Cultural transmission and correlational selection in Late Period projectile points from the Puna of Salta, Argentina (AD 900 – 1500).

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Abstract:

This work proposes a methodology for documenting metric patterns of trait correlation in Late Period (ca. AD 900-1500) projectile points from the Puna and pre-Puna of Salta, Argentina. In so doing, our main goal is to explain the patterns observed in terms of mechanisms of cultural evolution and selection. We apply this methodology to assemblages from four archaeological sites whose chronologies are well established. As a result, we were able to document low degrees of variation, as well as high co-variation between metrical traits, suggesting a process of correlational selection that preserved an artefact design with a structure of highly integrated traits. This lends support to the hypothesis where replication of these projectile points ocurred within a process of stabilizing cultural selection through biased transmission mechanisms, which in turn favoured the selection of artefacts suitable for effective weapons.

Key Words: Evolutionary Archaeology – Cultural Transmission – Highlands of Salta – Projectile Points – Metric Variation

1. Introduction

During the last 300 years before European contact, a particular type of lithic projectile point predominated in Northwest Argentina: concave-based triangular points (Figure 1). These artefacts had bifacial or unifacial reduction and marginal retouch along the edges, and were made from fine-grained raw materials. This concave-based triangular design was found all over Northwest Argentina, from the mesothermal valleys to the high altitude Puna across the modern-day Provinces of Jujuy, Salta and Catamarca. Use of this projectile point reached its dominance in the assemblages during the second half of the Late period (AD 1200-1500) (Álvarez 2004; Ávalos 2002, 2003; Carbonelli 2012, 2014; Chaparro 2008/2009, 2009; Chaparro and Ávalos 2014; Elías 2007, 2010, 2012; Escola et al 2006; Flores y Wynveldt 2009; Gaal 2011, 2014; Lavallé et al 1997; Ledesma 2003; Leoni et al 2014; López et al 2015; Muscio and Vardé 2015; Olivera and Grant 2009; Ratto 2003; Sprovieri 2007; Williams 2003; Yacobaccio et al

2011). Furthermore, this morphological type was found in other regions of Argentina, such as Cuyo, Patagonia and Sierras Centrales (Balena *et al* 2018; Nami et al 2015; Revuelta 2010).

Figure 1. An example of an obsidian concave-base triangular projectile point from Cueva Nacimiento 1, Salta Province, Argentina.

The appearance of the concave-based triangular points in the archaeological record was related to the introduction of a new hafting technology that required a change in the stem of the point to form a basal concavity (Ávalos 2002). This projectile point design show a certain homogeneity in form and the frequent use of non-local obsidian for their manufacture (Álvarez 2004; Ávalos 2002, 2003; Chaparro 2008/2009, 2009; Chaparro and Ávalos 2014; Elías 2010, 2012; Flores and Wynveldt 2009; Gaal 2014; Ledesma 2003; Sprovieri 2007). However, with very few exceptions (Ledesma 2003; Muscio and Vardé 2015; Varde 2017), specific and detailed analysis of metric and formal variation of the points have not been undertaken. This is the aim of this article. Below, we present a methodology for recording the variation and co-variation of metric variables on projectile points. The assemblages studied herein date to the Late Period and are geographically from the Puna and pre-Puna of Salta, Argentina. Based on these analyses, we can then hypothesise concerning the role played by transmission mechanisms acting during the replication of these technologies within a wider process of stabilizing cultural selection.

1.1 Theoretical background

Evolutionary studies of the archaeology of the Puna of Salta, Argentina, has witnessed growth over the last few decades (Azcune and Gomez 2002; Cardillo 2002, 2005, 2009; Coloca 2017; Hoguin and Restifo 2012; López 2008; Mercuri 2011; Muscio 2004; Muscio and Cardillo 2014; Muscio and Lopez 2009, 2011; Restifo 2013; Varde 2017). This research agenda has integrated different evolutionary approaches, such as the *human behavioral ecology* (Smith 2000), the *theory of cultural transmission* (Boyd and Richerson 1985), and the so-called *evolutionary archaeology* (O´Brien and Lyman 2000). Here we contribute to this line of research through the application of a methodology especially designed for analysing variation, while applying the theory of cultural transmission and cultural selection. Our case-study analyses variation in the lithic points of the Puna and pre-Puna of Salta Late Period in Argentina.

During the Late Period, camelid hunting was documented at several highland archaeological contexts. This contextual archaeological evidence was of two types, zooarchaeological evidence of wild camelids, and the presence of projectile points used as hunting weapons (Albeck and Ruiz 2003; Izeta 2008; Angiorama 2011; Grant and Escola 2015; López et al. 2015; Mercolli 2010; Mercolli and Nielsen 2011; Moreno 2011; Nielsen 2003; Olivera 1997; Olivera and Grant 2008, 2009; Raffino et al 1977; Ratto 2004; Tarragó 2000; Vardé et al 2017; Yacobaccio et al. 1997/98; Yacobaccio et al 2011). This evidence demonstrates that during the Late Period, hunting was an important and enduring economic strategy that was employed even when pastoralism was well developed in the region. Moreover, it has been argued that hunting was a means of optimising animal biomass production for human consumption, given that it allowed for preservation of the domesticated herd (Muscio and Varde 2015). From an adaptive viewpoint, several authors have emphasised the functional relationship between the economic strategies of human groups and their lithic technologies (Goodale and Andrefsky 2015). On this basis, and without disregarding the possible use of these projectile points as weapons in interpersonal conflict, we propose that the pressures towards greater efficiency and effectiveness in the hunting of wild camelids provided the evolutionary context for the continued development of this technology.

