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RESEARCH

Transformation via multiple processes: a quantitative assessment of the cultural consequences of the migration of Dene people to the American Southwest

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Abstract
The migration of Dene groups from the western subarctic of North America to the American Southwest is one of the longest prehistoric migrations. The starkly different environment of the Southwest, and the presence of groups who had been living in the region for millennia, have made this migration a focus of anthropological and archaeological interest for many years. In the study reported here, we analyzed 547 binary cultural traits pertaining to northern Dene groups, southern Dene groups, and non-Dene groups from the Southwest. First, we focused on the scale of the impact of the migration on the cultural repertoires of the southern Dene. Then, we investigated the relative importance of three processes of change: loss, invention, and borrowing from neighboring non-Dene groups in the Southwest. The results of the first analysis indicate that the migration led to the transformation of the cultural repertoires of the southern Dene. Not only were nearly two-thirds of traits changed, but also a majority of the traits in six of the seven trait categories we employed were altered by the migration. The second analysis indicated that the transformation was not the result of a single process of change. Loss, invention, and borrowing were all involved, and their relative importance varied among categories. These results are consistent with previous characterizations of the southern Dene as flexible and open to change. They also have broader implications. Most importantly, they challenge us to rethink how we approach cases in which there are cultural similarities between ethnographic groups or archaeological sites.

Keywords Dene migration · Comparative analysis · Cultural transformation · Retention · Loss · Borrowing

Introduction

This paper concerns the movement of Dene (alternatively Athabascan or Athapaskan) groups from what is now northwestern Canada and eastern Alaska to the American Southwest (Fig. 1), which was one of the longest human migrations in the Americas prior to the arrival of Columbus (Opler 1983; Ives 1990, 2003; Perry 1991; Magne and Matson 2010; Matson and Magne 2013; Seymour 2012). Specifically, we report a study that focused on the impact on the migrants' cultural repertoires of the substantial differences in physical environment between their subarctic homeland and the desertic Southwest as well as their interactions with neighboring non-Dene groups in the Southwest. We are not the first researchers to investigate this issue, by any stretch of the imagination. The migration of Dene-speaking people to the Southwest has been a target of anthropological, archaeological, and linguistic research for nearly a century (e.g.Sapir 1936; Hoijer 1956a, b; Meggers 1960; Opler 1961, 1971, 1983; Ives 1990, 2003; Magne and Matson 2010; Rice 2012; Matson and Magne 2013). What we contribute to the discussion in the present paper is an analysis of a well-known dataset that has always had the potential to illuminate the issue but has been ignored until now for some reason.

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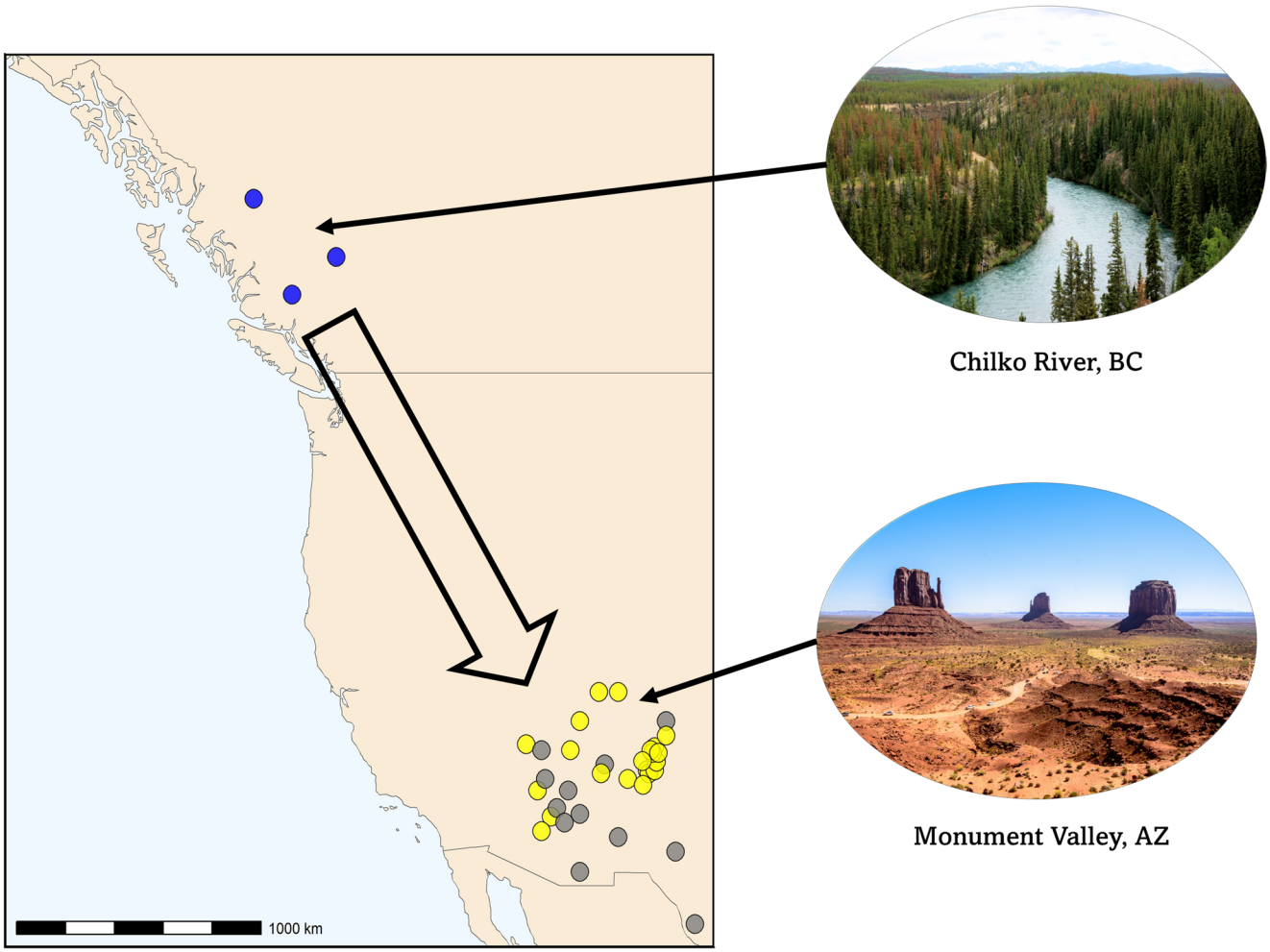

