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Testing an ethnographic analogy through geometric morphometrics: A comparison between ethnographic arrows and archaeological projectile points from Late Holocene Fuego-Patagonia

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ABSTRACT

Under certain conditions, ethnographic analogies can help to shed light on past behaviors registered in the archaeological record via observation and model-building from modern societies. In this context, ethnographic weapons are often used as morphometric models to assign a given function to archaeological projectile points. For southern Patagonia, J. Bird proposed a functional analogy between arrows used by the Ona (also known as Selk'nam), a hunter-gatherer group that inhabited northern Tierra del Fuego during historical epochs, and the type V Late Holocene projectile points from southern continental Patagonia. Based on the similarity in terms of small size and shape attributes between the type V archaeological points and Ona (Selk'nam) ethnographic arrows, Bird proposed that the former were arrow points. Here we test the morphometric analogy based on comparisons of size and shape variables defining Ona (Selk'nam) arrows from museum ethnographic collections, and type V projectile points from southern Patagonia archaeological sites. Then, we assess the relative importance of projectile point reduction as a source of morphometric variation. We compared both, archaeological and ethnographic points using geometric morphometrics and multivariate statistical analyses. Results showed significant shape differences between ethnographic and archaeological samples before and after controlling for size and reduction parameters, suggesting that both kinds of points had different designs and life histories. However, when spear-like points are included in the comparison, Ona (Selk'nam) and type V points tend to cluster together. The results obtained from this broader comparison framework suggest that, when functional diversity and reduction effects are taken into account, ethnographic weapons can be considered as useful morphometric models to infer the function of archaeological points. Our results highlight the importance of considering similarities in environment, subsistence, mobility, tool design constraints, and lithic characteristics prior any extrapolation based on ethnographic analogies.

1. Introduction

Ethnographic analogies are based on the analysis of variation patterns known from ethnographic or historical sources to infer or reconstruct technological behaviors that evolved on a different group, whose characteristics can only be inferred from archaeological evidence. Nevertheless, comparisons between contemporary and prehistoric societies cannot be made without caveats (Wobst, 1978; Binford, 1967; Spence, 2011; Currie, 2016, among others). As Wobst (1978) pointed out, the anthropological literature may be partly determined by constraints on ethnographic fieldwork and its particular boundaries of space, time and behavior patterns. Therefore it may be insensitive when dealing with behavioral variability in the archaeological record, which is expressed across larger units of space and time, a problem labeled as "the tyranny of the ethnographic record" (Wobst, 1978).

To cope with some of the abovementioned limitations, at least two conditions must be achieved. Firstly, some degree of historical continuity between the archaeologically-observed unit and the ethnographically referenced society must exist. Secondly, environmental similarity is important to maximize the utility of the analogy, under the basis that similar environments are likely to be exploited in similar ways (Binford, 1967). One way of ensuring that analogy-driven reconstructions are useful is to ask whether the behavior that one is trying

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to reconstruct has been previously documented in the ethnographic record, and if so, under what circumstances. These general criteria, whose significance has been addressed by archaeologists from different backgrounds, can be further explored using ethnographic weapons as a study case. Specifically, since preservation problems of the perishable materials (e.g. wooden shafts and bows) impede the archaeological recovery of the complete lithic point's technical system, ethnographic analogies become a very valuable, alternative source of information to infer the function of archaeological projectile points (Ratto, 2003; Shott, 1997; Thomas, 1978, among others). Moreover, fundamental similarities in subsistence, mobility, tool-design constraints, and lithic technology, for instance, generally enhance the linkage between the ethnographic model and the concomitant archaeological record (Hayden, 2015). As Hutchings (2016, 9) pointed out, the historical approach may reasonably be employed to construct functional hypotheses when, for instance, the breakage patterns associated with thrusting- and projectile-weapons are also observed in point types already reported as weapon tools.

Among weapon systems, bow and arrow technology is a relatively recent innovation, despite of its ubiquitous use in historical times (Ames et al., 2010; Hughes, 1994; Shott, 1997, among others). Archaeologists are usually interested in addressing questions such as when and why this technology was adopted, whether it was enough efficient to replace spear systems, if the replacement was abrupt or gradual, or if both kinds of technologies were used for different targets and/or contexts (Shott, 1997, see references therein). For this reason, the identification of arrowheads in the archaeological record is a fundamental issue, as well as a problematic one when the whole weapon system is unpreserved. In this context, ethnographic models are useful to estimate some parameters that could serve as proxies to assign a function to archaeological points. Such estimations must follow a careful, deductive procedure, thus avoiding straightforward and reductionist extrapolations from ethnographic data to the archaeological record (Binford, 1967).

In his seminal works in Fuego-Patagonia, Junius Bird (1938, 1946, 1988) indicated a large form similarity between historical Ona (i.e. Selḱnam) arrows from the Isla Grande of Tierra del Fuego (southern insular Patagonia) and projectile points recovered in Late Holocene archaeological sites located on mainland (southern continental Patagonia). According to this ethnographic analogy, and considering the smaller size of type V points in relation to older archaeological points such the type IV ones (see Charlin and González-José, 2012 for a comprehensive review on both types), Bird suggested that type V points were used as arrows. Further reports based on functional models and mophofunctional expectations suggested the simultaneous use of arrows and spears during the Late Holocene (Banegas et al., 2014; De Azevedo et al., 2014; González-José and Charlin, 2012; Ratto, 1994). A recent date of 1670 ± 30 BP for a bone spear thrower hook from Fell cave, recovered in 1959 and stored in the Instituto de la Patagonia (Magallanes University, Punta Arenas, Chile. Prieto and Mena, 2016) bring support to these suggestions. Even though several of the above-mentioned studies were focused on identifying functional variations on late archaeological projectile points of southern Patagonia, the size and shape similarities between Ona (Selk'nam) arrows and type V projectile points is a common assumption that is still to be formally tested. As Binford (1967) has emphatically argued archaeologists have generally used the analogy with ethnographic data as a means of "interpreting" archaeologically observed phenomena, rather than as a way to fuel new research avenues. Therefore, our aim here is threefold. Firstly, we aim to assess the Birdś suggestion of similarity between archaeological and ethnographic points by comparing size and shape variables measured on Ona (Selk'nam) arrows from museum ethnographic collections, and type V projectile points from southern Patagonia archaeological sites. Secondly, we estimate the potential impact of projectile point reduction in the observed morphometric variation. Finally, we discuss the utility of ethnographic models to estimate projectile point's past functions. In this context, we will highlight the importance of taking into account similarities in environment, subsistence, mobility, tool design constraints and lithic technology characteristics prior to any extrapolation based on ethnographic analogies.

2. Materials and methods

2.1. Regional background

After the pioneering archaeological research in Fell and Pali Aike caves (Magallanes, Chile), which provided solid evidence of ancient human occupation, J. Bird defined a regional, southern continental Patagonia settlement sequence from ca. 11,000 BP to historical times (18th century). It distinguishes five prehistoric periods prior to the European contact according to artifact types and faunal remains (Bird, 1938, 1946, 1988). Among stone tools, projectile points and scrapers' shape and size were the key traits used to discriminate among periods (Bird, 1946). Thus, periods IV and V, corresponding to the end of the prehistoric (Late Holocene) sequence, were defined on the basis of the presence of two specific projectile point types: IV or Patagonian- and V or Ona-points, respectively. Both point types were named according to the ethnographic groups known in historical times for southern continental and insular Patagonia, respectively.

The Ona (Selk'nam) were hunter-gatherers specialized in land resources, mainly guanaco (*Lama guanicoe*), who occupied northern Tierra del Fuego at the arrival of Europeans (Borrero, 2001; Chapman, 1986 [1982]). "Ona" was the name used by the Yámana, a marine hunter-gatherer group settled in the coast of the Beagle channel and southernmost islands of the archipelago of Tierra del Fuego, to refer to their northern land neighbors, who, in turn, recognized themselves as Selk'nam (Bridges, 1952). Some of the Ona (Selk'nam) weapons, as well as other kinds of artifacts, are currently stored in several museums across Argentina, Chile and Europe (see Charlin et al., 2016; Prieto and Cárdenas, 2002, 2006). Based on the morphological similarity between the archaeological projectile points belonging to the Period V (ca. 700 BP) and the ethnographic Ona (Selḱnam) arrows stored in museums, Bird labeled the Period V archaeological projectile points as "Ona points" (Bird, 1983, 1988). Such similarity also led him to note that "Small arrow points of a type characteristic of the *Ona* associated with other typical *Ona* artifacts (…) show the relative late presence of this tribe on the mainland*"* (Bird, 1946, 20). Hence, Bird proposed that this group had inhabited mainland areas during prehistoric times, a claim strongly questioned by other authors (Borrero, 1989–1990; however see Goñi, 2013). It is worth mentioning that during the Pleistocene and Early Holocene, the Isla Grande of Tierra del Fuego was connected to the continent due to lower sea-levels (McCulloch et al., 1997, 2005). This and other data suggest that early southern Patagonian hunter-gatherer populations shared a common population origin (González-José et al., 2001, 2002, 2004, 2008), a subsistence strategy based on guanaco hunting (Borrero, 2003; Massone, 1987, 2004; Mengoni Goñalons, 1987), and a lithic technology for weapons known as Fishtail projectile points (Bird, 1946, 1988; Jackson, 1987; Massone et al., 1993; Nami, 1985–1986; Prieto, 1991, among others). However, after the formation of the Magellan strait, ca. 8000 BP (McCulloch et al., 1997, 2005) mainland and Fuegian populations remained divided and isolated, an event that triggered a long-term cultural divergence process (Borrero, 1989–1990).