1.1.1. Designs as units for the evolutionary analysis of artefacts.

Researchers have affirmed that culture evolves in a similar manner to biology, given that like biological evolution, cultural evolution implies a system of inheritance at the population level (Eerkens and Lipo 2005, 2007; Mesoudi et al 2006). In this framework, two main mechanisms of cultural evolution have been highlighted. On the one hand, under a mechanism of guided variation, new cultural variants are created and tested via experimentation, and retained by social learning. So, the general outcome of this process is an increase in variation within the cultural pool. On the other hand, under a mechanism of biased transmission, one existing cultural variant is favoured over others through social learning, leading to a variability decrease within the cultural pool (Boyd and Richerson 1985; Durham 1991; Eerkens and Lipo 2007). Furthermore, biased transmission is a cultural selection process, which we would expect to happen whenever the cost of error in an adaptive response is high (Boyd and Richerson 1985; Durham 1991; Richerson and Boyd 1992; Shennan 2002; Eerkens and Lipo 2005; Muscio 2009).

Within this analysis framework, various evolutionary researchers referred to "recipes" as “(…) behavioral information that can be transmitted between people about how to produce something that may or may not leave a material trace (…) the recipe concept behaviorally links two general structures – ingredients and rules – that can be reconfigured to form different recipes and thus different products (…)” (O’Brien, Lyman, Mesoudi, and Van Pool 2010: 3802). Artefacts are the product of cultural information that is preserved across generations within a population through the transmission of recipes, and its evolution occurs due to the two mechanisms indicated above (Boyd and Richerson 1985; Durham 1991; Eerkens and Lipo 2007).

In addition, artefacts have a structure that renders them able to perform certain functions, such as being utilitarian and/or symbolic (Schiffer 2010). We term this: its design. From this perspective, the design is the organizational unit of an artifact that confers its functional integrity and that results from the application of a recipe. It is at this level where we would expect transmission and selection to act on the design of the artefact through replicative differentials (Neff 2001).

From a structural point of view, the artefact design may include both, packages of correlated traits, and more varyingly autonomous traits. This correlation of traits results from correlational selection, which preserves optimal co-variation of traits for a particular function. This is known as ¨phenotypic integrity¨ (Goswami 2010). Therefore, the design has sufficient structural integrity (*sensu* Pocklington and Best 1997). This structural integrity means that component features cooperate with each other at a larger unit of scale. In this manner, artefact evolution can be explained by understanding the processes whereby novel variation in recipes is introduced resulting in new designs, complemented by the selection of certain particular designs over others. The *theory of cultural transmission* was developed to model these processes of cultural evolution in terms of biased and unbiased mechanisms (Boyd and Richerson 1985; Richerson and Boyd 2004).

In applying the cultural transmission framework to archaeological projectile point assemblages, Bettinger and Eerkens (1997; 1999) showed that as long as biased transmission acted on a dataset, variation decreased due to a lesser degree of guided variation action, and of other mechanisms that introduced variation. This is precisely what Boyd and Richerson (1985) predicted when modelling the two general mechanisms by which culture evolves. Also, Bettinger and Eerkens (1999) proposed that the hallmark of biased transmission –particularly indirect bias - was the correlation of artefact traits. This is because they assumed that variation was transmitted in packages of traits taken from successful social role-models (Bettinger and Eerkens 1997, 1999; Boyd and Richerson 1985; Eerkens and Lipo 2005, 2007; Lyman et al 2008).

Alternatively, we propose that cultural evolution can also proceed through the selection of artefact designs with optimal combinations of some of its traits (correlational selection). On this basis, we built a methodology that took into consideration the fact that artefact designs (and not just role-models) can be the focus of biased transmission mechanisms and replication. More specifically, we propose that the designs of the artefacts can be replicated through recipes that integrate packages of correlated traits and traits that vary more autonomously. In this way, the role of biased transmission is to selectively preserve optimal designs with such a structure of traits integration. Moreover, the preservation of the correlation between traits in artefact designs can be the result of stabilizing selection. By stabilizing selection, we refer to the selection process acting against extreme values of traits at the population level, which in turn produces a persistence of low levels of variation. In turn, this has also been used to explain stasis in morphological designs (Lieberman and Dudgeon 1996) and trait combinations in genetics as result of correlational and stabilizing selection (Johnson and Barton 2005).

Therefore, our methodology seeks to document the correlation and variation between the metric traits of projectile points. Our hypothesis is that during the Late Period the need for efficiency in hunting led to a process of stabilizing cultural selection that favored optimal designs of projectile points that decreased the failure during hunting. Furthermore, the information related to the replication of these artefacts was mostly transmitted in packages of traits, thereby helping to maintain optimal designs.