Fig. 1 Locations of the groups included in the study. The circles show the approximate centers of the groups' territories, based on latitudes and longitudes from Jorgensen (1980). Blue circles = northern Dene. Gray circles = southern Dene. Yellow circles = non-Dene. The photographs show representative environments for the northern and southern Dene. The large arrow shows the general direction of the Dene migration from northwestern Canada and eastern Alaska to the Southwest. Photographs from Wikipedia

As with other indigenous Americans, the ancestors of Dene-speaking people lived in Siberia. Ancient and modern genetic data indicate that the ancestors of the Dene and all other indigenous Americans split from the ancestors of today's indigenous Siberians around 23,000 years ago (Raghavan et al. 2015). Linguistic and folklore evidence also connect the Dene to Siberia, specifically with the Altai-Sayan region (Ives 2010; Berezkin 2019). Between 14,500 and 11,500 years ago, the indigenous American population split. This divergence is thought to have occurred in the lower latitudes of North America and resulted in two lineages, a southern one and a northern one. The latter lineage is widely believed to have included the ancestors of today's Dene speakers (Flegontov et al. 2019; Malhi et al. 2003, 2008; Achilli et al. 2013; Raghavan et al. 2015).

Currently, there are three clusters of Dene-speaking groups—the northern Dene, the southern Dene, and the Pacific Coast Dene (Jorgensen 1980; Magne 2012; Rice 2012). The northern Dene are found from northern Manitoba to eastern Alaska in what is generally agreed to be the homeland of the Dene (Perry 1991; Magne 2012; Doering et al. 2020). The southern Dene are located in the American Southwest and northern Mexico, while the Pacific Coast Dene occupy parts of the Pacific Coast between northern California and southern Washington (Matson and Magne 2013; Spence 2013). As mentioned earlier, the study reported here focused on the cluster of Dene groups in the American Southwest.

Genetic data strongly support an ancestor-descendant relationship between the northern and southern Dene. Genetic studies focusing on Y chromosomes and mitochondrial DNA have supported a close affinity between northern and southern Dene groups (Malhi et al. 2003, 2008). Malhi (2012) summarized additional findings from several genetic studies that suggest the southern Dene's migration probably involved a small number of groups, and that the groups

likely absorbed non-Dene individuals along the way or in the Southwest after arrival.

Linguistic studies also support an ancestor-descendant relationship between the northern and southern Dene. Sapir (1936) was the first to argue for such a connection. He did so on the basis of phonological, morphological, grammatical, and lexical observations. Subsequently, multiple linguistic studies using a range of methods have supported the existence of unified Dene language family and suggested that the split between the languages spoken by the northern and southern Dene occurred relatively recently (Hoijer 1956a; Jorgensen 1980; Young 1983; Rice 2012).

How recently the ancestors of today's southern Dene separated from the ancestors of today's northern Dene is still under investigation, but archaeological work published in the last few years suggests the split occurred in the mid-9th century CE. For example, Jensen et al. (2021) have proposed that the eruption of Alaska's Mount Churchill that occurred around 852–854 CE forced the Dene located south of the devastated area to move further south and resulted in them losing contact with the more northerly Dene. Evidence of a disruption in obsidian procurement and exchange networks coincides with the timing of this eruption (Kristensen et al. 2019). Several authors have suggested that the eruption, and the associated ash fall, may have not only split the Dene into northern and southern populations, but also acted as the catalyst for the migration of some southern groups to the Southwest (Workman 1979; Ives 1990, 2003; Magne and Matson 2010; Magne 2012; Matson and Magne 2013; Kristensen et al. 2019; Doering et al. 2020).

The timing of the arrival of the ancestors of the southern Dene in the Southwest has long been a matter of debate (Hoijer 1956a; Opler 1961; Ives 1990, 2003; Seymour, 2009, 2012; Magne and Matson 2010; Magne 2012; Matson and Magne 2013; Kristensen et al. 2019). One hypothesis is that southern Dene groups moved to the Southwest 1500–2000 years ago (Dumond 1969). However, this can probably be discounted now because it is inconsistent with the date of 852–854 CE for the split between the southern and northern Dene. Of the arrival hypotheses that are consistent with the split date, the best supported one contends that the southern Dene colonized the Southwest in the late 13th century CE. This hypothesis is consistent with the results of glottochronological analyses carried out by Hoijer (1956a), which put the arrival time between 1000 and 1400 CE. It is also consistent with recent isotope work involving a fragmentary moccasin found in the Promontory caves in Utah (Metcalfe et al. 2021). Radiocarbon dating indicates that the moccasin dates to 1252–1290 CE. At this time, the Promontory caves are thought to have been occupied by Dene-speaking people (partly because the moccasin and many of the others found at the site are similar to those made by the northern Dene). Importantly for present purposes, the isotope work indicates that the ankle tie of the fragmentary moccasin is made from bison leather that originated 700 to 800 km to the east or south of the caves. The researchers who carried out the isotope analyses argue that the ankle tie was probably obtained in person rather than via trade, which suggests that the group using the Promontory caves were regularly travelling long distances in the late 13th century. The isotope analysis was not able to pinpoint where the bison ties were obtained but the Southwest is one of the candidate regions. Taken together, the southern Dene-northern Dene split date and the late 13th century CE arrival date imply that the migration lasted around 400 years. Before we move on, it is worth noting that it has been suggested that Dene groups may have arrived in the Southwest in two waves (Hoijer 1956a; Opler 1961; Seymour 2009). The first wave is argued to have comprised the Diné (Western Navajo and Eastern Navajo) and the San Carlos, Chiricahua and Mescalero Ndee, while the second wave consisted of the other Ndee groups (Jicarilla, Lipan, and Western). This hypothesis is not widely accepted, however.