In order to assess the incidence of this process on stone tool evolution at both sides of the Magellan strait, Cardillo et al. (2015) compared the composition of late lithic assemblages, and detected significant differences in tool types abundance and occurrence between southern continental Patagonia and northern Tierra del Fuego samples. An important result of this work was that the assemblage composition was not related to environmental variations, a common assumption held on inter-regional comparisons (Cardillo et al., 2015). In parallel, Charlin et al. (2013) explicitly tested the null hypothesis of morphometric similarity between Late Holocene projectile points from southern continental Patagonia and northern Tierra del Fuego. They did so by performing size and shape comparisons between archaeological samples recovered within an area of 100 km far away from both Magellan strait coasts. The obtained results showed statistical differences in the whole shape of the points as well as in the blade and stem shapes. Also, both parts showed differential shape covariation patterns between mainland and island samples, as well as a distinct general allometric pattern (Charlin et al., 2013). Franco (1999, referred in Franco et al., 2005) had also noted differences in terms of raw material and metrical attributes between northern and southern Magellan strait archaeological projectile points.

Departing from this general context of mainland/island divergence, here we aim to test the Bird's ethnographic analogy in terms of projectile point size and shape parameters. For decades, the sequence of projectile point types proposed by Bird for southern continental Patagonia constituted a general framework to develop archaeological research questions. Even though subsequent studies have discussed several assumptions of this periodization, they have especially focused on the chronological framework of the last periods (Gómez Otero, 1986–1987; Massone, 1979, 1989–1990; Nami, 1984a, 1984b, Sanguinetti de Bórmida, 1984, among others), rather than focusing on the analogy between type V and Ona points.

To achieve the abovementioned objectives, here we explore ethnographic and archaeological projectile points samples using geometric morphometrics (Bookstein, 1991), and traditional multivariate statistical methods.

2.2. Ethnographic and archaeological projectile points samples

The ethnographic sample includes 50 complete or slightly damaged Ona (Selk'nam) arrow points surveyed at Museo Etnográfico "J.B. Ambrosetti" (Facultad de Filosofía y Letras, Universidad de Buenos Aires, Argentina), Museo de la Patagonia "Francisco P. Moreno" (Administración de Parques Nacionales, San Carlos de Bariloche, Argentina), Instituto de la Patagonia Austral (Universidad de Magallanes, Punta Arenas, Chile), Weltmuseum Wien (Vienna, Austria), Musée du quai Branly (Paris, France), and Ethnologisches Museum (Berlin, Germany) (Table 1, Fig. 1). All the points were collected from the late 19th–early 20th century by European and Argentinean expeditions (see Charlin et al., 2016 for a broad description about collections details), and all of them are made in glass. The use of glass to make projectile points was quickly adopted by the aboriginal populations; indeed, it was the first cultural change produced by colonialism, even before the direct contact with Europeans took place. The glass was available from shipwrecks (Borrero, 2001, 146), and it was frequently used by native populations for making points and scrapers on bottle fragments (Jackson, 1991a, 1991b).

The archaeological sample is composed by 189 lithic stemmed projectile points from Late Holocene southern continental Patagonia (southern Santa Cruz Province, Argentina and Magallanes, Chile, Fig. 2). Forty-five of them correspond to type V, which are the focus of the study, and 144 to type IV, included later in a comparative analysis.

Table 1
Ona (Selk'nam) ethnographic points studied here.

Museum/Research Institution	Collection	N
Museo de la Patagonia Francisco P. Moreno	E.A. Artayeta	4
Instituto de la Patagonia Austral	no data	1
Museo Etnográfico J.B. Ambrosetti	no data	20
Quai Branly	H. Rousson and P. Willems	1
	no data	3
Ethnologisches Museum	Herr Mallman	20
Weltmuseum Wien	M. Gusinde	1
Total		50

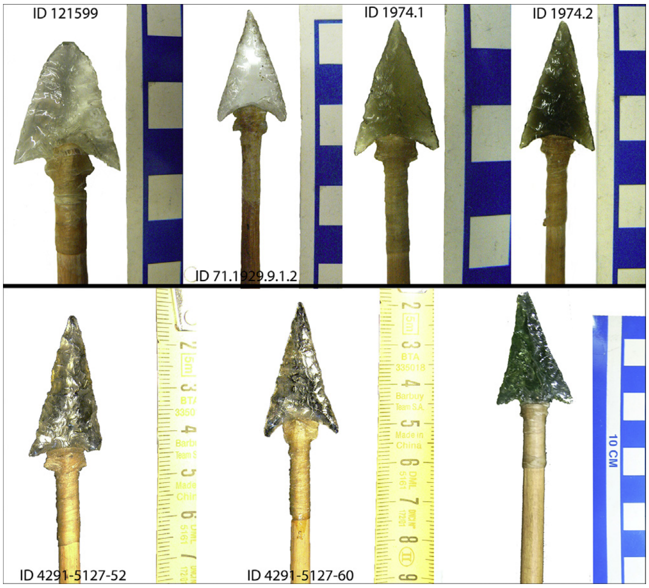

Fig. 1. Ona (Selk'nam) arrows from Weltmuseum Wien (ID 121599), Museé du Quai Branly (71.1929.91.2), Ethnologisches Museum (ID 1974.1 & 2), Museo Etnográfico J.B. Ambrosetti (ID 4291-5127-52 & 60), and Instituto de la Patagonia Austral (without ID).

The major part of southern continental Patagonia is covered by a volcanic field that represents the southernmost occurrence of the Cenozoic back-arc Patagonian Plateau Lavas, between 51°26′ and 52°16′ of south latitude, a system known as Pali Aike Volcanic Field (PAVF) (ĎOrazio et al., 2000, 2004). Note that the continental Patagonia southern limit, the Magellan strait, is located immediately southwards of PAVF (see Fig. 2).

Typological classification of archaeological points was done according to Bird's general description (Fig. 3), and stem size and shape characteristics according to Charlin and González-José (2012) analyses aimed to test the reliability in the discrimination between types IV and V.

The sample derives from authors' research projects, published literature revision, and survey of museum collections (Table 2). It comprises complete or very slightly damaged tools. Most of the type V points are made on black dacite (51%, n = 23), a high quality lithic raw material available in low density in some PAVF secondary deposits (Charlin, 2009a, 2009b; Charlin and D'Orazio, 2010). Chalcedony (27%, n = 12) represented the second-most used resource, whereas chert and obsidian are represented by a few cases (n = 2 in each case). Five specimens scanned from published local literature presents no data about lithic raw material. According to Nami's studies on reduction sequence on type V points, these are made on small-medium flakes involving four stages of reduction (Nami, 1984a, 1986, 1986–1987). In fact, the particularity of this kind of points in relation to type IV, is that they were manufactured directly on flakes without any previous preparation of a biface before the final thinning (Nami, 1984a, 1986, 1986–1987).

2.3. Geometric morphometrics analysis

Geometric morphometric shape analysis allows quantification of variation in size and shape as separate variables using discrete points called landmarks and semilandmarks (Zelditch et al., 2004). In general, landmark configurations are analyzed using the generalized least-squares Procrustes method (Generalized Procrustes Analysis-GPA) that, in the case of bilateral structures with object symmetry like projectile points, superimposes the original configurations and their mirror images, and subdivides the total shape variation into components of