2. Materials and methods

The analysed assemblage consisted of a set of concave-base triangular projectile points (Figure 2) obtained from four sites with well-established archaeological contexts and radiocarbon dates, these are: Tastil, Cueva Nacimiento 1, Ojo de Agua, and Kilómetro 15 (Figure 3). Insofar as broken points were concerned, we only analysed those that had a broken tip or barbs, which allowed us to reconstruct their form, and so measure their metric variables. Those points which were too broken or reused were not used in this study. At the end, sample size was of 44 points. For each specimen, six (6) metric variables were measured using a calliper in order to record metric variation and covariation patterns (Figure 4). We used the Coefficient of Variation (CV), to measure the amount of variation in each metric trait. This consists of the standard deviation expressed as a percentage of the mean, and it offers a standardized value, useful for the comparison of different datasets (Vaughan 2001).

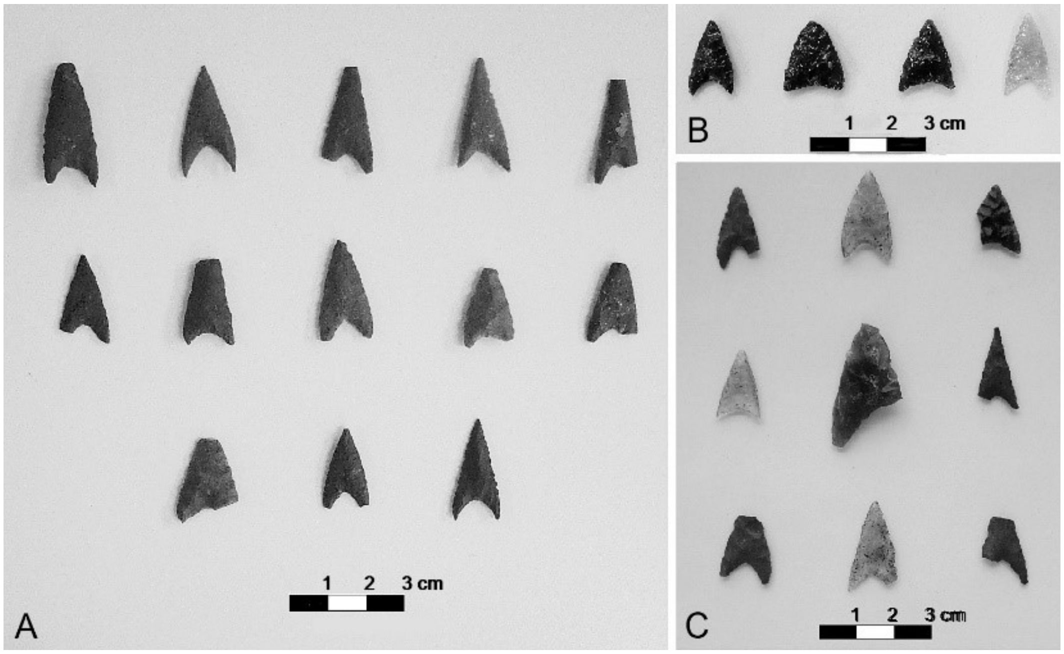

Figure 2. A selection of projectile points from the sample: A) Tastil; B) Ojo de Agua; C) Nacimiento 1 Cave.

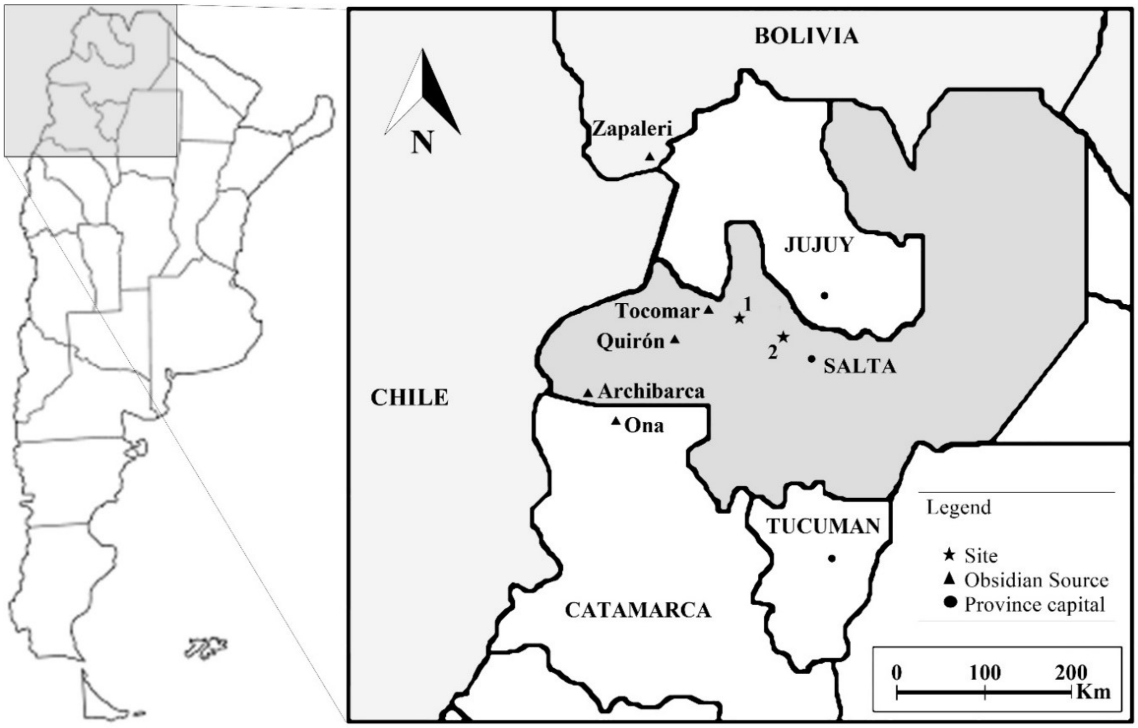

Figure 3. Map of the Northwest Argentina showing the main obsidian sources and the archaeological sites mentioned in the text: 1) Nacimiento 1; 2) Tastil, Ojo de Agua and Kilómetro 15.