The route that the southern Dene took to the Southwest is another issue that has yet to be resolved. The main hypothesized routes are through the Rocky Mountains and Great Basin (Steward 1936; Huscher and Huscher 1942, 1943; Opler 1961, 1971, 1983; Brugge 2012; Seymour 2012) or through the eastern foothills of the Rockies and the central Plains (Wedel 1959, 1982; Gunnerson 1968, 1987; Workman 1979; Ives 2003, 2010, 2014; Magne and Matson 2010; Matson and Magne 2013; Hill and Trabert 2018). Supporters of the former route argue that the Dene were adapted to mountainous environments and therefore would have used the mountains of the west as a migration corridor (Steward 1936; Huscher and Huscher 1942, 1943; Opler 1961, 1971, 1983; Seymour 2012). Researchers who favor the eastern foothills/central Plains route have claimed that the Dene migration is evidenced by the Dismal River Complex of the Central Plains (Wedel 1959; Gunnerson 1968, 1987). A recent reanalysis of the radiocarbon and OSL dates from Dismal River Complex sites by Hill and Trabert (2018) may provide a temporal framework for the eastern foothills/central Plains route. Hill and Trabert (2018) concluded that occupation of the sites began before 1400 CE and ended in the 1700s CE. It should be noted, however, that they are skeptical about the association between the Dismal River Complex and the Dene.

After the southern Dene arrived in the Southwest, they interacted with a new environment and groups of people who spoke languages that belong to different language families. Researchers analyzing the impact of this arrival have tended to focus on language (Sapir 1936; Landar 1960; Rice 2012), kinship (Hoijer 1956b), and sociopolitical

organization (Meggers 1960, 1961; Opler 1961). Work on these topics has focused on changes effecting Ndee and Diné groups specifically, rather than the southern Dene as a whole. Several studies of the Ndee groups have suggested that they adopted local knowledge (Seymour 2008, 2012), new technologies (Kluckhorn and Leighton, 1962), and ceremonies (Ives 2010) after arriving in the Southwest. Ndee languages, on the other hand, have been characterized as being more resistant to change (Ives 2010) and the changes that have been documented are usually losses of particular words referring to species not encountered in the Southwest (Landar 1960). For Diné groups, Brugge (2012) has argued that religious and ceremonial life was a mix of retained and borrowed traits, and that some aspects of technology reflected their northern ancestry.

In the study reported here, we analyzed data for hundreds of cultural traits pertaining to multiple domains of life. We obtained the data from a digital version of the dataset reported in Joseph G. Jorgensen's 1980 monograph *Western Indians*[1]. This book is well known in anthropological and archaeological circles and the data it contains have been used by many researchers in the last 20 years (e.g., Sellen and Hruschka 2004; Borgerhoff Mulder et al. 2006; Towner et al. 2012, 2016; Collard et al. 2013; Mathew and Perreault 2015; Buchanan et al. 2019; Smith and Codding 2021; Hamilton et al. 2024). As mentioned earlier, the goal of our study was to investigate the extent to which the southern Dene retained or changed cultural traits in the face of the novel environmental and social conditions they encountered in the Southwest. We also sought to shed light on the processes of change involved.

For the purposes of the study, we defined retention as the transmission of a cultural trait from one generation of a social group to the next, without modification (e.g., a young boy adopting the religious beliefs of his parents, a teenage girl learning how to make a particular tool from a co-resident member of her age cohort). The processes of culture change we considered were loss, invention, and borrowing. We defined loss as the abandonment of one or more cultural traits by a group. We deemed invention to entail a member of a group creating—or sometimes several members of a group collectively creating—a new cultural trait and that trait becoming normative for at least some members of the group. The spread of an invention is sometimes referred to as "innovation" (e.g., Erwin and Krakauer 2004). We chose not to use this term to avoid confusion. We defined the final process of change we considered, borrowing, as the adoption of a cultural trait from another group via social learning. We focused on borrowing from non-Dene neighbors in the American Southwest.

[1] The *Western Indians* dataset can also be accessed via D-PLACE (Kirby et al. 2016).

Materials and methods

Western Indians presents data pertaining to 293[2] cultural and 132 environmental traits for 172 ethnolinguistic groups. The cultural traits are diverse and are grouped into eight categories: (1) *Technology and Material Culture*, (2) *Subsistence Economy*, (3) *Economic Organization*, (4) *Settlement Pattern*, *Demography*, *and Community Organization*, (5) *Social and Kinship Organization*, (6) *Political Organization*, *Sodalities*, *and Warfare*, (7) *Ceremonialism*, *Including Life Cycle*, and (8) *Spirit Quest*, *Shamanism*, *Causes of Illness*, *and Magic.* The environmental traits include geographic and climatic variables as well as the presence/absence of numerous animal and plant species. The geographic area spanned by the sample extends from Yakutat Bay, Alaska, to northern Baja California, and from the Rocky Mountains to the Pacific.

Western Indians grew out of the Cultural Element Distribution Survey, which was led by Kroeber and Driver (e.g., Driver and Kroeber 1932; Kroeber 1936, 1941). Jorgensen, a student of Driver, continued the work of the Cultural Element Distribution Survey by recruiting additional researchers to evaluate ethnographic information for a wide range of traits (Jorgensen 1980). Most of this information was gathered through interviews with tribal elders who were asked to recall behaviors and artifacts from the pre-contact period. Jorgensen's team used several processes to reduce bias in the recording of data and rating of traits, and they performed several checks on the values assigned to the groups. Thus, there is reason to be confident about the quality of the data. However, *Western Indians* does not provide references for individual observations, which makes independent verification difficult (Barnes 1980). The 172 groups included in the book were selected from approximately 250 groups, on the basis that they had high-quality data available.

In our study, we focused on 15 of the Dene groups in *Western Indians*. Three of the groups we selected were northern Dene: The Alkatcho Carrier[3], Lower Carrier, and Chilcotin. Twelve were southern Dene: the North Tonto Western Apache, South Tonto Western Apache, San Carlos Western Apache, Cibecue Western Apache, White Mountain Western Apache, Warm Springs Chiricahua Apache, Huachuca Chiricahua Apache, Mescalero Apache, Lipan Apache, Jicarilla Apache, Western Navajo, and Eastern

[2] In the introduction to *Western Indians*, Jorgensen (1980) states that he utilized 292 cultural traits in his analyses, but this appears to be a typographical error. The list of definitions of variables in the book's appendices includes 293 cultural traits and so does the digital version of the dataset we used.

[3] The tribal names and spellings used here are those employed by Jorgensen (1980). We have retained all of them to facilitate cross checking. A list of ethnonyms for the groups is provided in the Supplementary Material 1.

Navajo. The geographic distribution of the 15 Dene groups in our sample is shown in Fig. 1.