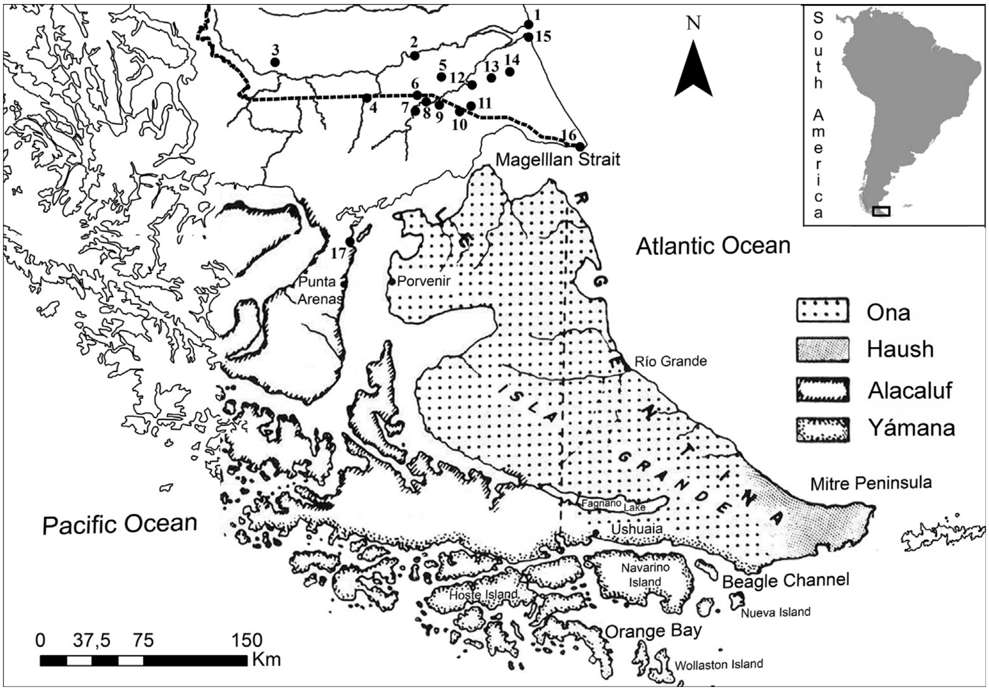

Fig. 2. Location of type V projectile point archaeological samples from southern continental Patagonia and territories of ethnographic groups from Tierra del Fuego at historical times (taken from Chapman, 1986 [1982] with modifications). References: 1. RUD0 2, 2. Las Buitreras 1, 3. Laguna Cóndor, 4. Juni Aike 1, 5. Cerro Mackenzie, 6. Don Ariel, 7. Peggy Bird, 8. Fell, 9. Thomas Gould, 10. Pali Aike, 11. Laguna Azul, 12. El Volcán 4, 13. Cueva Cóndor 1, 14. Frailes 2, 15. Punta Loyola, 16. Punta Dungeness 2, 17. Laredo 1.

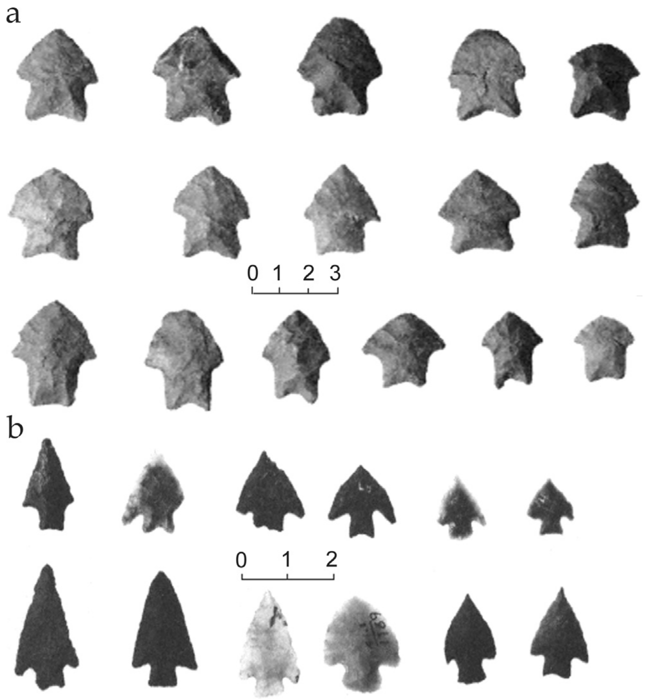

Fig. 3. Type IV (a) and V (b) projectile points identified by Junius Bird from Pali Aike cave (taken from Bird, 1988, Fig. 34 and 35 with modifications).

Table 2
Type V archaeological points studied here.

Archaeological sites	N	References and Collections
Don Ariel	1	Nami (1999)
Punta Loyola	1	Carballo Mrina and Ercolano (2007)
El Volcán 4	3	Nami (1984a, 1984b, 1986) and Ratto (1994) (IMHICIHU col.)
Laguna Cóndor	2	Gómez Otero (1986–1987, 1987) (CENPAT col.) and Charlin et al. (2011)
RUD0 1 BK	1	Mansur et al. (2004)
Pali Aike	8	Bird (1988)
Las Buitreras 1	1	Sanguinetti de Bórmida (1976) (IMHICIHU col.)
Juni Aike 1	1	Gómez Otero (1989–1990), Prieto (1997) and Ratto (1994)
Thomas Gould	1	Massone (1989–1990)
Cerro Mackenzie	1	Nami (1999)
Fell	15	Bird (1988) (Instituto de la Patagonia Austral col.)
Laredo 1	2	Prieto (1988) (Instituto de la Patagonia Austral col.)
Punta Dungeness 2	2	Massone (1979) (Instituto de la Patagonia Austral col.)
Peggy Bird	3	Prieto (1989–1990) (Instituto de la Patagonia Austral col.)
Cueva Cóndor 1	1	Charlin (2009)
Frailes 2	1	Charlin (2009)
Laguna Azul	1	Charlin (2009)
Total	45	

symmetric and asymmetric variation (Mardia et al., 2000; Klingenberg, 2009). The first step of this method generates a reflected copy of each configuration and relabels it in order to make the arrangement of landmarks compatible with the original forms. Then, a Generalized Procrustes Analysis superimposition is performed with the original forms and their mirrored-relabeled counterparts (Klingenberg, 2009). The consensus obtained from this fit is a perfectly symmetric shape with an exact axis or plane of symmetry determined by the unpaired landmarks together with the midpoints of the paired landmarks. The variation among individuals in such consensus is referred to as the symmetric component of the total shape variation.

Geometric morphometrics analyses have been applied for several purposes, such as to control the effect of potential noisy factors (e.g. resharpening), or to study differences in lithic raw materials and hafting, geographical origin or distance among samples, among others (Buchanan and Collard, 2010; Castiñeira et al., 2011, 2012; Buchanan et al., 2012). Some of these works used elliptic Fourier analysis performed on the point's contour (Iovită, 2009, 2011), multivariate regression correction of landmark coordinate data (Charlin and González-José, 2012), or composite corrections involving proportions, shape, asymmetry, and size parameters (González-José and Charlin, 2012). Recently, we have adopted the Factor Model (Mitteroecker and Bookstein, 2007, 2008; De Azevedo et al., 2014), a method explicitly aimed to separate the effects of common factors generating global patterns of covariation, from local factors influencing localized (withinmodule) shape covariation. As a whole, geometric morphometric methods provide a powerful suite of tools that enhance the morphometric analysis of stone tools, and open new analytic avenues of research.

2.3.1. *Size and shape variables*

All pieces were photographed keeping constant their orientation and image size (100 dpi). The same criteria were used on scanned figures (illustrations and photographs) from published literature. The raw images were compiled in TpsUtil (v.1.58, Rohlf, 2013a), and morphometric points (landmarks and semilandmarks) were digitized using TpsDig2 (v. 2.17, Rohlf, 2013b). A total of seven landmarks and fourteen semilandmarks were located on the outline of each projectile point. In comparison to previous analyses (Charlin and González-José, 2012; Charlin et al., 2013; González-José and Charlin, 2012; De Azevedo et al., 2014), we have reduced the number of semilandmarks on the stem in order to capture its form avoiding the bias that the coverage of the shaft upon the stem could generate in the ethnographic sample. Fortunately, in all cases the stem is larger than the shaft, thus its lateral margins are always slightly outside, so they outline can be properly captured via landmark digitizing. In this way we guarantee a proper coverage of stem form, without affecting the original ethnographic specimens.

Semilandmarks were adjusted following the minimum bending energy criterion (Bookstein, 1996–1997), and landmark configurations were superimposed using a Generalized Procrustes Analysis (GPA, Rohlf and Slice, 1990). Both procedures were done in TpsRelw (v. 1.62, Rohlf, 2015). The GPA removes the effects of translation, rotation, and scaling (Rohlf and Slice, 1990), thus pure shape information is preserved in the specimens' aligned landmarks (Procrustes coordinates). Aligned specimens were exported to MorphoJ (v. 1.06d, Klingenberg, 2008) in order to perform further statistical analyses.

A principal component analysis (PCA) was computed on the covariance matrix of the Procrustes coordinates in order to extract general patterns of shape variation between Ona (Selk'nam) arrows and type V projectile points, and subsequently including type IV spear-like points for comparative purposes.

Between-group shape differences were evaluated using discriminant function analysis (DA) and canonical variates analysis (CVA) according to the number of groups being compared. A permutation test on Mahalanobis distance was used to assess the significance of among-group differences. We used the Mahalanobis distance since its computation minimizes any between-group potential difference in the covariance structure.

Point size was estimated after centroid size, the square root of the summed distances between each landmark coordinate and the centroid of the projectile (Dryden and Mardia, 1998). Between-group size differences were statistically assessed using a Student *t*-test for unequal variance computed in PAST (v. 2.17c, Hammer et al., 2001). All the shape comparisons were based on the Procrustes coordinates, before and after controlling the effects of point reduction and size variations.