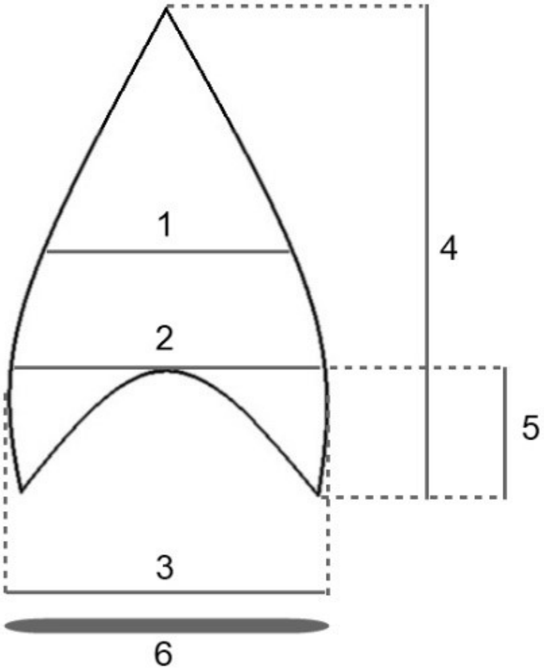

Figure 4. Metrical variables used for variation analysis: 1: Mid-width; 2: Width at the concave base; 3: Maximum width; 4: Length; 5: Concavity depth; 6: Thickness.

To assess the whole variation within the assemblage, we calculated the confidence intervals of each CV through resampling by using PAST (Hammer, Harper and Ryan 2001) and running it 10,000 times. As a result, we obtained a graph for each CV as observed in the sample, coupled with its respective confidence interval at 95%. This allowed us to compare each CV against the Averaged Coefficient of Variation (ACV) calculated as the mean of all the variation coefficients of the metric variables. ACV is important for documenting the degree of transmission homogeneity biases across the variables.

Eerkens (2000) suggests that CVs in the range of 2.5/4.5 % are typical of the minimum error individuals make during manual production of artefacts, if they do not use external rulers. Eerkens and Bettinger (2001), suggested a theoretically derived value of CV= 57.7 % as the baseline standard for random production of artifacts among humans. Variation above this figure suggests intentional introduction of variation by the artisans. On this basis, we used an ordinal scale between these two limits to assess the amount of variation within the dataset (Table 1).

To analyse the covariation between pairs of traits, we used the Pearson Correlation Coefficient (R), considering only p-values less than 0.05. For interpreting the magnitude of the correlations, we followed the Cohen scale (1988) which establishes that correlation coefficients in the order of 0.10 are "small," those of 0.30 are "medium", and those of 0.50 are "large" in terms of effect size magnitude (Table 2)

In order to identify the degree to which the correlations between pairs of variables were influenced by the variation of the other variables, we used partial correlation analysis. Partial correlation is a method for identifying the correlation between two variables, with the effects of a third variable being constant (Brown and Hendrix 2014). By this method, the variables correlated in relation with a third variable are expected to show a low or insignificant partial correlation coefficient. Conversely, the variables with the highest coefficients of partial correlation are those that correlate well and are less affected by the variance of a control variable. Hence, using this this procedure we could identify packages and pairs of correlated variables in the design of the projectile points, and the variables with a high degree of influence on the correlation matrix. To ease interpretation of the relationships between variables, we made a table that shows the different effects of each control variable in each pair of observed variables.

Table 1. Ordinal scale for the amount of variation within the dataset.

CV	Level of Variation
0 – 5	Standardization
5.1 – 31.35	Low
31.36 – 57.7	High
57.8 – 100	intentional introduction of variation

Table 2. Ordinal scale for the degree of the correlation between pairs of metrical traits.

PC	Degree of Correlation
0.1 – 0.3	Small
0.3 – 0.5	Medium

0.5 – 1	Large

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Finally, in order to record the lithic raw materials used in the manufacture of these artefacts and their provenance, a characterization of the rocks using chemical and petrographic analyses was generated. In assessing sourcing distances, we considered a distance of twenty-five kilometres as the limit between local and non-local sources (Lopez 2008).

4. Results

The results of the raw material analysis showed that all the projectile points in the sample were made from good quality raw material: obsidian, green silica, and aphanitic andesite (Figure 5). These are rocks with a very fine grain and conchoidal fracture. Some of the obsidian in the assemblage is from sources located at more than two hundred kilometres from the sites, such as the Zapaleri and Ona sources (Figure 3). In sum, the use of these rocks shows a strong preference for high quality materials in the manufacture of this design of projectile points, even when these materials came from very distant sources.

