

Individuals amongst the pots:
How do traditional ceramic shapes vary between potters?

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1. Introduction

Human inheritance is not only genetic but also cultural (Boyd and Richerson, 1985; Cavalli-Sforza and Feldman, 1981; Richerson and Boyd, 2005). Both biological and cultural attributes evolve through the successive mechanisms of: (i) production of variations, (ii) transmission of variations, and (iii) differential selection of variations (Cavalli-Sforza and Feldman, 1981; Endler, 1986; Lewontin, 1971). Because they subsist across generations, human artifacts are cultural attributes that are particularly suitable for the study of cultural evolution. In this respect, knapped stones and ceramics are generally considered of prime interest. From a behavioral point of view, individuals learn to produce cultural artifacts channeled by their social surrounding and they transmit these cultural artifacts to their peers and to the younger generations. In this light, one may ask to what extent cultural artifacts are influenced by an individual's own style. Adopting an experimental approach, in this contribution we analyze the inter-individual variations in traditional ceramic shapes produced by Nepalese craftsmen.

As a widespread, traditional and artisanal skill, wheel-throwing provides an excellent model for analyzing the cultural transmission and evolution of motor skills and their ensuing artifacts (Gandon et al., 2013; Gandon et al., 2014a; Gandon et al., 2014b; Gandon, 2014). Starting with a formless lump of clay, the goal of wheel-throwing is to produce a pot – of a shape and size chosen in advance – using a wheel rotating in the horizontal plane at speeds varying between 50 and 150 rotations/min (Gandon et al., 2011a; Pierret, 2001; Rye, 1977). Ceramics are primarily defined by their shapes, which correspond to specific uses (such as storage, cooking, or rituals). Our ethnographic observations in workshops located in different cultural settings (France, Morocco, Turkey, India, Nepal, Thailand, and Spain) indicated that expert craftsmen usually reproduce the traditional ceramic shapes by relying on their practical

experience (that is, without requiring any visual model). One could say that these shapes are standard shapes (in their cultural area) in the sense that they are called by specific names and well recognized by craftsmen and customers. Ethno-archaeological studies have long documented that traditional ceramic shapes characterize cultural groups, although borrowings are sometimes noted between distinct groups (Hodder, 1979; Gelbert, 2002; Gosselain, 1992, 2000). In archeology, ceramic shapes are classified according to morphometric attributes which are then put in relation with functions, places or periods in order to construct functional or chrono-cultural ‘types’ (Gardin, 1980; Karasik and Smilansky 2011; Orton et al., 1993; Read, 2009; Whallon, 1972). The variability of these types is used by archaeologists to construct the history of ancient societies. In the present context, we call the ceramic shapes ‘traditional’ in the sense that they are the outcomes of motor skills transmitted through lineages of specialized craftsmen (Cochrane, 2008, 2013; Eerken and Lipo, 2007).

Although they result from transmitted gestures, traditional ceramic shapes tend to change over time if no operations of stabilizing selection occur (Orton et al., 1993; Cochrane, 2013). Change indicates the existence of sources of variation in the production of ceramic shapes and/or in the cultural transmission of these shapes. Certain sources of variation (such as borrowing through interactions between populations, or innovations due to external factors like evolution of the market demand) come from the socio-economic context (Kramer, 1985; Winslow, 2009). They differ from the sources of variation inherent in the practice itself, that is, occurring at the behavioral level where individuals play a role (Schiffer, 1976; Schiffer and Skibo, 1997).

The first behavioral source of variation supposedly operates during apprenticeship, through the cultural transmission of motor skills. For learning of wheel-throwing, model

observation occurs when tutors (i.e. expert potters) encourage their apprentices to observe the gestures used (i.e. adoption and sequence of specific hand positions on the lump of clay), so that they can reproduce them. In the framework of ecological psychology, motor learning of cultural skills is not be understood as resulting from strictly reproducing the gestures of a model (i.e. tutor) but rather as a behavior elicited by the observation of a model (Newell, 1991; Bril, 2002a; Bril, 2015; Parry et al., 2015). As Bril argues, the role of a model is to orient the learner towards the discovery of any motor skill effective for the task (Bril, 2015). Following this perspective, we assume that the novice adapts the motor skill shown by the tutor. Apprentices are therefore likely to develop idiosyncratic motor skills leading to inter-individual variations of the traditional shapes. In favor of this hypothesis, a study conducted on three groups of potters (French, Multani-Kumar Indian, and Prajapati Indian) revealed that expert potters belonging to the same cultural group shared a considerable part of their hand positions repertoires but also developed some individual-specific hand positions (Gandon, 2014).