2.3.2. *Point reduction control*

Abundant experimental and allometric studies on projectile points have shown that the major size and shape changes most frequently occur in the point blade, especially in its length (Ahler and Geib, 2000; Andrefsky, 2006; Buchanan, 2006; Castiñeira et al., 2011; Charlin and González-José, 2012; Fenniken and Raymond, 1986; Hunzicker, 2008; Iriarte, 1995; Morrow and Morrow, 2002; Shott et al., 2007; Towner and Warburton, 1990), and they are usually associated with modifications in the tip angle and blade convexity due to impact damage (Ahler and Geib, 2000; Castiñeira et al., 2011; Charlin and González-José, 2012; Flenniken and Raymond, 1986; Odell and Cowan, 1986). For this reason, some sort of minimization of such effects is useful to enhance the assessment of any inter-group variation. Most of the Ona (Selk'nam) arrowheads studied here were collected during expeditions carried out between the end of 19th and the beginning of 20th century, when the production of tools for trade or bartering with explorers and colonialists was a common practice (see Harrison, 2006; Prieto and Cárdenas, 2002, 2006; Torrence, 1993, 2000, 2002). In this context, some tools were no longer manufactured for their use as hunting weapons, but just for exchange with Europeans (see Borrero and Borella, 2010; Scheinsohn, 1990–1992, 1997, for harpoons in Fuego-Patagonia, and Harrison, 2006; Torrence, 1993, 2000, 2002, for spear points in Australia). Therefore, it is likely that reduction effects due to use, fracture, resharpening and reuse are absent or small in many historical artifacts, whereas larger effects are expected in the archaeological sample. Reduction effects on point size and shape configurations, especially on archaeological samples, were controlled by regressing shape on three metrical variables extracted from interlandmark Euclidean distances and trigonometry: tip angle (TA), shoulders mean angle (SMA, both in plain view), and blade and stem length. Since blade length is expected to decrease after successive cycles of use, breakage and rejuvenation, blade and stem length were used to compute the blade-to-stem length ratio (IBS), a reduction index proposed for stemmed projectile points (Iriarte, 1995) which is inversely proportional to reduction. Even though the experimental work of Shott et al. (2007) on replicated Folsom points has demonstrated that indices such as length/thickness, mass/thickness, and area/thickness correlate significantly with reduction stages, indices derived from stem dimensions, like blade-to-stem length ratio (IBS), are the only option available in a 2D study. Like thickness, stem dimensions are good parameters to build reduction indices, since its form has small modifications during weapon use life. Odell and Cowan (1986, 204) point out that while every piece in their experimentation with arrows and spears (n = 80) exhibited tip damage, basal damage was not observed on a majority of points. Moreover, the concentration of damage on the tip is independent of the propulsion method (Odell and Cowan, 1986), and hafting type (Hunzicker, 2008). According to Nami, 1984a, 1986, 1986–1987), type IV and V points were resharpened on the haft, a factor that favors stem conservation. This fact was confirmed by a previous comparison of stem and blade size and shape changes before and after controlling for point reduction (Charlin and González-José, 2012). These analyses show that reduction has a major impact on shape rather than on size, being the blade more affected than the stem (Charlin and González-José, 2012).

The metric data for Elko projectile points from the Great Basin (USA) published by Flenniken and Raymond (1986, Tables 1 and 2) help to understand changes in shoulder angle due to use and rejuvenation. The shoulders mean angle computed here is the average between right and left shoulder angles, measured in the same way that the notch opening index (NO) from Thomas (1981, 14) Monitor Valley typology. NO values were measured prior and after projectile point experimental use in the Flenniken and Raymond's work. The *t*-test for unequal variance (n = 24) shows significant differences ($t = -4.7659$, $p < .001$) in NO with a mean of 23.58° and 53.37° before and after reduction, respectively. We would expect higher values in the archaeological points since the experimental points were used only until noticeable damaged occurred (Flenniken and Raymond, 1986, 607), but not until the end of their use-life, a more likely situation in the archaeological record. Unfortunately, we are not able to test modifications in tip angle by a *t*-test on this dataset, but they are evident in Flenniken and Raymond's Figs. 4–6. Also, the experiments carried out by Odell and Cowan (1986) have highlighted the concentration of damage in the tip, independently of the propulsion mode. Snap, hinge and step macrofractures are the most frequent types of tip damage, and because the fracture often ends a considerable distance from its initiation, they remove much of the tip area (Odell and Cowan, 1986, 204, Table 1 and Fig. 2), causing changes in tip angle after repairing. Ahler and Geib (2000, 809) clearly show a pattern in Folsom point front angles and length according to reworking and resharpening: the longest whole points or most lengthy distal tip fragments appear to have the most acute front angles, and points of shorter length usually have 90° or

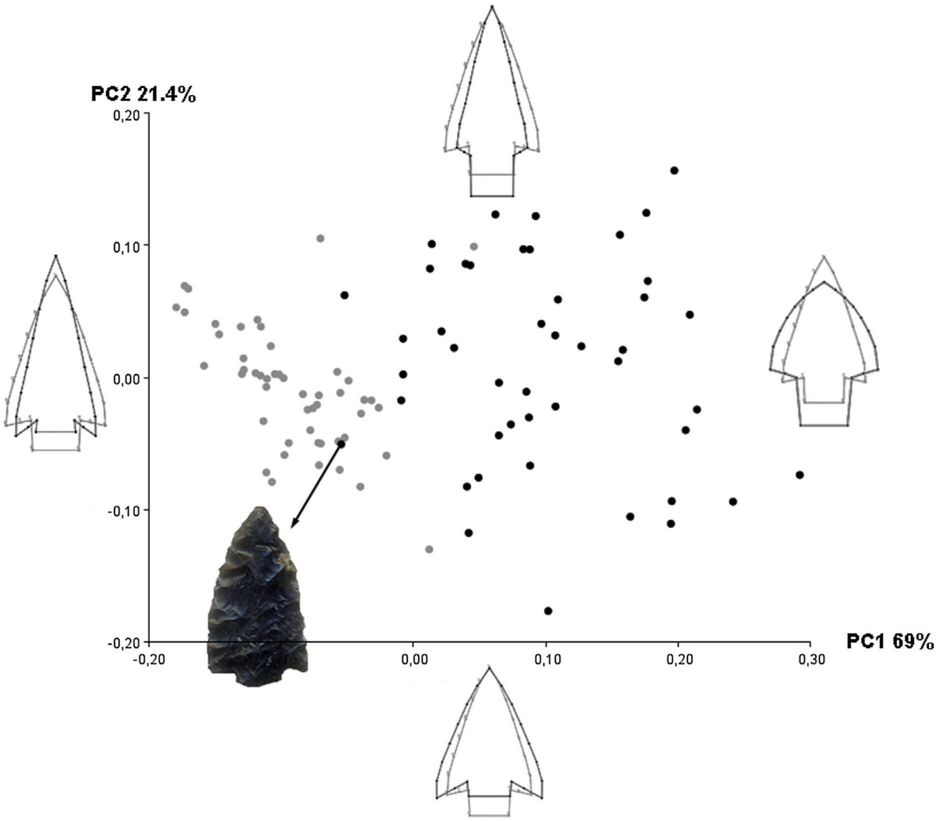

Fig. 4. Principal component analysis computed on Procrustes coordinates. Gray dots: ethnographic Ona (Selk'nam) points, black dots: archaeological type V points. Gray outlines: mean shape, black outlines: target shapes. Point image from Laguna Cóndor (18th century archaeological site, Santa Cruz, Argentina).

greater front angles.

Thus, reduction and allometric effects were collectively controlled using a multivariate regression of Procrustes coordinates on reduction variables (TA, SMA and IBS), and centroid size (CS). The resulting residual coordinates were subsequently used to repeat the discriminant analysis on reduction and size-effects corrected data.

Finally, a PCA and a CVA including a sample of 144 type IV projectile points, considered as spears according to different previous studies (Banegas et al., 2014; Bird, 1988; González-José and Charlin, 2012; Ratto, 1994), were included in order to perform an overall, complementary comparative analysis. These analyses are included to assess the role of ethnographic models when larger functional diversity is considered.