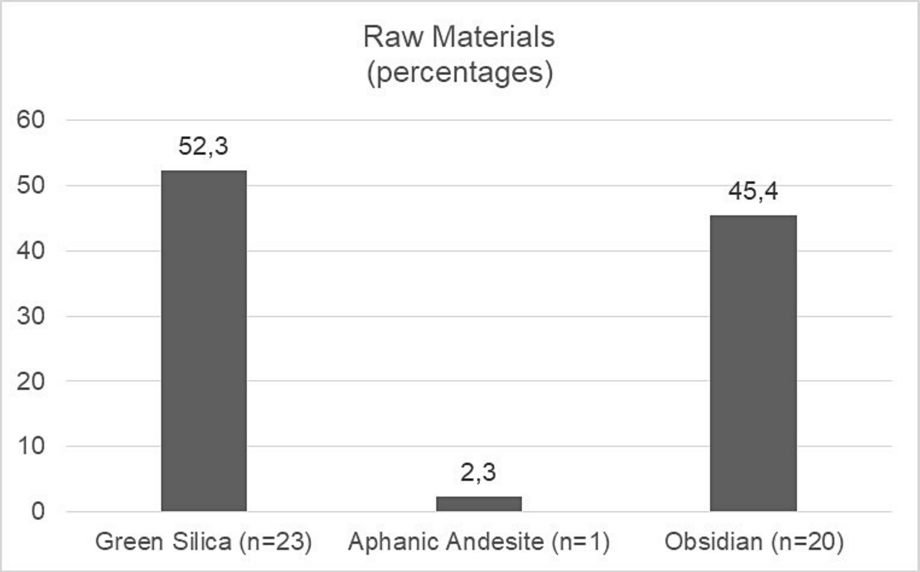

Figure 5. Percentages of the different lithic raw materials in the sample.

Regarding the degree of variation within the dataset (Table 3, Figure 6), with the exception of the concavity depth, the metrical traits show low amounts of variation measured by the CV. Also, the overall variation shown by the distribution of the CVs around the ACV indicates that when we consider the confidence intervals for each variable, the variation in the sample is not homogeneous. In fact, while the concavity depth is the trait with greatest variation, the maximum width and the width at the concave base have the lowest variation, and the rest of the variables remain close to the average CV of 19.8 %. We propose that this low level of variation in these two width traits could be explained by a strong replication bias towards maintaining regularity of the hafting system.

Table 3. Dataset with the statistics summary

Specimen	Length	Thickness	Maximum width	Mid-width	Width at the concave base	Concavity depth
1	38.7	5.3	14.4	11	14	5.7
2	30.5	3.5	15	10.8	14.2	7.9
3	35.9	3.1	13.7	10	13.5	7.9
4	32.6	3.7	14.7	7	13.4	5.3
5	37.4	3.3	12.2	8	12	8.4
6	23.7	2.4	13.3	10	12.9	5.1
7	27.3	3.5	14.4	10.8	14	4.9
8	26.3	4.8	13.6	10	13.4	3.8
9	25.2	3.9	14	8.5	12.9	4.4
10	28.5	2.9	13.6	9.4	13.4	6.5
11	26.5	3.1	16.7	11.6	16.5	3.5
12	25	2.8	12.3	10	12	6.2
13	26.7	3	12.6	8.4	12.2	5
14	25.6	4	13.7	9	13.2	4.3
15	25.5	3.3	12.4	9	12.4	5.7
16	23.9	2.8	13.2	8.7	12.4	4.5
17	31.6	2.9	12.9	10.4	12.5	8.1
18	30.4	3.5	13.4	10.7	12.9	6.6
19	30.5	3	15.2	11.5	14.7	4.9
20	29.4	2.8	14.5	12	14.3	7
21	25	2.7	12.8	8.7	12.2	6.4
22	21.3	2.6	12	12.6	15.7	4.3
23	24	3.3	15.3	12.2	15.2	5
24	20.1	3.1	12.6	9.4	12.6	3.7
25	18.8	3.5	16	12.5	16	1.5
26	20	3.5	15.2	10.5	14.6	2.8
27	21.5	3.2	12.5	10	12	4
28	20.8	3.3	10.8	9.3	10.6	3
29	30.2	3.4	15	11.2	14.5	5.2
30	34	4.8	15.5	10.5	14.5	6.2
31	22	2.5	11.5	8.5	11	6.1
32	24.44	3	13	11	13	4.9
33	18	2	13	9.5	13	3.1
34	21	3	9.5	10	9.5	5.9
35	17.5	3	12	8.5	11	3.1
36	37	5.2	18.5	16	19	7.9
37	23	2.8	11	12.5	10	3.1
38	27.5	3	13.5	10	13.5	9
39	31	3	14	17.5	12	7.5
40	22	2	12.5	9	11	5
41	25	2.9	13	8	11	5.9
42	23	3	13	9.5	11	6.1
43	30	2.8	15.3	11.9	15.3	8
44	25	3	12	9.7	12	6.9
Mean	26.44	3.23	13.53	10.35	13.11	5.46
St.Dev.	5.30	0.71	1.65	1.95	1.83	1.74
CV	20.03	21.87	12.20	18.86	13.99	31.91
ACV	19.81					

