-gatherers, which may help explain how complex cultural traditions can develop and be retained in ostensibly small groups.

**Keywords**

Arctic, cultural evolution, folktale, group size, hunter-gatherer

**1. Introduction**

It has long been recognized that nearby ethnolinguistic groups (groups defined by shared language and cultural identity; henceforth “groups”) share more cultural traits than those that are far away (Boas, 1896). In recent years, method and theory from evolutionary biology has been used to disentangle the cultural evolutionary processes that account for this geographic gradient (Borgerhoff Mulder et al., 2006; Gray et al., 2007; Levinson & Gray, 2012; Mace & Jordan, 2011; Nettle, 2009). Three broad classes of processes have been identified. First, vertical transmission – new groups inherit cultural traits from a parent group, and groups that have diverged recently have had less time to spread. Second, horizontal transmission – contemporaneous groups exchange cultural traits, and groups that are near one another have had more opportunities for cultural exchange. Third, independent innovation – groups that are near one another tend to live in similar environments, and groups can converge on similar cultural traits in response to shared ecological opportunities and challenges. The relative influence of these three processes varies across aspects of culture. Language frequently exhibits highly tree-like patterns of vertical transmission (Bouckaert et al., 2012; Gray et al., 2009; Lee & Hasegawa, 2011), as do a variety of social practices (Currie et al., 2010; F. M. Jordan et al., 2009; Opie et al., 2014), and aspects of material culture (P. Jordan & Shennan, 2009; Larsen, 2011; Tehrani & Collard, 2002). By contrast, other social practices and aspects of material culture show high levels of horizontal transmission (Gray et al., 2010; P. Jordan & Shennan, 2003; Towner et al., 2012). And environmental commonalities can spur independent cultural innovation (Saslis-Lagoudakis et al., 2014).

Storytelling is a highly conspicuous cross-cultural universal (D. E. Brown, 1991), and a variety of theories propose that it has played a key role in human evolution (B. Boyd, 2009; Carroll, 2006; Coe et al., 2006; Davies, 2012; Gottschall, 2012; Scalise Sugiyama, 2001; Wiessner, 2014). The importance of cultural evolutionary processes is underscored by the fact that the folktales, myths and legends of nearby groups tend to be more alike than those of groups separated by large distances. Folktales, in particular, have been the target of a long tradition of careful documentation and classification (Goldberg, 1984; Krohn, 1926; Uther, 1997, 2004). Nevertheless, the processes underlying this geographic relationship remain poorly understood, with competing theories invoking vertical transmission, horizontal transmission, and independent innovation (Dorson, 1972; Dundes, 1986; Teverson, 2013; Thompson, 1946).

Research on folktale transmission has the potential to inform broad debates about cultural evolution (Ross & Atkinson, in press; Ross et al., 2013; Tehrani, 2013), including recent discussions about the relationship between cultural complexity and demography. It has been hypothesized that a suitably large population of potential learners is crucial for developing and maintaining complex culture, with larger groups predicted to have richer and more complex cultural repertoires than smaller groups (Henrich, 2004). To date, research on this broad hypothesis has focused on the specific case of toolkit complexity, particularly food-getting technologies (Collard et al., 2013a; Collard et al., 2013b; Henrich, 2004; Kline & Boyd, 2010; Powell et al., 2009; Read, 2006, 2012). One challenge for interpreting toolkit data is to account for how some small groups developed and retained remarkably complex toolkits despite their small group sizes. One possibility is that the “effective population size” (the size of the interacting pool of social learners) of groups can be substantially larger than the size of groups themselves if social learning occurs across group boundaries (Henrich, 2004). This is an important question for empirical examination. However, it is difficult to index the degree of intimacy of inter-group social learning by analyzing toolkits because tools can diffuse between groups not only through explicit teaching and apprenticeship (Sterelny, 2012; i.e. high intimacy), but also through trading and stealing (i.e. low intimacy). We propose that horizontal transmission of folktales provides a novel marker of high intimacy, high bandwidth social learning between groups since folktales, unlike food getting technologies, are necessarily exchanged through language.