3. Results

3.1. Shape analysis

The main trends in point shape variation were explored using principal component analysis (PCA, Fig. 4). This method is useful to explore the patterns of covariance from complex multidimensional data (Manly, 1994; Zelditch et al., 2004). The two first principal components (PCs) collectively explain 90.4% of total shape variation. PC1 shows a clustering of ethnographic points in the negative scores, whereas archaeological specimens occupy the positive ones. This PC, which explains 69% of total variation, depicts points with longer and narrower blades, smaller stems, and acute tip and shoulder angles in the negative

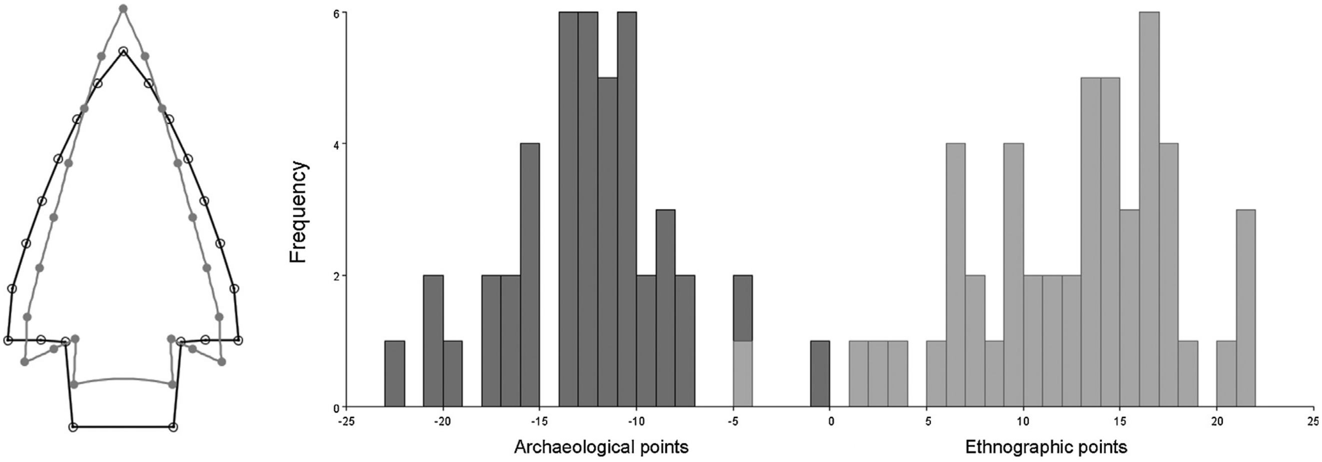

Fig. 5. Discriminant analysis on Procrustes coordinates. Black bars: archaeological type V points, gray bars: ethnographic Ona (Selk'nam) points. The mean shape for each group is shown on the left.

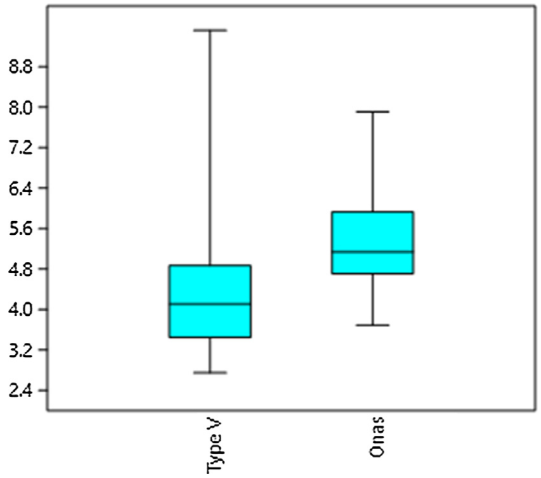

Fig. 6. Box-plot on centroid size archaeological type V and ethnographic Ona (Selk'nam) points.

(ethnographic) scores, while the positive (archaeological) ones show points with shorter and wider blades, bigger stems, rounded tips and shoulders with obtuse angles. The observed pattern of shape change from negative to positive scores across the first PC is expected under a scenario of increasing point reduction (Charlin and González-José, 2012; De Azevedo et al., 2014; González-José and Charlin, 2012). It is worth noting here that an obsidian archaeological point recovered from an 18th century archaeological site (220 ± 41 ^{14}C BP, 1729 ± 79 cal AD; 187 ± 41 ^{14}C BP, 1795 ± 120 cal AD. See Charlin et al., 2011, and Fig. 4) presents a negative value, being placed in the shape space occupied by the ethnographic points. Lithic raw material and recent dates are two important aspects to highlight here, since this pattern suggests an incidence of both variables in the shape similarity between the ethnographic sample and this archaeological point.

A discriminant analysis (DA) was computed to assess and describe the axis of inter-group shape separation (Fig. 5). DA maximizes between-group variation relative to within-group variation (McCune and Grace, 2002; Strauss, 2010), and the results show the existence of significant between-group differences, as intended from Mahalanobis distance ($D^2 = 4.992$; $p < .0001$). The percentage of correctly classified cases is high using both the discriminant function and the cross-validation procedure (Table 3).

3.2. Size analysis and allometry

Taking into account that both assemblages of points are made in different raw materials (glass and stone) using distinct blank-forms (bottle fragments and flakes), and that the pattern of shape variation presented above suggests different degrees of reduction intensity, the existence of between-group size differences is an expected result. In fact, Student *t*-test for unequal variance shows significant results (t: 2.9511, $p = 0.0043$), being the archaeological points both, the smallest and the most variable ones (Fig. 6, Table 4), an expected result considering the higher levels of reduction in archaeological contexts.

Table 3
Group allocation according to discriminant function and cross-validation.

Allocation from Discriminant function				
Group	Type V points	Ona points	Total	% correctly classified
Type V points	45	0	45	100
Ona points	1	49	50	98
Allocation from Cross-validation				
Group	Type V points	Ona points	Total	% correctly classified
Type V points	42	3	45	93
Ona points	3	47	50	94

Table 4
Descriptive statistics for reduction variables in ethnographic Ona (Selk'nam) points and archaeological type V samples. The values of the blade length/stem length index are inversely proportional to reduction.

	IBS		TA		SMA	
	Ona	Type V	Ona	Type V	Ona	Type V
Min.	3.78	1.61	23.98	35.9	32.49	57.33
Max.	14.32	11.73	52.31	108.02	89.21	142.51
Mean	7.99	3.86	35.86	55.42	62.20	97.376
Variance	3.27	3.43	33.38	196.45	188.62	446.79
Std. dev.	1.81	1.85	5.78	14.016	13.74	21.137
Median	8.08	3.43	35.79	52.76	61.41	97.64
25 percentil	6.86	2.79	31.56	45.47	52.95	79.61
75 percentil	8.92	4.2	40.24	60.68	68.01	110.75

Considering the existence of significant shape and size differences, we evaluated the relationship between both variables through a regression of shape on size on both samples independently, in order to assess the potential allometric behavior of each sample separately. Both kinds of points show a significant relationship between size and shape (Figs. 7 and 8), being slightly stronger in the case of the archaeological sample.

3.3. Controlling reduction

The mean comparison of the three measures of reduction (tip angle, shoulders mean angle, blade length/stem length index) between ethnographic and archaeological samples showed significant differences in all cases (t-test $= -8.71$; $p < 0.001$ for TA; t-test $= -9.50$; $p = < 0.001$ for SMA, and t-test $= 10.99$; $p = < 0.001$ for IBS). According to the obtained descriptive statistics, the Ona (Selk'nam) sample is both, the least reduced and the more standardized group (Table 4).

To control for these differences we performed a pooled within-group multivariate regression of shape coordinates on the log-transformed reduction variables and the log-transformed centroid size aiming to remove the influence of these covariates on shape data. The regression results were significant ($p < 0.0001$ after 10,000 permutation runs), showing that covariates explain 78.5% of shape variation (Fig. 9). The regression residuals were used to repeat the discriminant analysis on the corrected data and to corroborate the existence of shape differences between ethnographic and archaeological projectile points (Fig. 10). The corrected-data analysis corroborates the existence of significant between-group differences, according to permutation tests on the Mahalanobis distance ($D^2 = 4.31$; $p < 0.0001$). In other words, Ona (Selk'nam) arrows and type V points display shape differences, even after size and reduction effects are statistically controlled. In sum, these results suggest that both kinds of points depict different designs and life histories.