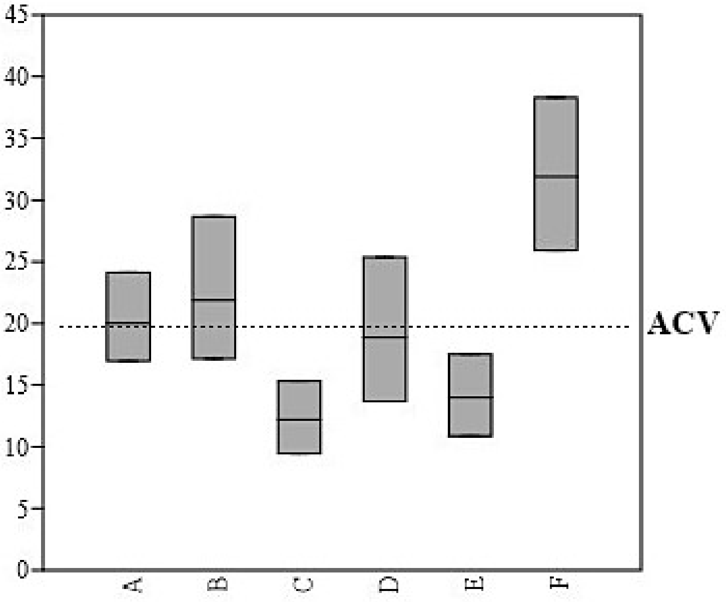

Figure 6. Boxplot of the six metric variables of the dataset with the average of the variation coefficients (ACV) (dotted line). A: length; B: thickness; C: maximum width; D: mid width; E: width at the concave base; F: concavity depth.

Table 4. R of Pearson for all the pairs of variables with p-values. Highlighted in grey all the coefficients with p-values of less than 0.05.

Pair of variables	R	P-value
Length – Thickness	0.53	0.00
Length – Maximum Width	0.46	0.00
Length – Mid-width	0.23	0.13
Length – Width at the concave base	0.38	0.01
Length – Concavity depth	0.69	0.00
Thickness – Maximum Width	0.49	0.00
Thickness – Mid-width	0.20	0.19
Thickness – Width at the concave base	0.44	0.00
Thickness - Concavity depth	0.04	0.81
Max width – Mid-width	0.47	0.00
Max width – Width at the concave base	0.89	0.00
Max width – Concavity depth	0.09	0.56
Mid-width – Width at the concave base	0.51	0.00
Mid-width – Concavity depth	0.13	0.42
Width at the concave base – Concavity depth	0.06	0.72

Table 5. Partial correlations for all the pairs of variables controlling every single variable of the dataset. Asterisks show statistically insignificant coefficients with p-values > 0.05.

	A	B	C	D	E	F
AB			0.39	0.50	0.44	0.69

AC		0.27*		0.41	0.29*	0.55
AD		0.15*	0.02*		0.05*	0.20*
AE		0.19*	-0.07*	0.31		0.47
AF		0.79	0.73	0.68	0.72	
BC	0.33			0.46	0.25*	0.49
BD	0.1*		-0.04*		-0.03*	0.20*
BE	0.30		0.00*	0.40		0.44
BF	-0.53		-0.01*	0.01*	0.01*	
CD	0.42*	0.43			0.03*	0.46
CE	0.87	0.86		0.85		0.89
CF	-0.35	0.08*		0.04*	0.09*	
DE	0.47	0.48	0.24*			0.51
DF	-0.05*	0.12	0.09*		0.11*	
EF	-0.30	0.04*	-0.06*	-0.01*		

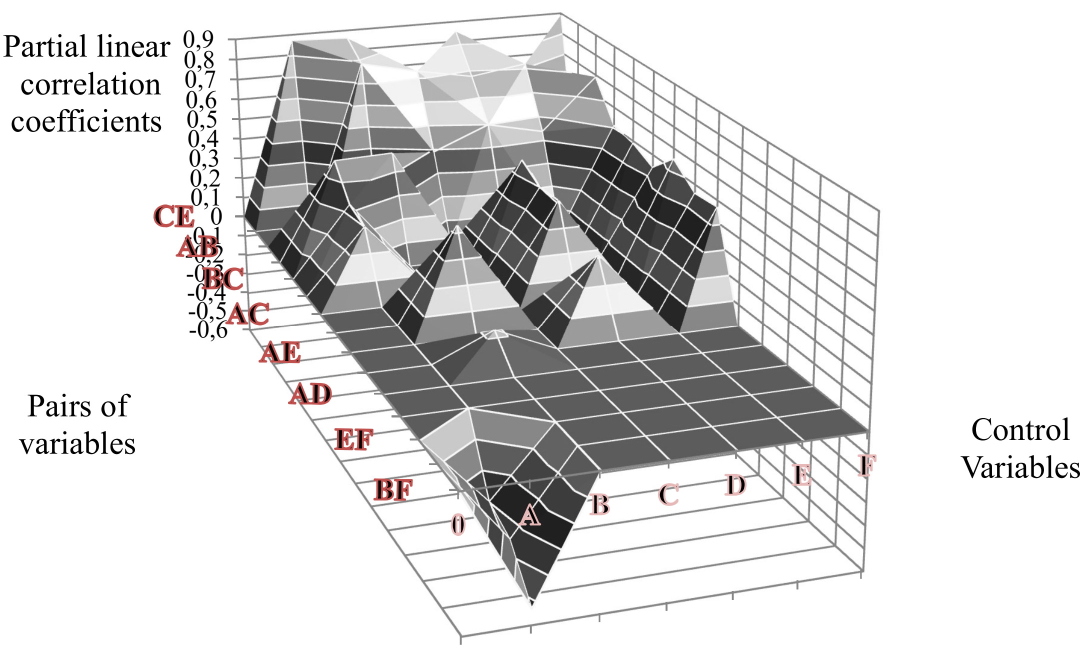

Figure 7. 3D-plot of the partial linear coefficients of the sample for every pair of variables and every control variable.