Although cultural evolution approaches have been widely applied to the study of material culture, language, and social practices (Mesoudi, 2011), little research has explored storytelling. Recently, however, Ross et al*.* (2013) used method and theory from population genetics to quantify the extent to which geographic distance, group affiliation, and cultural ancestry independently predict the distribution of 700 variants of a folktale across 31 European groups. At the level of individual folktales, they found that geography explained most variation, followed by group affiliation, and finally cultural ancestry. At the group level, they found significant cultural differentiation among groups, with geography explaining more differentiation than is explained by cultural ancestry. And Tehrani (2013) used phylogenetic methods to examine 58 variants of a folktale from cultures of Europe, the Middle East, Africa, and Asia. He found evidence for phylogenetic signal, with the degree of branching and blending varying in different geographic regions.

Many of the groups included in the studies by Ross et al*.* (2013) and Tehrani (2013) are characterized by social structures, cultural practices, population densities, and technologies that are radically different to those of the hunter-gatherer groups that characterized much of our recent evolutionary past. In particular, many of the groups are large, complex nation states with writing systems, print technologies, and widespread literacy and schooling. Importantly, it has been argued that these cultural innovations initiate profound changes in patterns and processes of cultural transmission, malleability and fixity of traditions, group identity, cooperation, memory, and other cognitive processes (Eisenstein, 1979; Goody & Watt, 1963; Mullins et al., 2013; Ong, 1982; Poe, 2010; Rubin, 1995). Furthermore, these cultural innovations feature prominently in recent debates about folktale transmission, particularly in Europe. Some scholars maintain that many of the earliest attested European folktales have long been transmitted orally and were widely distributed many centuries before being written down (Zipes, 2006, 2012). By contrast, other scholars argue that many of these folktales were invented relatively recently and became widely distributed primarily as a result of dissemination via print media (Bottigheimer, 2009; de Blécourt, 2012). Consequently, it is uncertain whether it is appropriate to use the results of the studies by Ross et al*.* (2013) and Tehrani (2013) to make inferences about cultural transmission in traditional hunter-gatherer groups.

In the present study we quantify the extent to which geographic distance and cultural ancestry predict overlap in the folktale inventories of 18 groups spread across vast Arctic regions of Siberia, Alaska, Canada, and Greenland. This dataset is especially well-suited to enhance our understanding of two key issues about cultural evolution. First, in contrast to the groups examined in recent studies of folktale evolution (Ross et al., 2013; Tehrani, 2013), these Arctic groups were hunter-gatherers who lacked writing systems prior to European colonization. Consequently, these groups are particularly useful for making inferences about patterns of cultural transmission prior to recent cultural and technological developments associated with literacy. Second, many of these Arctic groups were very small, yet had strikingly complex toolkits (R. Boyd et al., 2011). Consequently, evidence for horizontal transmission of folktales between these groups would suggest that the effective population for high intimacy, high bandwidth cultural learning is larger than nominal group size, and thus provide scope for explaining how complex cultural traditions can develop and be retained in ostensibly small groups.

**2. Materials and methods**

**2.1 Data**

We sourced folktale data from a study of Arctic folktales (Sheppard, 1998)[[1]](#footnote-1). This study coded the presence or absence of 45 folktales across 18 groups from Arctic regions of Siberia, Alaska, Canada, and Greenland whose approximate locations are shown in Fig. 1. In two instances, the presence of a folktale in a group was coded as “possible fragment,” which we recoded as absent prior to analysis. The mean number of folktales per group was 18.06 (Baffin, 22; Bering Strait, 23; Caribou, 22; Chugach, 7; Chukchi, 15; Copper, 22; Greenland, 27; Iglulik, 26; Koniag, 12; Labrador, 15; Mackenzie, 14; Mainland Southwest Alaska, 15; Netsilik, 27; North Alaska, 23; Northwest Alaska, 28; Nunivak Island, 5; Quebec, 13; Siberian Yupik, 9; for raw data see electronic supplementary materials, Table S1).