3.4. Including spear-like samples

The older point type in the archaeological sequence proposed by Bird to southern Patagonia is the type IV, considered as a spear point due to its larger size (Bird, 1988). As we previously mentioned, later studies have shown the coexistence of types IV and V during Late Holocene. Several other studies using morphometric variables and performance expectations have suggested that these points were used as hand-throwing and thrusting spears (González-José and Charlin, 2012; Ratto, 1994; Banegas et al., 2014). Therefore, we performed an additional PCA including a sample of 144 type IV points in order to consider a wider spectrum of functional diversity and its concomitant shape variation. The resultant first two PCs explain 88.32% of total shape

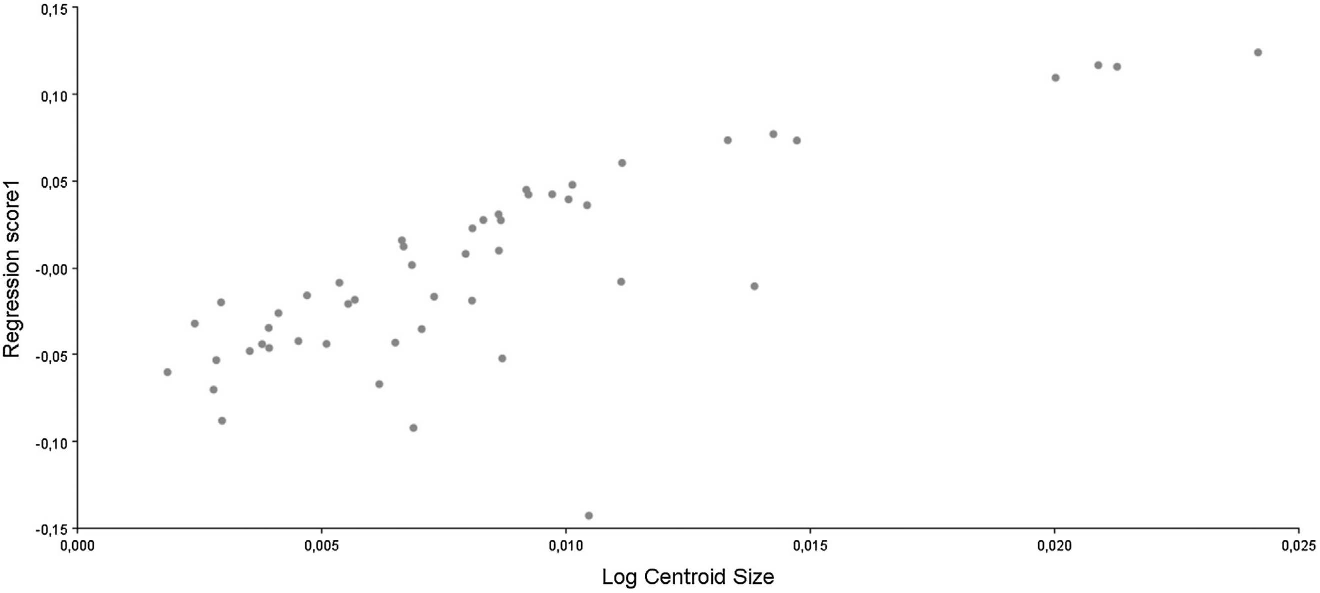

Fig. 7. Regression analysis of shape on size in ethnographic Ona (Selk'nam) points ($R^2 = 34.4$; $p < 0.001$).

variation (Fig. 11). PC1 accounts for 79.58% of total variation, and depicts shape changes, with points characterized by elongated and narrow blades, smaller stems, and acute angles in the shoulders and the tip in the positive scores, versus points displaying shorter and wider blades, rounded tips, shoulders with obtuse angles, and bigger stems in the negative scores. In this axis, which explains most of variation, the three groups of points show a spatial arrangement from right to left, being the Ona (Selk'nam) points placed in the highest positive values, and the type IV points occupying the highest negative ones. The type V points are located in the center of the morphospace (Fig. 11). Note that some Ona arrows overlap with type V but never with type IV points. Furthermore, the CVA analysis performed on corrected data shows that Ona (Selk'nam) and type V points are closer in the morphospace ($D^2 = 4.75$), being both of them more differentiated from type IV points (D^2 Ona-type IV = 8.45; D^2 type V-type IV = 9.14). According to the permutation test (10,000 rounds) all these distances are significant at $p < 0.0001$.

The results of these analyses show that, into a broader comparative framework including points used in different ways, and despite of the existence of mean shape differences among groups, ethnographic arrows exhibit morphometric attributes that put them closer of type V archaeological points, and contribute to a differentiation of both types from type IV, spear-like points (see Fig. 12). Unfortunately, stone-tipped ethnographic spears (excepting darts) are uncommon in museums around the world, thus making difficult any refinement on these comparisons.

4. Discussion

Ethnographic analogies were ubiquitously proposed as a valid tool to infer past behaviors and other characteristics departing from evidence observed on ethnographic, contemporary groups. However, many authors have stated that such analogies are valid (or at least its validity increases) if some pre-conditions are met (Wobst, 1978; Binford, 1967; Spence, 2011; Currie, 2016, among others). These conditions usually refer to problems of space and time scales (see Wobst,

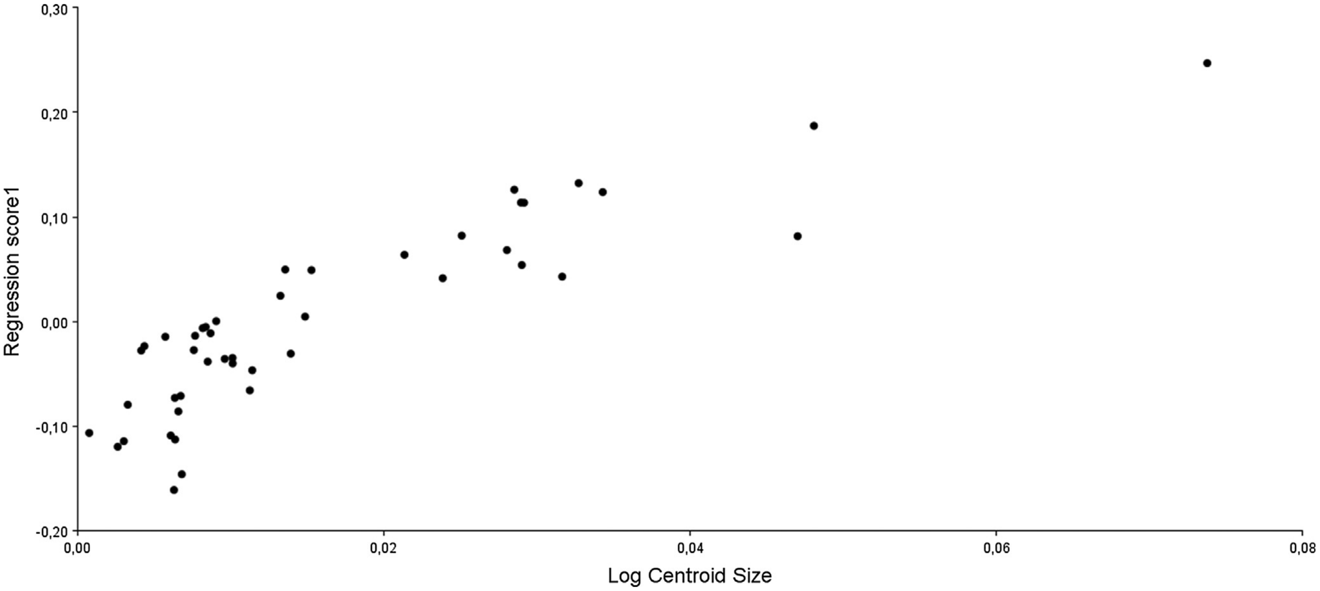

Fig. 8. Regression analysis of shape on size in archaeological type V points ($R^2 = 37.95$; $p < 0.001$).

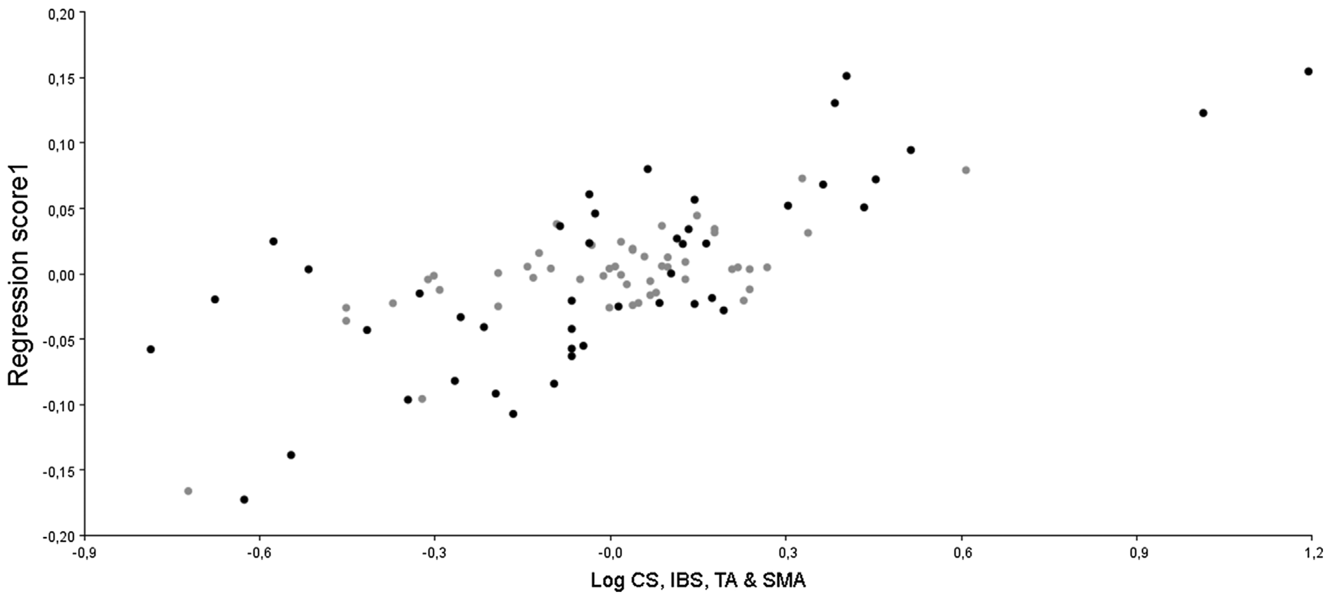

Fig. 9. Multiple regression of shape on reduction variables and centroid size. Gray dots: ethnographic sample, black dots: archaeological sample.