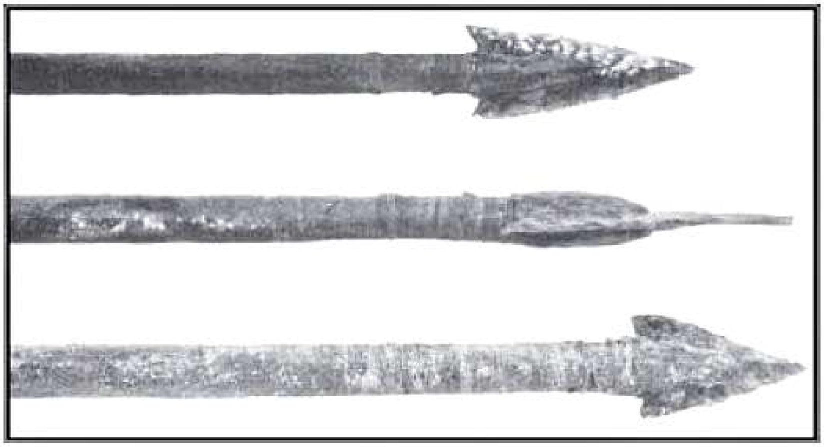

Figure 8. Arrows from the Late Period archaeological context of Tastil, Salta, Argentina (Cigliano 1973, p.197)

As Table 4 shows, we can see four variable pairs with statistically significant, large Pearson correlation values. These variable pairs are: length – concavity depth (A-F), length – thickness (A-B), maximum width – width at the concave base (C-E) and the mid-width – width at the concave base (D-E). These results demonstrate the existence of significant correlation between the design variables. We can see this more consistently when we analyse the results of partial correlation.

In the partial correlation matrix of variable pairs with the control of the individual effects of each variable (Table 5, Figure 7), we find a total of 60 correlation pairs, 20% of which are high values, 1.7% are statistically significant low values, while the remaining 48.3% correspond to associations with no statistical significance. As we can see in Figure 7, the distribution of the correlation pairs and their values in respect to each individual variable, indicates an area of large and medium correlation and a level where the correlation value for these pairs is zero or insignificant. In this second case, we found that the absence of correlation between those variables is highly influenced by the action of a third variable. Indeed, when we analyse the results of the Pearson correlation, these same pairs were not correlated in a statistically significant manner. This occurs with the pairs: length – mid width and thickness – mid width across all the variables in the sample. Contrawise, there are some variables that are correlated in a significant manner only when a single third variable is controlled. This is the case for the mid width – concavity depth; width at the concave base – concavity depth; maximum width – concavity depth; and thickness – concavity depth. None of these are correlated under Pearson. Of these, the last three pairs appear inversely correlated, whereas they are correlated only when the length is controlled. In sum, across the data matrix, 51.7% of the variation documents significant correlation between variables of the projectile point design. This suggests the action of biased transmission producing a high degree of correlation among several design variables. This same fact was noted in the Pearson correlation.

Interestingly, the two variable pairs that most co-vary independently from the rest of the variables are those related to the hafting system, given that these are the variables that give form to the basal portion of this design. These pairs are: maximum width – width at the concave base, with values above 0.8 for each control variable, and length – concavity depth, with values close to, and above 0.7. These represent the highest distribution peaks in Figure 7. The first case could be documenting the positional dependence of the base of the concavity in respect to the point of maximum width within the design. In the second case, the correlation between variables must have been functional in relation to the hafting system, limiting the expansion of the concavity over the blade area. In these two pairs, we notice high correlation accompanied by low variation, although this variation was slightly higher in the concavity depth, as we saw in Table 3 and Figure 6. In the data matrix (Table 5) the variables that most affect the correlation of the rest are the maximum width and the width at the concave base, which in turn are the ones with the least variation. Therefore, as we can observe in Tables 4 and 5 and Figure 7, the variables with the lowest variation coefficients are those that pertain to the width of the specimens, which likewise show clear correlation patterns with the other variables. These also have a major influence on the correlation observed between the remaining variables. We propose that the width variables of this projectile point design are directly and strongly related to the hafting system, in such a manner that the edge-area of the blade was increased to the maximum in relation to the hafting area. We can see this in the hafted points of this type found at Tastil (Figure 8).

On the other hand, length and thickness are strongly correlated, without the influence of other variables. The interaction between length and thickness is functionally related to the size of the wound inflicted on the prey such as wider thick points inflict larger wounds that increase the bleading (Cheshier and Kelly 2006). Also, length and thickness are related to the potential breaking of the tool and its durability (Cheshier and Kelly 2006). Actually, as length and thickness increase so does the lethality and the strength of the piece, until a point when these variables are optimal.

Following, the variables that appear correlated at a significant, though medium, degree, are always variables of the width. These pairs are: mid-width – width at the concave base; maximum width – thickness; and width at the concave base – maximum width. As Figure 7 shows, these correlations disappear when we introduce all the variables of the width. This means that they are not independent. For example, the pair mid width-width at the concave base shows strong correlations, but in relation with the maximum width this correlation loses statistical significance. In this sense, the width is a central variable in the design of these projectile points, a variable which interacts functionally with almost all the other variables. Likewise, we should highlight the strong correlation between the variables of the width and the length.