Our sample also included 21 groups from the Southwest who did not speak a Dene language as their primary language. These groups were the Hopi, Zuni, Acoma, Sia Keres, Santa Ana Keres, Santa Domingo Keres, Cochiti, San Juan Tewa, San Ildefonso Tewa, Santa Clara Tewa, Nambe Tewa, Taos, Isleta, Jemez, Uncompahgre Ute, Wimonuch Ute, San Juan Southern Paiute, Havasupai, Northeast Yavapai, Southeast Yavapai, and Pima. We chose these groups because they were spatially adjacent to at least one of the southern Dene groups, according to Jorgensen (1980). The approximate geographic locations of the 21 non-Dene groups are shown in Fig. 1.

Our sample was not as complete as we would have liked. Most frustratingly, we were unable to include any plains-dwelling Dene groups, such as the Sarsi Dene (Tsuut'ina) and Plains Apache (Kiowa), because they are not among the groups for which *Western Indians* provides data.

We only included Jorgensen's (1980) 293 cultural traits in our analyses; we did not make use of any of his environmental traits. Jorgensen's (1980) cultural traits are categorical and multistate. Multistate traits are complicated to analyze with the approach we opted to use in the study, so we binarized the 293 traits. In the course of carrying out the binarization process, we deleted four traits—235, 241, 243, and 273—because all three of the northern Dene groups are coded as "no information" in Jorgensen (1980), which means that they are uninformative regarding the impact of the migration on the cultural repertoires of the southern Dene. After deleting the four traits, we were left with 547 binary traits. Details of these traits are provided in Supplementary Material 2.

Because there are only 16 traits in Jorgensen's (1980) *Settlement Pattern*, *Demography*, *and Community Organization* category, we combined them with the most closely related traits, which are those in Jorgensen's (1980) *Economic Organization* category. As a consequence of this, we used seven trait categories in our study. We renamed some of the categories to improve communication. The trait categories we employed are as follows:

- *Ceremonialism.* This category includes traits related to public and private ceremonies and rituals, birthing, naming, puberty and death rituals and ceremony. Eighty-three traits were assigned to this category.
- *Economic Organization.* This category includes traits related to the age and sex of specialists and task groups in the production of technology, food processing, and the extraction of both wild and domesticated resources; the structure of reciprocity both locally and extra-locally; the exchange, ownership, and inheritance of land and resources; and mobility, density, and integration of populations. One-hundred-and-forty-two traits were assigned to this category.
- *Political Organization.* This category includes traits relating to types of governmental organization, sodalities, and clubs, as well as raiding and warfare. Fifty-four traits were assigned to this category.
- *Religion and Magic.* This category includes traits related to vision quests, shamanism, illness, and magic. Forty-five traits were assigned to this category.
- *Social Organization.* This category includes traits related to the organization of kinship and marriage. Eighty traits were assigned to this category.
- *Subsistence Economy*. This category includes traits relating to agricultural, horticultural, animal husbandry, and hunting and gathering extraction and processing techniques, dominant types of domesticated or wild plants and animals, and whether the extraction was local or extra-local. Fifty-nine traits were assigned to this category.
- *Technology*. This category covers food extraction and processing tools, transportation, housing, and clothing devices and materials. Eighty-four traits were assigned to this category.

Having re-organized the data, we carried out two analyses. The first focused on the scale of the impact of the migration on the cultural repertoires of the southern Dene. The second analysis assessed the relative importance of the three processes of change mentioned earlier, i.e., loss, borrowing from non-Dene neighbors in the Southwest, and invention. These analyses were carried out with an Excel spreadsheet, a copy of which is included as Supplementary Material 3.

We began the first analysis by inferring the states of the ancestor of the southern Dene for the 547 traits. This was accomplished by comparing the states of the three northern Dene groups for each trait. If the same state was present in all three, then the ancestor's state was deemed to be that state (e.g., if all three had "1 – present" as their state, then the state exhibited by the ancestor was inferred to be "1 – present"). If both "1 – present" and "0 – absent" were found among the northern Dene groups, then the ancestor was deemed to be polymorphic for the trait in question.

Next, we compared the state(s) found among the southern Dene to the state(s) inferred to have been exhibited by the ancestor of the southern Dene for each of the 547 traits and classified the traits as either "retained", "lost", or "added". A trait was classified as retained if none of the southern Dene groups had a novel state, i.e., none of them had a trait that was not also found in the ancestor (e.g., if all the southern Dene groups had "1 – present" and the ancestor of the southern Dene was inferred to have had "1 – present" too,

then the trait was deemed to have been retained). A trait was classified as lost if one or more of the southern Dene groups had "0 – absent", while the ancestor of the southern Dene was inferred to have had "1 – present." A trait was classified as added if one or more of the southern Dene groups had "1 – present", while the ancestor of the southern Dene was inferred to have had "0 – absent."

Thereafter, we calculated the percentages of retained, lost, and added traits for all 547 traits. We also calculated the percentages of retained, lost, and added traits for each category of traits.

The second analysis focused on the traits classified as lost and added in the first analysis. We began by comparing the southern Dene's traits with those of their non-Dene neighbors in the Southwest and then classified the traits as either "borrowed" or "invented". A trait was deemed to have been borrowed if the novel state found among the southern Dene was also found among the non-Dene. A trait was classified as invented if the novel state found among the southern Dene was not found among the non-Dene.

After classifying the added traits as either borrowed or invented, we calculated the percentages of lost, borrowed, and invented traits across all categories. In addition, we calculated the percentages of lost, borrowed, and invented traits for each category of traits.

Both sets of classifications—i.e., the classifications that focused on the retention, loss, and addition of traits, and the classifications that concentrated on borrowing versus invention—can be justified with the principle of parsimony. This can be illustrated by considering a trait in the southern Dene that was added relative to their ancestor and is also found among the non-Dene in the Southwest. There are three potential explanations for this distribution. One is that the southern Dene borrowed the trait from their non-Dene neighbors. Another is that the southern Dene and their non-Dene neighbors invented the trait independently. The third potential explanation is that the non-Dene borrowed the trait from the southern Dene. The first of these explanations requires fewer cultural evolutionary events than the other two and therefore is more parsimonious. As a second example of the use of the principle of parsimony to justify the classifications, consider a trait in the southern Dene that was added relative to their ancestor but is not found among the non-Dene. There are two potential explanations for this distribution. The first is that the southern Dene invented the trait. The second is that the southern Dene copied the trait from their non-Dene neighbors and their neighbors subsequently lost the trait. Once again, the first explanation requires fewer cultural evolutionary events than the second and therefore is more parsimonious.