1978). Others, for instance, have mentioned the importance of detecting social information on items of the material culture, or how different patterns of stylistic variation over space correspond to intergroup and intragroup relations, which is of key importance to delimit the validity of the analogy under study (Wiessner, 1983). When using "ethnographic analogy" by appealing to anthropological variation patterns observed on contemporary groups to estimate the ones observed among extinct societies, there is an underlying logic called "comparative method": the appeal to contemporary facts to state hypotheses about the past. The comparative method is a well-developed, often quantified and rich set of epistemic techniques which are essential for reconstructing the biological past (Currie, 2016). Thus, the comparative method can be seen as a fundamental approach in most of the advances made in evolutionary biology during the last centuries. In this sense, ethnographic analogies and the comparative method used in biology represent the same patterns of reasoning.

Studying museum ethnographic collections of arrows and darts, as well as several archaeological hafted darts from USA, Thomas (1978) and Shott (1997) obtained a discriminant function, and then used it to classify archaeological specimens of unknown function. Thomas (1978) proposed a classification function considering point maximal length, width and thickness, and neck width that successfully classified 86% of the already known arrowheads (115 out of 132), and atlatl darts (7 out of 10). Furthermore, using a larger dart sample (n = 39), Shott (1997) improved this function based on a single-variable solution that can be applied also to stem-less points. In his analyses, shoulder width emerged as the most-significant discriminator between dart and arrow points and enhanced the correct classification performance of the discrimination function (Shott, 1997, 98). Since then, these models have been applied to archaeological points in order to discuss functional variations (Ames et al., 2010; Shott, 1993; Walde, 2014, among others).

A similar analysis based on Tierra del Fuego ethnographic collections and optimal engineering variables was reported by Ratto (1988, 1991a, 1991b, 1992, 1994, 2003). Her analysis of design variables and raw material properties enabled the discrimination of three technical systems from southern Patagonia: throwing-hand spear, bow and arrow, and hand-held weapons (Banegas et al., 2014; Ratto, 1994). She suggested the coexistence of the three weapon systems in space and time, at least between 3600 and 740 BP. Thus, Ratto highlights that projectile point differences are neither cultural nor chronological -as pioneering studies claimed- but purely functional (Ratto, 1994). Subsequent papers based on geometric morphometric approaches have

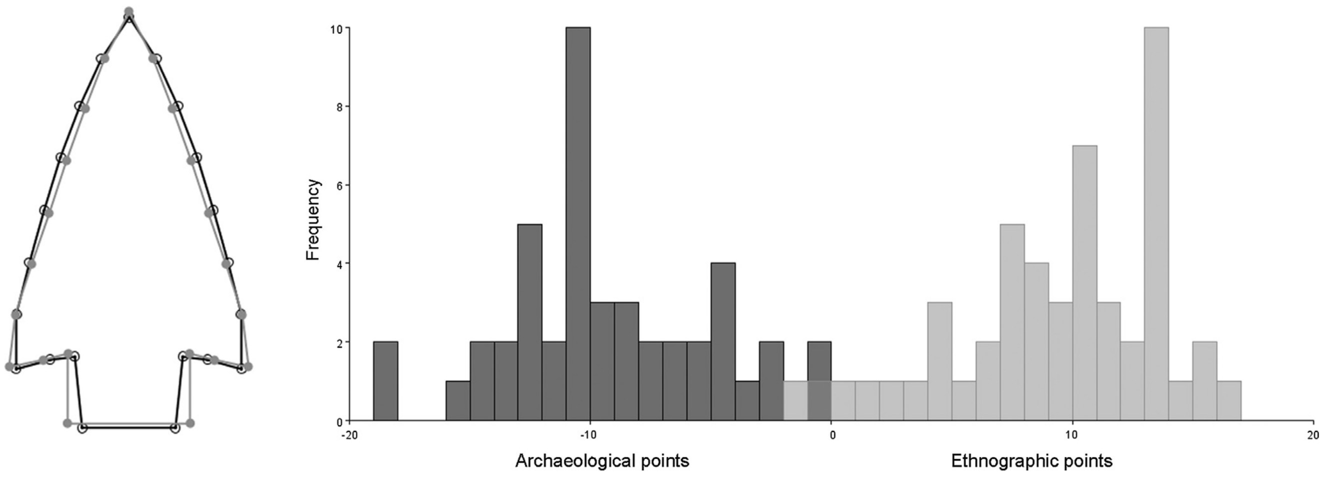

Fig. 10. Discriminant analysis on size and reduction-corrected shape data. Black bars: archaeological points, gray bars: ethnographic points. The mean shape for each group is shown on the left.

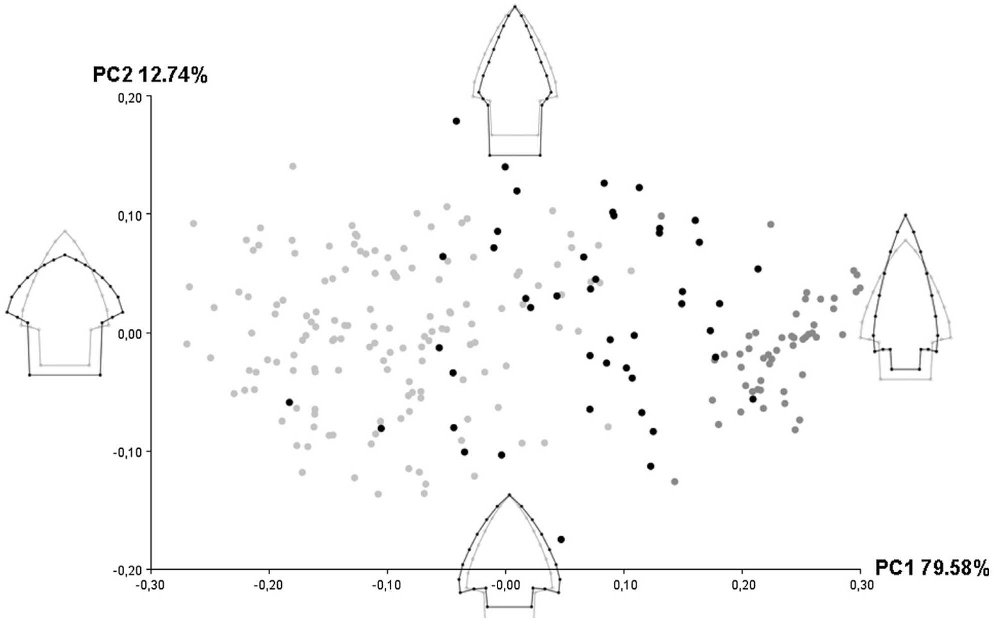

Fig. 11. Principal component analysis including spear-like, type IV archaeological points. Light gray dots: archaeological type IV points, black dots: archaeological type V points, dark gray dots: ethnographic Ona (Selk'nam) points. Gray point shapes: mean shape, black point shapes: target shapes.

arrived to similar conclusions. For instance, our study on projectile point modularity, asymmetry, and other morphometric variables allowed the identification of three types of points with different performance expectations among Late Holocene projectile points from southern continental Patagonia (González-José and Charlin, 2012). While type 1 points show an optimal design as arrows, type 2 and 3 points displayed optimal thrown and thrusting spears traits, respectively. De Azevedo et al. (2014) further explored patterns of blade-stem covariation on Late Holocene projectile points using the Factor Model derived from the Evo-Devo field in biology (Mitteroecker and Bookstein, 2007, 2008), and used to separate the effects of common shape factors related to design from modular-like shape modifications due to using, damage and repairing activities. Results showed that design differences explain most of the total shape variation between IV and V point types, but also indicated that maintenance patterns differ between types due to distinctive stress ratios and loading forces of low and high-speed weapon systems (arrows versus spears). This study showed that whereas arrow reduction is focused on tip modifications, spears present a broader array of shape changes including the tip and the shoulders (De Azevedo et al., 2014), a differential pattern of damage (and resharpening) that was also suggested by Banegas et al. (2014).