-- Insert Fig. 1 about here --

**Fig. 1.** Approximate geographic locations of the 18 groups: 1 – Chukchi, 2 – Siberian Yupik, 3 – Bering Strait, 4 – Nunivak Island, 5 – Mainland Southwest Alaska, 6 – Northwest Alaska, 7 – North Alaska, 8 – Koniag, 9 – Chugach, 10 – Mackenzie, 11 – Copper, 12 – Caribou, 13 – Netsilik, 14 – Iglulik, 15 – Quebec, 16 – Baffin, 17 – Labrador, 18 – Greenland. Coloring shows a simple Kriging interpolation of the first axis of variation of Principle Coordinate Analysis (PCoA) of folktale data. (Online version in color.)

We recoded the presence or absence of a folktale as “1” or “0”, respectively, to produce a matrix of 45 binary traits across 18 groups. For analysis, this presence/absence matrix was converted to a pairwise folktale distance matrix using Jaccard distances (see electronic supplementary materials, Table S2). The Jaccard distance for each pair of groups was calculated as the sum of the number of folktales that are present in one group but not the other, divided by the sum of the number of folktales that are present in one or both groups. We used the Jaccard distance because it standardizes for the number of traits observed for each pair and shared absences do not contribute to similarity, which is particularly appropriate for cultural data (Rogers & Ehrlich, 2008).

We estimated geographic coordinates for groups using information provided by Sheppard (1998) and sources referenced therein. These geographic coordinates were used to calculate a pairwise geographic distance matrix. Pairwise distances were calculated using great circle distances in GenAlEx v6.501 (Peakall & Smouse, 2006, 2012; see electronic supplementary materials, Table S3).

We used language divergence to index cultural ancestry. The degree of divergence between languages was inferred using the language classification presented in the *Ethnologue* (Lewis et al., 2015; see electronic supplementary materials, Fig. S4). All but one of the groups included in the dataset speak a language that is a member of the Eskimo-Aleut language family. The other language, Chukchi, is a member of the small Chukotko-Kamchatkan language family. Pairwise language distances were coded as follows: 1 – closely related dialects (languages with identical ISO 699-3 codes according to the *Ethnologue*), 2 – same shallow branch of the same language family, 3 – same deep branch of the same language family, 4 – different deep branches of the same language family, 5 – different language families. These pairwise distances were used to infer a pairwise language distance matrix (see electronic supplementary materials, Table S5).

**2.2 Analysis**

We quantified the association between geographic, language, and folktale distance matrices by calculating correlations and partial correlations using Mantel and partial Mantel tests (Mantel, 1967; Smouse et al., 1986) in Arlequin v3.5.2.1 (Excoffier & Lischer, 2010). Statistical significance was assessed using 50,000 random permutations.

We calculated spatial autocorrelations for folktale distances using the method implemented in GenAlEx v6.501 (Banks & Peakall, 2012). This method was used to calculate an autocorrelation coefficient *r* within 500 km distance classes for the folktale distance matrix, which provides a measure of the similarity between pairs of folktales whose geographic separation falls within each distance class. Tests for statistical significance were performed using two methods: calculating *r* across 10,000 random permutations and 10,000 bootstrap estimates (Peakall et al., 2003).

We performed Principle Coordinate Analysis (PCoA; also known as Multidimensional Scaling) to visualize major trends in the data using the covariance-standardized method implemented in GenAlEx v6.501 (Peakall & Smouse, 2006, 2012). The first two dimensions of the PCoA were correlated against latitude and longitude to explore geographic associations.

In order to further visualize specific relationships among groups, we constructed a NeighborNet (Bryant & Moulton, 2004) using the folktale distance matrix in SplitsTree v4.13.1 (Huson & Bryant, 2006). The splits on the NeighborNet are proportional to inferred differences, with longer splits being supported by more differences. The NeighborNet is useful for identifying complex transmission histories of group divergence and convergence because it does not assume a strictly tree-like model of evolution (Bryant et al., 2005; Gray et al., 2010). Instead, evidence for a tree model appears as bifurcating tree-like splits. Conversely, conflicting signal, such as that caused by parallel independent innovations or horizontal transmission, appears as box-like structures with sizes that are proportionate to the magnitude of conflicting signal.