Results

Assessment of the scale of impact of the migration

Five-hundred-and-forty-seven traits were scored as retained, lost, or added for the southern Dene. The trait-by-trait assessments can be found in Supplementary Material 3. The percentages of the three types of traits in each of the seven categories are shown Table 1.

Table 1 indicates that only 40% of the 547 traits were classified as retained, and that retained traits were the minority in six of the seven trait categories we utilized. The only category that retained a majority of traits was *Political Organization* (63%). These results suggest that the migration led to a cultural transformation.

Assessment of the relative importance of loss, borrowing, and invention

A total of 90 traits were classified as lost and 238 were classified as added in the first analysis. The trait-by-trait results of reclassifying the added traits as either borrowed or invented can be found in Supplementary Material 3. Table 2 shows the percentages of lost, borrowed, and invented traits in each of the seven categories, along with the ranks of the percentages by trait category.

Table 2 and Fig. 2 indicate that lost, borrowed, and invented traits are present in all seven categories, but their

Table 1 Counts and percentages of retained, lost, and added traits

Category	Traits	Retained		Lost		Added	
		#	%	#	%	#	%
Ceremonialism	83	39	47	11	13	33	40
Economic Organization	142	60	42	33	23	49	35
Political Organization	54	34	63	10	19	10	19
Religion and Magic	45	19	42	9	20	17	38
Social Organization	80	26	33	13	16	41	51
Subsistence Economy	59	22	37	8	14	29	49
Technology	84	19	23	6	7	59	70
All	547	219	40	90	16	238	44

Table 2 Counts and percentages of lost, borrowed, and invented traits in each of the seven categories, along with their rank order by category

Category	Traits	Lost			Borrowed			Invented		
		#	%	Rank	#	%	Rank	#	%	Rank
Ceremonialism	44	11	25	2	25	57	1	8	18	3
Economic Organization	82	33	40	2	36	44	1	13	16	3
Political Organization	20	10	50	1	6	30	2	4	20	3
Religion and Magic	26	9	35	1	8	31	3	9	35	1
Social Organization	54	13	24	2	35	65	1	6	11	3
Subsistence Economy	37	8	22	2	24	65	1	5	14	3
Technology	65	6	9	2	57	88	1	2	3	3
All	328	90	27	2	191	58	1	47	14	3

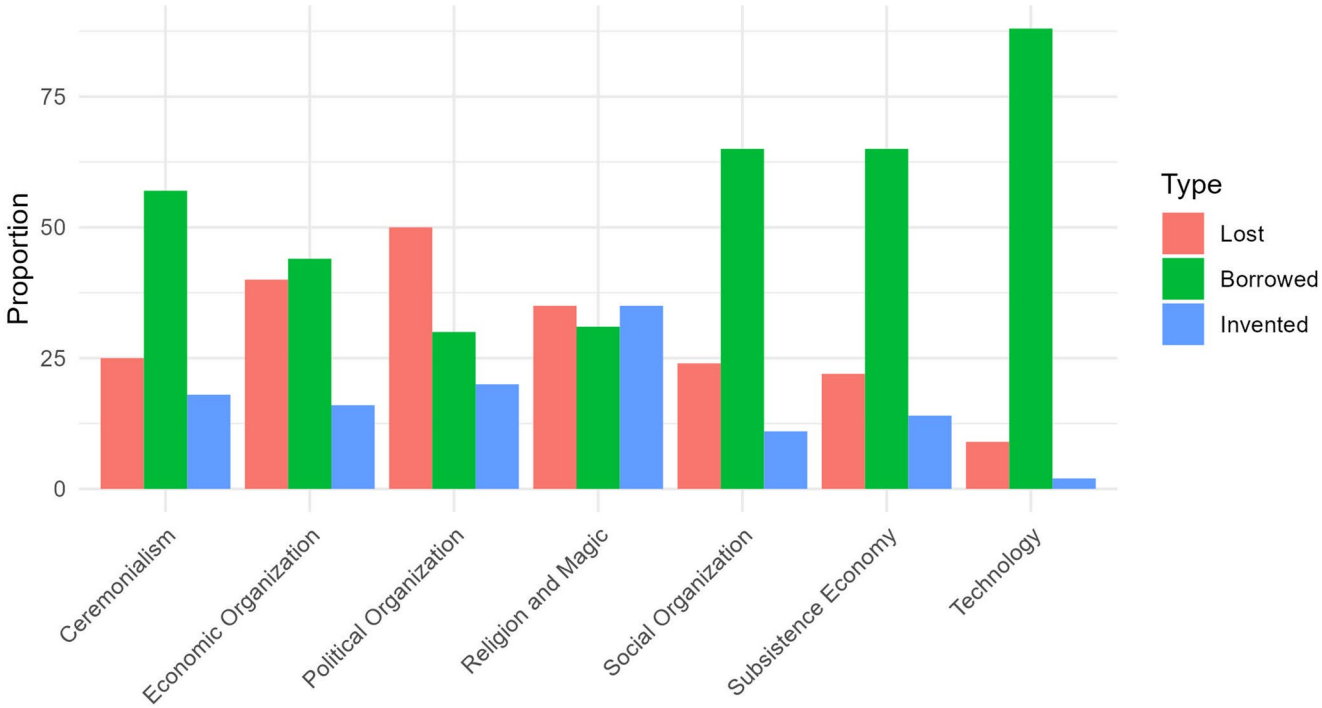

Fig. 2 Bar chart showing the proportions of lost, borrowed, and invented traits in each of the seven categories

relative frequencies vary markedly among the trait categories. The proportion of lost traits ranges between 40% (*Economic Organization*) and 9% (*Technology*), while the proportion of borrowed traits ranges between 88% (*Technology*) and 30% (*Political Organization*). The proportion of invented traits ranges between 35% (*Religion and Magic*) and 3% (*Technology*). Turning now to the rank order of the types of traits within each category, borrowed traits and lost traits are more common than invented traits, and borrowed traits are more common than lost traits, in the majority of categories. However, there are exceptions. For example, lost traits are more common than borrowed traits in *Political Organization* and *Religion and Magic*. The fact that the ranking of the proportions of the three types of traits varies by category suggests that the transformation of the cultural repertoires was not the result of a single process of change.