As we observe, the majority of the resulting patterns in the Pearson correlation analysis are maintained when we undertake partial correlations for each pair of variables. All this lends support to a selection process for a projectile point design with correlated traits, just as our hypothesis suggested for this concave-based triangular point design. Moreover, we document that these variables were replicated in packages, maintaining the functional relations between the variables at the design scale. This suggests selection towards optimal character combinations, or correlational cultural selection.

In this correlated variables package, the negative covariation between the concavity depth – thickness and maximum width – width at the concave base, could be explained in functional terms. As suggested by Dunnel (1978), on projectile points the presence of barbs is a functional trait that is favourably selected when there is limited necessity for removing the projectile quickly from the prey. Indeed, in our case, the size of the barb, defined by the concavity depth, increases when the projectile points become thinner and narrower. This could allow the projectile to stay stuck in the prey once impacted, and increase the lethality of thinner and narrower pieces. Ideed, this could explain the high frequency of these projectile points in the archaeological record of Cueva Nacimiento 1, as they probably were introduced into the cave inside the preys (Varde 2017). This functional hypothesis will require larger assemblages and the use of a different methodology –such as experimentation– to further prove or disprove it.

5. Discussions and conclusions

During the Late Period in the Argentine Puna (*ca.* AD 900–1500), hunting was a critical strategy for the obtention of animal biomass. Along with this, the use of domesticated llama livestock, as well as trade networks, created a mixed economy which contributed to manage the risks of resource fluctuation in the Puna desert environment (Escola 2002; Hocsman and Escola 2006/07; López 2002, 2003; Moreno 2011; Muscio 2004; Olivera and Grant 2009; Yacobaccio *et al.* 1997/98).

The Puna environment is particularly hostile to llama neonates, given that these suffer a high mortality rates due to early frosts (Yacobaccio *et al* 1997/98). Currently this situation is managed through the breeding of mixed herds of goats, sheep and llamas (Yacobaccio *et al.* 1997/98; Yacobaccio and Vila 2013). This solution was not available in the Prehispanic past. So, whereas it is true that domesticated livestock herds were a risk-management strategy, for this strategy to work the demographic viability of the herds had to be maintained (Flannery, Marcus and Reynolds 1989; Yacobaccio *et al.* 1997/98; Olivera and Grant 2009). Therefore, from an optimal decision-making viewpoint (Winterhalder and Goland 1997), we can predict that high-ranked wild animal preys –which are production cost free– will be exploited whenever possible, thereby mitigating the need to kill members of the herd. This is crucial towards improving livestock's demographic viability. Due to this, in this paper we propose that hunting was a strategy that optimized animal biomass obtention, as well as enhancing domestic herd viability. In turn, this led to a selective context that favoured a highly efficient and lethal projectile point design. Given that increasing hunting efficacy required reliable projectile points, cultural transmission acted selectively towards maintaining optimal character correlations, high levels of replication fidelity, and low variation patterns, as our results document.

The low metrical variation documented in our sample supports the hypothesis of high incidence of biased transmission mechanisms concerning the concave-base triangular projectile point design. This is indicative of a stabilizing selection process that acted against extreme values of the traits. Moreover, as we showed through the Pearson correlation and partial correlation analyses, there was significant correlation between the metrical traits of the studied design. This is the mark of transmission and replication in packages of correlated traits, and of a process of correlational selection that maintained the functional integrity of these Late Period triangular points. As we saw in the results, the variables with the least variation are those of width. In turn, these correlate well and strongly with the other variables, and at the same time affect the correlation between other metric variables. This resulted in a blade design that maximised the edge-area in relation to the haft, turning these projectile points into very lethal weapons, even for potential use in interpersonal violence. We also documented a strong preference for high quality rocks for use in reduction and retouch, shaping sharp cutting edges. As we have shown, some of these materials were sourced far from the sites analysed, and were probably obtained through trade (see obsidian sources in Figure 3).

It is important to note that these artifacts were part of a complex system, such as the bow and arrow, and that cultural selection could also have acted at this higher level. This could potentially make other traits, such as those of the haft and the bow, liable to be controlled by biased transmission. This might be exemplified by the very low variation in the maximum width of this design, where the point would have interacted with the width of the haft.

Furthermore, as we noted, this projectile point design quickly achieved a large geographical dispersion throughout Northwestern Argentina, dominating the archaeological assemblages of the Late period. As we have suggested throughout this article, this phenomenon can be explained in selective terms by taking into account the high efficacy for hunting, and probably for defence, of this design. In fact, there is ethnohistoric documentation of inter-human competition in the Calchaqui Valley, as well as archaeological rock-art scenes showing group conflicts using bows and arrows from the Argentine Puna (De Hoyos 2010; Martel 2010; Martel y Aschero 2007). From a selective point of view, it is expectable that an advantageous trait such as this kind of artefact would spread out quickly throughout a population (Cavalli-Sforza 2001). This is why we believe that both selection and biased cultural transmission best explains the geographical dispersal and perseverance of this projectile point design throughout the Late Period. In sum, we suggest that the high degree of social interaction between distant geographical areas of Northwestern Argentina and Chile facilitated access to distant raw materials, and provided the context for the spatial dispersal of this design via mechanisms of horizontal cultural transmission and adaptive learning among groups.

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