**3. Results and discussion**

**3.1 Horizontal transmission**

The present results provide strong evidence that between-group social learning plays an important role in the evolution of folktales in these groups. A Mantel test reveals a moderate correlation between folktale similarity and geography (*r* = .505, *p* < .001), which suggests that the folktale inventories of nearby groups are more similar than those of distant groups. Crucially, a partial Mantel test reveals a moderate correlation after controlling for language (*r* = .451, *p* < .001), which supports the hypothesis that there is an independent effect of horizontal transmission after controlling for vertical transmission down cultural lineages.

Spatial autocorrelation analysis reveals an overall spatial autocorrelation (omega = 129.920, *p* < .001). The positive autocorrelation is of greatest magnitude at the shortest distance class of 500 km and decreases in magnitude as distances increase until passing through the intercept at approximately 2441 km and leveling off for longer distance classes (see Fig. 2).

-- Insert Fig. 2 about here --

**Fig. 2.** Folktale spatial autocorrelation analysis showing correlation coefficient (*r*) as a function of geographic distance. The permuted 95% confidence interval (dashed lines) and the bootstrap 95% confidence interval error bars are also shown. Variation in error estimates is influenced by the number of pairwise comparisons within each distance class. (Online version in color.)

PCoA of the folktale matrix reveals that the first axis of variation accounts for 22.38% of the variance (eigenvalue = 0.323) and the second axis accounts for 10.70% (eigenvalue = 0.154). Pearson product-moment correlations reveal that the first axis of variation is correlated with longitude (*r* = .923, *p* < .001), but not latitude (*r* = -.003, *p* = .991); and the second axis of variation is correlated with latitude (*r* = -.567, *p* = .014), but not longitude (*r* = -.067, *p* = .792). To visualize the relationship between the major geographic axis and the first axis of variation we plotted the results of the ordinary Kriging spatial interpolation technique implemented in ArcGIS v10.1 (ESRI, 2011) on a map (see Fig. 1). This map suggests a smooth gradient across the major geographic axis of dispersion of these groups. Nevertheless, given the relatively small number of data points and large geographic distances between them, some caution is warranted when interpreting this apparently smooth cline since it would be difficult to identify barriers if they exist.

This clear geographic patterning, which cannot be explained by vertical transmission down cultural lineages, is consistent with research showing that many Arctic groups were embedded in complex systems of interaction, including trade networks, friendly relations, and hostile relations (Aporta, 2009; Burch Jr., 2005; Friesen, 2013; Pratt, 2012). Our folktale analyses add a new dimension to this scholarship by providing quantitative evidence for the existence of between-group cultural learning of sufficiently high bandwidth and fidelity for orally transmitted folktales to diffuse between groups. Consequently, our result provides novel evidence that effective population size can be larger than group size for complex orally transmitted culture, an important finding for theories that link cultural complexity to demography (Henrich, 2004; Kline & Boyd, 2010; Powell et al., 2009).

**3.2 Vertical transmission**

The present results also provide strong evidence that cultural ancestry plays an important role in the evolution of folktales in these groups. A Mantel test reveals a moderate correlation between folktale similarity and language relatedness (*r* = .465, *p* < .001), which suggests that the folktale inventories of groups that diverged more recently exhibit greater similarity than those of groups that diverged less recently. Crucially, a partial Mantel test reveals a moderate correlation after controlling for geography (*r* = .401, *p* = .003), which supports the hypothesis that there is an independent effect of vertical transmission down language lineages after controlling for horizontal transmission between groups.

The Eskimo-Aleut language family is thought to have originated in coastal Alaska up to 5000 years ago (Fortescue, 1998, 2013). Archaeological and linguistic evidence suggests that starting at about 1000 AD there was rapid migration eastward into Canada and Greenland (Fortescue, 1998, 2013). It has been argued that this “Thule migration” resulted in the replacement of earlier Dorset peoples, seemingly with little or no inbreeding (Raghavan, 2014), exchange of material culture (Friesen, 2013), or influence on Eskimo-Aleut languages (Fortescue, 2013). That a major expansion in the Inuit-Inupiaq branch of the Eskimo-Aleut language family occurred relatively recently might help account for our strong evidence for vertical transmission of orally transmitted folktales.