Discussion

The study reported here focused on the cultural effects of the migration of Dene groups from northwestern Canada and eastern Alaska to the American Southwest, which is thought to have begun shortly before 850 CE and taken 600−500 years. Specifically, we were interested in the extent to which the migration led to changes in the cultural repertoires of the southern Dene given the marked environmental and social differences between their ancestral homeland and the Southwest. We were also interested in the relative importance of three processes of change: loss, invention, and borrowing from neighboring non-Dene groups. To shed light on these issues, we carried out comparative analyses of 547 binary cultural traits derived from the data presented in Jorgensen's (1980) *Western Indians*.

The results we obtained indicate that the migration led to the transformation of the cultural repertoires of the southern Dene. Retained traits were the minority in six of the seven trait categories we utilized. The only category that retained a majority of traits was *Political Organization* (63%).

Regarding the relative importance of the three processes of change, the analyses indicated that all three affected each of the seven categories of cultural traits but did so to different degrees. The analyses also indicated that none of the processes of change was always dominant. In most categories, borrowing was the most important process and loss the second most important processes, but this was not always the case. This finding suggests that the transformation of the cultural repertoires of the southern Dene was not the result of a single process of change. Loss, borrowing, and invention were all involved.

The suggestion that the migration led to the transformation of the cultural repertoires of the southern Dene requires further discussion. There is no universally agreed way of identifying a sociocultural transformation (e.g., there is no consensus about the number of traits that need to be altered before it is justifiable to apply the term "transformation"). In general, though, for an instance of sociocultural change to be deemed a transformation by anthropologists and archaeologists three criteria have to be met (cf., Malinowski 1944, 1945; Plog 1974). First, a majority or at least a substantial minority of the cultural traits under consideration have to change. Second, multiple cultural domains have to be affected. The changes cannot be limited to one cultural domain, even if the traits in that domain represent the majority of traits under consideration. Lastly, the changes have to be irreversible, or at least long lasting. The episode of cultural change associated with the migration of the southern Dene to the Southwest meets all three of these criteria, in our view. Our finding that the percentage of retained traits was <50% in six of the seven categories is consistent with both the first and second criteria. The first criterion is even more clearly met if the categories of traits are ignored and the proportion of retained traits is calculated for all 547 traits that were scored as "retained," "lost," or "added". When this is done, only 40% of the traits were retained, meaning that almost two-thirds of traits were altered. The third criterion—that the change is irreversible or at least long lasting—is also met, although the possibility of reversion was presumably curtailed by European colonization.

The importance of borrowing as a process of change is also worth considering further. To reiterate, our analyses indicated that borrowing was the most common process of change for five of the seven trait categories and the second most common form of change for one of the other two (Table 2). A review of the trait-by-trait results (Supplementary Material 3) reveals that the southern Dene did not just borrow simple traits from their non-Dene neighbors. They also borrowed complex ones. The traits in the *Technology* category illustrate this. The technological traits that the southern Dene borrowed from their non-Dene neighbors included relatively simple ones like digging sticks, stone mortars, and headgear, but also relatively complex ones like boats and houses. They also borrowed the practice of weaving, which is highly complex. The fact that our analyses suggest that the southern Dene borrowed heavily from their non-Dene neighbors and copied not just simple traits, but also complex ones is interesting for several reasons. First, it is consistent with previous characterizations of the southern Dene as flexible and open to change (e.g., Meggers 1960; Seymour 2008, 2012; Ives et al. 2014 ; Doering et al. 2020). Second, it implies that relationships between the southern Dene and their neighbors were sufficiently peaceful that southern Dene individuals were able to spend enough time with their non-Dene neighbors to learn complex skills like weaving, which usually involves active teaching (Irons 1980; Tehrani and Collard 2009). Third, it points to a willingness and ability to overcome language barriers. The consensus among linguists is that the languages of the southern Dene contain relatively few loan words (Sapir 1921; de Reuse 2017) and there is no evidence for the existence of pidgins in the Southwest (Bereznak 1995). The implication of this is that groups in the Southwest likely employed a sign language alongside their spoken language and/or were proficient in more than one spoken language. Consistent with this, Ford (1983: 720) reported that Navajo was often used as a trade language in the Southwest in the historic period, with bilingualism being "extensive" as a consequence of "the stimulus of exchange".

The loss of so many cultural traits is perhaps the most surprising of the results we obtained. As noted previously, our analyses indicated that traits were lost in all seven trait categories, with the proportions of lost traits ranging from 7% to 23% (Table 1). The prevalence of loss is perhaps even clearer when the categories of traits are ignored, and the percentage of lost traits computed for all 547 traits. A total 90 traits were lost according to our analyses, which means that approximately 16% of the 547 traits were lost in connection with the migration. This suggests that the migration led to the cultural repertoires of the southern Dene being reduced in richness by nearly a fifth.

There would seem to be three main potential explanations for the loss of the 90 traits. One is that the traits were abandoned because they are no longer economically beneficial or beneficial in some other way. That is, the abandonment of the traits was an adaptive response to the novel environmental and social conditions encountered in the Southwest. Interestingly, a number of studies have found a positive association between hunter-gatherer toolkit richness and complexity on the one hand, and latitude on

the other, and argued that the association reflects cultural adaptation to environmental risk (e.g., Collard et al., 2005, 2013; Buchanan et al. 2016). This hypothesis predicts that a southward migration of hunter-gatherers should lead to a reduction in cultural richness. The second potential explanation is that the traits were lost due to a cultural analogue of the founder effect. A type of genetic drift, the founder effect is a loss of genetic variation that often occurs when a new population is established by a small group of individuals that are geographically isolated from a larger population (Ridley 1993). Importantly, these changes are the result of random sampling and therefore are not adaptive. A number of theoretical studies have shown that cultural richness and complexity can be lessened by a reduction in population size in a manner that is consistent with the founder effect (e.g., Shennan 2001; Henrich 2004). Hence, it is possible that the loss of traits by the southern Dene is a non-adaptive consequence of the decision to migrate. The third potential explanation is also a non-adaptive one. Recent work has suggested that cultural richness and complexity may be strongly influenced by the regularity with which skills are practiced (Arinyo i Prats et al. 2025). For most skills, there is a minimum frequency at which they have to be practiced if they are to be maintained by a population, and if the frequency of practice drops below this level, they can be lost even if they would still be beneficial (Arinyo i Prats et al. 2025). It is not hard to imagine that a migration of several thousand kilometers to a novel environment might lead to the frequency of practice of a number of skills dropping below the minimum required for the skills to be retained.