The analyses presented here demonstrated that Ona (Selk'nam) historical arrows from Isla Grande of Tierra del Fuego and type V archaeological projectile points from the southern continent differ statistically in terms of size and shape in a pairwise comparison. However, in a broader comparison including spear-like points, the grouping of samples shows a clear divergence between well-known ethnographic arrows plus archaeological arrow-like points in one hand, versus spear-like ones on the other hand, indicating that the former group share

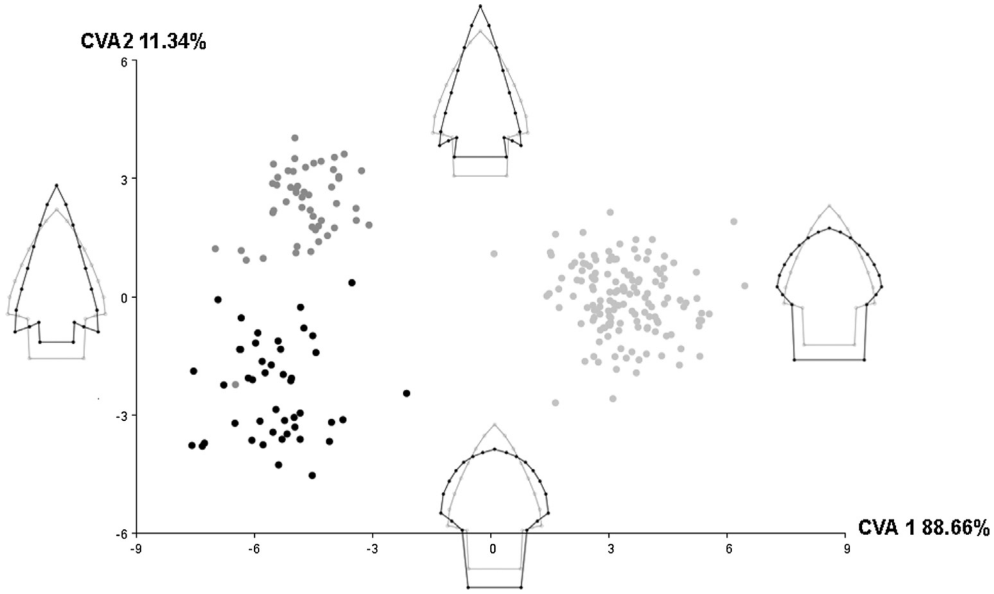

Fig. 12. Canonical variates analysis including spear-like, type-IV archaeological points. Light gray dots: archaeological type IV points, black dots: archaeological type V points, dark gray dots: ethnographic Ona (Selk'nam) points. Gray point shapes: mean shape, black point shapes: target shapes.

many design attributes.

Three important factors should be taken into account to understand the aforementioned Ona (Selk'nam) and type V points' dissimilarity: raw material differences (stone versus glass), chronological variations, and life-history considerations. The first two factors are closely related. Indeed, the principal component analysis showed that only the 18th century archaeological point manufactured on obsidian (the lithic raw material closest to glass) cluster together with ethnographic arrows from late 19th-early 20th century. In contrast with the short time span covered by the Fuegian ethnographic arrows analyzed here, type V archaeological projectile points goes back to ca. 3600 years ago, although most of them appear in the last 700–800 years BP across southern continental Patagonia (Bird, 1988; Cirigliano, 2011; Charlin, 2009a, 2009b; Gómez Otero, 1986–1987, 1989–1990; Massone, 1979, 1989–1990). The oldest date of 3600 ± 100 BP from El Volcán cave 4 (Sanguinetti de Bórmida, 1984) in the Pali Aike volcanic field suggests our study region as the place of origin of this kind of technology. Chronological variations on archaeological specimens should be controlled in future analysis, although the available information from stratigraphic contexts is still scarce (see Cirigliano, 2011 for a discussion of this topic). As soon as more radiocarbon dates are available, smaller temporal scale analyses will be necessary to identify time-specific shape and size variations within the archaeological sample. Regarding the Laguna Cóndor case, for instance, it is clear that raw material and chronological variations deserve more attention, but sample size is a limitation at the moment. Other factors need further attention in the type V projectile points to adjust the comparison, like potential functional variations during the three millennia these points have been used.

One of the most interesting results obtained here is that the reduction variables measured on archaeological and ethnographic points indicate that reduction is an important source of variation on size and shape differentiation between point assemblages. While archaeological type V points present the highest levels of reduction showing a longer history of use, damage, repairing and resharpening, the ethnographic arrows are always less reduced, depicting scarce use, a pattern possibly related with their manufacturing as “souvenirs” or “handicrafts” for exchange with colonialists. This can be seen as an ubiquitous bias present in higher or lower degree in the historical assemblages, especially from the end of the 19th century when most of ethnographic museum collections were acquired (e.g. Borrero and Borella, 2010; Harrison, 2006; Prieto and Cárdenas, 2002, 2006; Scheinsohn, 1990–1992; Torrence, 1993, 2000, 2002). In general, those “artifacts for exchange” show a standardized design with scarce variation, a pattern observed here. Our approach indicates that reduction is an important factor responsible for most of projectile point size and shape variation between southern mainland and Tierra del Fuego island, even though design differences were also identified.

The incorporation of spear-like type IV points into the analyses suggests that, besides the differences observed in reduction patterns, Ona (Selk'nam) and type V points are much more similar between them than in relation to type IV points, indicating some degree of functional similarity. While Ona (Selk'nam) and type V points are different in size and shape pairwise comparisons, when a broader context of functional diversity is used, they cluster together and clearly distinguish from spear points. Therefore, we might reject the “morphometric analogy” proposed by Bird in terms of size and shape variables *sensu strictu*, but our results inhibit the rejection of the functional analogy. Conversely, the analysis of a more diverse sample including type IV points shed light on Ona and type V overall design similarity in relation to spear-like points.

In accordance with the expectations of Borrero's divergence model (Massone, 1989–1990), which predicts genetic and cultural changes in the populations on both sides of the Magellan strait over a long temporal scale, the evolution of lithic technology in general (Cardillo et al., 2015), and projectile point designs in particular (Charlin et al., 2013 and this study) show a different trajectory between Tierra del Fuego and southern mainland after the formation of the marine channel ca. 8000 years ago. Indeed, such process of population divergence has been noted in several lines of evidence, such as rock art (Fiore, 2006), bioanthropological data (Cocilovo and Guichón, 1985–1986; Béguelin and Barrientos, 2006; González-José et al., 2001, 2002, 2004, 2008), and body size of guanaco populations (L'Heureux, 2008). Collectively, these evidences did not support Bird's (1938, 1946, 1988) proposal of late presence of the Ona (Selk'nam) in the mainland, nor the hypothesis of projectile point technology parallelism between continental and insular populations, as Charlin and Cardillo (2018) have recently shown. It is worth mentioning here that the interaction and exchange between southern continental Patagonia and Fuegian populations during the Late Holocene via canoe people seems to be a frequent phenomenon (Borrero et al., 2011 and references therein). Information sharing and circulation was an important, but frequently underestimated result of those contacts, if not the main reason behind them, at least since ca. 2000 BP (Borrero et al., 2011: 263). According to Morello et al. (2001, 2004, 2012, 2015; see also Stern, 2017 for a recent synthesis) canoe populations controlled green obsidian source (from the Otway Sea and Riesco Island, western Chilean Patagonia)[1] and exchanging from ca. 6500 years BP. The profuse evidence for the presence of this non-local lithic raw material in terrestrial hunter-gatherer hinterland sites, up to 400 km to the northeast (Charlin, 2009b; Cruz et al., 2011; Morello et al., 2004, 2015, among others), indicates that the interaction between land and sea hunter-gatherers, from west to east and between the north and south of the strait of Magellan, was more frequent than expected.

Finally, multiple lines of evidence are needed to make further progress in discriminating weapon systems. Other functional models based on metrical and design variables according to mechanical physics and ethnographic parameters (Ratto, 2003; Hughes, 1994; Shott, 1999; Thomas, 1978) should be applied to adjust the functional classification of archaeological type V projectile points on a proper way. Recent controlled experiments on type and size of diagnostic impact fractures and fracture velocity propagation have opened an encouraging avenue (Clarkson, 2016; Hutchings, 2011, 2016; Iovită et al., 2014, 2016), and ethnographic weapons may yet offer valuable insights into past projectile delivery systems.

5. Conclusions

We implemented an ethnographic and archaeological morphometric comparison of projectile points in order to disentangle functional attributes of archaeological points, as viewed from variations in well-known historical weapons. We report significant size and shape differences between the ethnographic arrow “model” from Tierra del Fuego and archaeological projectile points from southern continental sites. However, when these points are compared to type IV spear-like specimens, strong similarities between Ona (Selk'nam) arrows and type V points become patent. Thus, differences in shape and size between Ona (Selk'nam) arrows and type V projectile points do not invalidate the use of ethnographic samples to build functional models. As Binford (1967) pointed out, the formal, functional, and structural characteristics of arguments from analogy in archaeological analytical method must be made explicit. Our study reinforces the notion that ethnographic analogies in lithic points need to take into account the control of reduction noisy effects, and require to be based on a certain degree of continuity across environments, subsistence, mobility, tool design constraints, and technology.

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[1] A lithic raw material used for the manufacture of projectile points.

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