Whilst the Mantel tests provide some evidence for vertical transmission of folktales, the NeighborNet (Fig. 3) reveals that the pattern of folktale variation between populations is not very tree-like, with box-like structures in the NeighborNet providing evidence for widespread conflicting signal. This suggests that these folktales are not transmitted together as a cohesive cultural package but often have disparate histories, with the inventory of folktales appearing in each of these cultures being an assemblage of somewhat independent units (R. Boyd, et al., 1997). This pattern is predicted under a model of horizontal transmission, but not under a model of vertical transmission as part of an expansion. Furthermore, this interpretation of the NeighborNet supports Sheppard’s (1998) suggestion that the folktales may have originated at diverse locations.

-- Insert Fig. 3 about here --

**Fig. 3.** NeighborNet of the 18 groups based on the Jaccard folktale distance matrix. Evidence for a tree model appears as bifurcating tree-like splits, while evidence for conflicting signal appears as box-like structures.

Interestingly, large splits in the NeighborNet point to two geographic clusters: a western cluster and an eastern cluster, with Copper, the group that is geographically situated between these two clusters, falling between these clusters on the NeighborNet. It is possible that these large splits are the result of geographic or cultural barriers to the spread of folktales between these broad geographic regions. However, these apparent barriers could also be artifacts of low spatial density sampling in the middle region between the clusters of relatively high spatial density sampling in the western and eastern regions.

 **3.3 Comparisons with other folktale analyses**

The associations found in the present analyses are somewhat stronger than those found in a comparable study of European folktale variation. Ross et al*.*’s (2013) analysis of 700 individual variants of a folktale in 31 groups in Europe (in terms of group level differentiation using the *ΦST* statistic) revealed a relatively strong correlation between folktale differentiation and geography (*r* = 0.384, *p* < 0.001), even when controlling for language relatedness (*r* = 0.355, *p* = 0.005). They also found a correlation between folktale differentiation and language relatedness (*r* = 0.274, *p* = 0.014), but no correlation when controlling for geography (*r* = 0.207, *p* = 0.099). It could be the case that the stronger associations found in the present study are due to differences in patterns of transmission in Europe and the Arctic. One intriguing possibility is that the development of writing, print technology, and widespread literacy weakened the association between folktales, geography, and cultural ancestry in Europe, which would be consistent with theories that argue that these cultural innovations precipitate major changes in cultural transmission (Eisenstein, 1979; Goody & Watt, 1963; Mullins et al., 2013; Ong, 1982; Poe, 2010; Rubin, 1995), including folktale transmission (Bottigheimer, 2009; de Blécourt, 2012). Nevertheless, there exist important differences between the two studies with respect to how the folktale data were coded. Of particular note, the study of European folktales examined variation in narrative elements in versions of the *same* folktale, while the present study examined the presence or absence of *different* folktales. Consequently, it is possible that differences in the “grain of analysis” (Godfrey-Smith, 2012) are responsible for differences in the strength of associations.

**3.4 Limitations and future research**

There are at least four respects in which the data analyzed in the present study are somewhat imprecise. First, traditional linguistic subgroup classifications were used to index cultural ancestry. These classifications are not ideal estimates of relative time depths since a variety of factors, such as branching (Atkinson et al., 2008) and group size (Bromhan et al., 2015), can influence rates of language evolution in different lineages. Second, many Arctic groups were highly mobile and traversed large geographic ranges, making the estimated locations for some of these groups inexact. Third, the number of folktales examined by Sheppard (1998) varies considerably across groups. Although an important reason for this is likely to be differences in the true size of folktale inventories of these groups, it is probable that some of this variation is also due to some groups having been documented more thoroughly than others. Fourth, members of some of these groups had become literate in their own language before folktale data were collected. For instance, the Greenland and Labrador Inuit groups became literate during the 18th century, and other Inuit groups in Alaska and Canada followed during the 19th century (Dorais, 2010). Nevertheless, we are not aware of any evidence to suggest that writing was used to transmit folktales between groups.