We will now shift focus and consider how our findings compare to previous research. Surprisingly few studies have examined the propensity for different categories of cultural traits to be retained, lost, borrowed, and/or invented, and even fewer permit direct comparison with ours. So far, we have only identified two such studies—Cavalli-Sforza et al. (1982) and Guglielmino et al. (1995). Unfortunately, even these studies only allow for the comparison of relative rankings of the proportion of retained traits and borrowed traits. To reiterate, in our analyses the category that retained the largest number of traits unchanged was *Political Organization* (63%) (Table 1). This was followed by *Ceremonialism* (47%), *Economic Organization* and *Religion and Magic* (both 42%), *Subsistence Economy* (37%), and *Social Organization* (33%). The category that retained the lowest number of traits unchanged was *Technology* (23%). With regard to borrowing, the category with the highest proportion of borrowed traits was *Technology* (88%) (Table 2). This was followed by *Social Organization* and *Subsistence Economy* (both 65%), *Ceremonialism* (57%), *Economic Organization* (44%), *Religion and Magic* (31%), and *Political Organization* (30%).

Cavalli-Sforza et al. (1982) sought to identify the cultural transmission processes by which a sample of young adult Americans acquired a range of different cultural traits. The traits were assigned to six categories: *Religion*, *Politics*, *Sports*, *Entertainment*, *Habits*, and *Beliefs*. Cavalli-Sforza et al. (1982) found that the traits in their religious and political categories were learned from parents and subsequently retained markedly more often than were traits in the other four categories. This mode of inheritance, which Cavalli-Sforza et al. (1982) called "vertical cultural transmission," should result in retention of traits across generations. Thus, Cavalli-Sforza et al.'s (1982) study suggests that the categories to which religious and political traits are assigned in our study should have the highest proportions of retained traits. Our results are only partly consistent with this. The categories to which such traits are assigned in our study are *Political Organization* and *Religion and Magic*, respectively. *Political Organization* had the most retained traits of the seven categories (63%), but *Religion and Magic* had the third most retained traits (tied with *Economic Organization* at 42%) (Table 1).

Guglielmino et al. (1995) investigated the distribution of 47 cultural traits among 277 African societies and sought to account for their distribution in terms of one or more of the following three processes: demic diffusion, cultural diffusion, and ecological adaptation. With demic diffusion, the distribution of cultural traits among societies is the result of a combination of a bifurcating radiation of societies and vertical cultural transmission. With cultural diffusion, the distribution of cultural traits is the result of societies copying from neighboring societies, which Guglielmino et al. (1995) refer to as "horizontal cultural transmission." With ecological adaptation, societies invent traits to cope with new environmental conditions. The 47 traits were assigned to six categories (*Family and Kinship*, *Economy*, *Social Stratification*, *Labor Division by Sex*, *House*, and *Various Others*) and Guglielmino et al. (1995) examined the ability of the three processes singly and in combination to explain the distribution of the traits in each category. They found that one of the trait categories, *Family and Kinship*, could be explained by demic diffusion. Two others, *Labor Division by Sex* and *Various Others*, could be explained by cultural diffusion. The remaining three categories required all three processes to be invoked.

As with Cavalli-Sforza et al. (1982), the trait categories used by Guglielmino et al. (1995) do not map exactly onto the ones we employed, but their *Family and Kinship* category and our *Social Organization* category are roughly equivalent, and their *Labor Division by Sex* overlaps with our *Economic Organization* category (Supplementary Material 2). Based on Guglielmino et al.'s (1995) results, our *Social Organization* category should have had one of the highest

percentages, if not the highest percentage, of retained traits among the seven categories, and our *Economic Organization* category should have had one of the highest percentages, if not the highest percentage, of borrowed traits among the seven categories. This is not the case, however. *Social Organization* had one of the lowest percentages of retained traits (33%) (Table 1), while *Economic Organization* had the lowest percentage of borrowed traits along with *Political Organization* (both 30%) (Table 2).

Obviously, these comparisons are less than ideal due to the limited overlap between the studies with regard to the trait categories. However, the comparisons do invite one tentative conclusion, which is that there is variation among cultures in the propensity for different categories of cultural traits to be retained and borrowed. More rigorous studies are required to be certain, but it seems unlikely that the disagreement between our results and those of Guglielmino et al. (1995) with regard to the propensity for family and kinship traits to be retained is simply a methodological artifact. Given the category to which we assigned family and kinship traits, *Social Organization*, had one of the lowest proportions of retained traits, it seems more probable that the disagreement is real and that the propensity for certain categories of cultural traits to be retained varies among cultures. The same holds for the disagreement between our results and those of Guglielmino et al. (1995) with regard to the propensity for *Labor Division by Sex* / *Economic Organization* traits to be borrowed. It seems more likely that the disagreement is a result of there being cross-cultural variation in the propensity for certain categories of cultural traits to be borrowed than that the disagreement is a methodological artifact.

This hypothesis—that there is cross-cultural variation in the propensity for certain categories of cultural traits to be retained or borrowed—is also supported by the work of Collard et al. (2006). These authors used a technique from evolutionary biology called cladistics to fit a bifurcating tree model (the model normally used to represent the tree of life) to 21 cultural and 21 biological datasets and calculated the model's goodness-of-fit to each dataset. They then compared the average goodness-of-fit for the biological datasets with that for the cultural datasets. The goal of this analysis was to assess the longstanding assumption in anthropology that blending processes such as trade, exchange, and copying have always been more important in the evolution of cultural similarities and differences among human populations than the branching process of population fissioning. Their main finding was that, on average, the tree model did not fit the cultural datasets any worse than it fit the biological datasets, which they took to mean that blending has *not* always been more important than branching in cultural evolution, contrary to what anthropologists have often assumed. More important for present purposes, though, is the fact that their analyses indicated that the cultural datasets varied widely in terms of how well the tree model fit them. The tree model fit some cultural datasets well, but fit others poorly. How well a bifurcating tree model fits a cultural dataset can be thought of as a measure of trait retention versus borrowing. Thus, Collard et al.'s (2006) analyses indicate that the cultural datasets they utilized varied widely in terms of the prevalence of retained and borrowed traits. Given that their cultural datasets come from different regions and time periods, this is in line with the hypothesis that there is cross-cultural variation in the propensity for certain categories of cultural traits to be retained or borrowed.

This hypothesis is probably still too simple. The fact that our analyses indicated the existence of marked differences among the seven trait categories in terms of the proportions of traits that were retained, lost, borrowed, and invented implies that there is not just cross-cultural variation in the propensity for certain categories of cultural traits to be retained or borrowed. It appears that categories of traits also vary in their propensity to be retained or borrowed, and in their propensity to be lost or invented. Collard et al.'s (2006) results are in line with this extension of the hypothesis, since their cultural datasets can be assigned to several of the trait categories we employed in the present study, including *Technology*, *Ceremonialism*, and *Religion and Magic*. Perhaps the most important implication of the revised hypothesis—that there is both cross-cultural and cross-trait-category variation in the propensity for cultural traits to be retained, borrowed, lost, and invented—concerns how we think about empirical cases in which cultural similarities between ethnographic groups or archaeological sites are evident (e.g., similar puberty rites, similar motifs on sherds of painted pottery). The default with such cases has long been to assume that the similarities reflect the operation of borrowing. However, the revised hypothesis implies that this approach is flawed and that a better way to proceed is to treat the cause of the similarities as an unknown and design analyses that will shed light on which process, or combination of processes, gave rise to the similarities in question. The revised hypothesis also implies we should avoid assuming that the process or set of processes responsible for generating the similarities between groups or sites in one cultural domain (e.g., housing) is also responsible for generating the similarities between groups or sites in another domain (e.g., weaving).

Turning now to future research, there are several possibilities that would build on the work reported here. One possibility is to compare the northern Dene with the Dene peoples of the north Pacific Coast. The Pacific Coast Dene also migrated south from their northern Dene homeland at roughly the same time as the southern Dene made their

longer migration to the Southwest. The Pacific Coast Dene, like their southern Dene relatives, also relocated to a new environment different from their original northern Dene homeland. However, as the Pacific Coast environment differs in many ways from the environment of the southern Dene in the Southwest it follows that their pattern of cultural trait retention, loss, borrowing, and invention may also differ. A useful question for this study to address is, Did the Pacific Coast Dene show similar rates of retention, loss, invention, and borrowing as the southern Dene?

A second possibility is to re-do the present study using smaller analytical units. In the study reported here, we treated the northern Dene, southern Dene, and non-Dene groups in the Southwest as units of analysis and therefore lumped together groups with different languages and cultures. While this level of comparison was appropriate for the purposes of the study, future work could use the framework and data from the present study to explore finer-grained comparisons. One interesting possibility would be to separate the Ndee and Diné groups to determine if these groupings reveal different patterns of retention and change. While both the Ndee and Diné are Athapaskan, we know that the cultural repertoires of these groups diverged after their arrival in the Southwest (Underhill 1974; Basso 1970, 1996) and identifying how these groups differ specifically in terms of traditional cultural traits would be illuminating.

A third possibility for future research would be to separate the southern Dene groups by arrival time in the Southwest to determine the effect of time spent in the region on borrowing and invention. As we pointed out in the Introduction, it has been suggested that Dene groups may have arrived in the Southwest in two waves (Hoijer 1956a; Opler 1961; Seymour 2009). The first is hypothesized to have comprised the Diné (Western Navajo and Eastern Navajo) and the San Carlos, Chiricahua, and Mescalero Ndee, while the second wave consisted of the other Ndee groups (Jicarilla, Lipan, and Western). Seymour (2009) suggested that the groups in the first wave adopted more Puebloan traits than groups in the second wave. The latter, Seymour (2009) argued, tended to interact with different neighbors and maintained a more mobile lifestyle for longer. It seems likely that this hypothesis could be tested with comparative analyses in which southern Dene groups are separated by arrival time and location in the Southwest.

Conclusions

In the study reported here, we investigated how the cultural repertoires of the southern Dene were affected by their ancestors' migration from the western subarctic of North America to the American Southwest, which began shortly after 850 CE and is thought to have lasted between 150 and 550 years. Specifically, we investigated the extent to which the migrants retained or changed cultural traits in the face of the novel environmental and social conditions they encountered in the Southwest. We also investigated the processes of change involved. To address these issues, we carried out comparative analyses of data from Jorgensen's (1980) classic book *Western Indians*. Jorgensen's (1980) data have been employed in many studies, but they have not previously been used to shed light on the Dene migration to the Southwest.

The results of the first analysis we carried out indicate that the migration had a major impact on the cultural repertoires of the southern Dene. Not only were nearly two-thirds of traits changed (60% of 547 traits), but also a majority of the traits in six of the seven trait categories we employed were altered by the migration. Given this, it is not hyperbole, we suggest, to talk in terms of the cultural effects of the migration being "transformational."

The second analysis we carried out focused on the relative importance of three processes of change: loss, borrowing from non-Dene neighbors in the Southwest, and invention. The results of this analysis indicated that all three processes affected each of the seven categories of cultural traits but did so to different degrees. Additionally, the analyses indicated that none of the processes of change was always dominant. In most categories, borrowing was the most important process and loss the second most important process, with invention the least common process. But this was not always the case. This finding is consistent with previous characterizations of the southern Dene as flexible and open to change (e.g., Meggers 1960; Seymour 2008, 2012; Ives et al. 2014; Doering et al. 2020).

Our results have implications beyond the issue of the southern Dene's migration to the Southwest. Most importantly, they challenge us to rethink how we approach empirical cases in which there are cultural similarities between ethnographic groups or archaeological sites. The default with such cases has long been to assume that the similarities reflect the operation of borrowing. However, our results cast doubt on this assumption and suggest that a better way to proceed is to treat the cause of the similarities as an unknown and design analyses that will shed light on which process, or combination of processes, gave rise to the similarities in question. The results of our analyses also imply that we should avoid assuming that the process or set of processes responsible for generating the similarities between groups or sites in one cultural domain is also responsible for generating the inter-group or inter-site similarities in another domain.

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Author contributions BB and MC designed the study. BB and MC transformed the data and ran the analyses . BB and MC interpreted the results, wrote the main text, and prepared the supplementary materials.

Data availability The data are included in Supplementary Material 3.

Declarations

Competing interests The authors declare no competing interests.

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