Despite these limitations in the data, we suggest that our results reveal genuine patterns in cultural transmission among these groups. The associations between folktales, geography, and cultural ancestry are of moderate size and strongly supported by statistical analyses. Furthermore, we have no reason to believe that imprecisions in the coding of folktales are manifestations of underlying systemic biases that might inflate the sizes of associations with geography or cultural ancestry. Nevertheless, we suggest that future research that enhances the precision of the folktale, geographic, and linguistic data could prove to be useful. In particular, the source materials used by Sheppard (1998) could be used to code the presence and absence of narrative elements in different versions of the same folktale, and thus examine these folktales at the “grain of analysis” used in studies that focused on European groups (Ross et al., 2013; Tehrani, 2013), which could provide useful data for testing theories about cultural group selection (Ross & Atkinson, in press). In addition, Eskimo-Aleut cognate data (e.g. Fortescue et al., 2011) could be used to infer an Eskimo-Aleut language phylogeny, and thus index cultural ancestry with increased precision, as has been done in studies of cultural inventories of groups belonging to other language families (Currie et al., 2010; F. M. Jordan et al., 2009; Opie et al., 2014).

It is important to note that evidence for widespread social learning of folktales across group boundaries does not imply that other aspects of culture have likewise been transmitted across group boundaries via social learning. Nevertheless, horizontal transmission of folktales indicates that there is scope for this. Other cultural datasets could be collected and analyzed to provide a more comprehensive picture of the relative importance of vertical transmission and horizontal transmission in these groups; tools (especially food-getting technologies) would be particularly appropriate targets of research since they have been the focus of much recent discussion (Collard et al., 2013a; Collard et al., 2013b; Henrich, 2004; Kline & Boyd, 2010; Powell et al., 2009; Read, 2006, 2012). Likewise, it would be useful to examine associations with genetic data, as has been done in a recent study of indigenous Taiwanese folk music (S. Brown et al., 2014). Such follow up research could make important contributions to general debates about the extent to which genes, culture, and language travel together; and specific debates about the peopling of the Americas (Fortescue, 1998, 2013; Friesen, 2013; Raghavan, 2014).

**4. Conclusion**

The present study makes a novel contribution to our understanding of cultural transmission. Previous studies of folktales focused on large nation states with writing systems, print technologies, and high rates of literacy (Ross et al., 2013; Tehrani, 2013) for which there is vigorous debate about the relative importance of written and oral transmission of folktales (Bottigheimer, 2009; de Blécourt, 2012; Zipes, 2006, 2012). The present results demonstrate that in traditional hunter-gather groups without writing systems both vertical transmission down cultural lineages and horizontal transmission between groups can play important roles in folktale transmission. In addition, these results provide a novel source of quantitative evidence for high bandwidth, high intimacy social learning across group boundaries. As a consequence, these results provide evidence that the effective population size for social learning of orally transmitted culture can be larger than nominal group size, which might help explain how cumulative cultural evolution is possible in small groups.

**Supplementary Materials**

The datasets supporting this article have been uploaded as part of the Supplementary Materials.

**Acknowledgements**

We thank K. L. Pratt, M. J. O’Brien, M. Coltheart, and one anonymous reviewer for helpful comments that improved the manuscript. This research was supported by a MQRES PhD scholarship awarded by Macquarie University (R.M.R.), a Rutherford Discovery Fellowship (Q.D.A.), John Templeton Foundation grant no. 28745 (Q.D.A.), and an ESRC Large Grant (REF RES-060-25-0085) entitled ‘Ritual, Community, and Conflict’ (Q.D.A.).

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1. The data presented in Sheppard (1998) include a number of inconsistencies. Where these inconsistences could not be harmonized we favored the data presented in the appendix, rather than the table in the main text, as per the recommendation of a friend and colleague of the deceased author who has some familiarity with the raw data (Kenneth L. Pratt, pers. com. 28 Nov. 2013). [↑](#footnote-ref-1)