The second behavioral source of variation in craft production is (so-called) copying error, which has been empirically highlighted (Eerkens and Lipo, 2005; Hamilton and Buchanan, 2009; Steele et al., 2010; Kempe et al., 2012; Gandon et al., 2014b; Schillinger et al., 2014). Copying error has been defined as “a small amount of error introduced into any copying event in which information is communicated about what an artifact should look like and how it should be made” (Eerkens and Lipo 2005, 321). According to Eerkens and Lipo, copying errors are generated through (i) errors in perception generated by cognitive limits in evaluating metric differences between two objects; and (ii) errors due to imprecision in manual dexterity. Intrinsic to any handicraft, copying error occurs throughout the potter’s career and gives rise to intra-individual variations in produced artifacts. In other words,

perceptual/cognitive and dexterity limits would explain why potters, whatever their skill level, cannot produce perfectly standardized assemblages of given types. The degree of ceramics standardization has been shown to increase with the frequency at which the ceramics are made, with highly standardized ceramics being characterized by a coefficient of variation of around 3% and even less in the case of mass production (Roux, 2003; Gandon et al., 2011b; Gandon et al., 2014b).

Thus, although the traditional ceramic shapes are identified as standard shapes by craftsmen and customers, in fact these shapes vary at the intra-individual level due to copying error; we assume that they also vary at the inter-individual level due to the learning process. Some of these variations may then be transmitted, and different selective forces can operate on them causing evolution of the traditional shapes. It is likely that the inter-individual variations (occurring during learning) are particularly important for the cultural evolutionary process. Indeed, we hypothesize that individuals develop their own manner of producing the traditional ceramic shapes, developing – consciously or not – their own style. Yet, empirical assessment of such inter-individual variations in ceramic shapes of the same type is still in its early stages. Roux and Karasik (in press) have recently studied a type of wheel-thrown water jar produced in North India by contemporary potters and did indeed report small but identifiable shape differences among potters. In the present study, we expect to confirm these first results. We decided to follow the ethno-archaeological approach of Roux and Karasik (in press) because experimenting with contemporary potters is the only way to provide direct evidence regarding the existence of individual features on ceramics. For the present purposes we chose to work in Nepal, a country where the pottery handicraft is still organized in a traditional way. We analyzed the 2D profiles of three different traditional ceramic shapes produced, in five replicates, by each of five expert potters working in their familiar conditions

of practice. The shape analysis method used in this study was borrowed from biology (McLellan and Endler, 1998). This method – detailed below – provided an accurate quantification of variation in shape within and among potters, allowing statistical tests and direct estimates of variation. Going a step further, in a complementary experiment we examined the ability of potters to visually identify the individual styles in the experimental assemblage. If individual styles indeed exist, their identification by potters could be determinant in terms of cultural selection.

2. Materials and Methods

The field experiment took place in a traditional pottery workshop in Bhaktapur (Nepal, Kathmandu district). As in India, the pottery handicraft in Nepal is learned within endogamous castes which produce standardized traditional objects in mass production (Kramer, 1997; Roux and Corbetta, 1989; Saraswati and Behura, 1964). In the Newar community of Bhaktapur the electrical wheel has been adopted since 2009. Five expert potters gave their written consent to participate in the experiment: LAX, SAN, RAM, SHI, and DIN. The participants all originated from Bhaktapur and belong to the Newar community (Prajapati Hindu caste). They work either in the same pottery workshop (LAX and SAN are father and son) or in neighboring workshops (same street) (DIN who is SAN's brother and RAM and SHI who are SAN's uncles). They use the same clay, share the same drying area (which is the central square) and fire their pots in two shared kilns. Moreover, they manufacture the same traditional shapes responding to the same market demand. The participants (all right handed men) were all over 25 years old (Mean \pm SD: 38.0 \pm 8.7 yrs) and had a minimum of ten years of wheel-throwing experience (26.0 \pm 8.9 yrs). These five potters produce traditional ceramic shapes comparable to the ones produced by North Indian potters studied by Gandon et al.

(2014a). Nevertheless, as can be seen from Figure 1, their geometrical analysis demonstrated that they were clearly different. In this regard, their production thus signals a distinct cultural group.

***** Fig. 1 about here *****

In the main experiment, the five potters were asked to produce three different shapes. These three shapes are frequently made and referred in the local language as *Anchora* (vessel containing water used in rituals), *Money-Bank* (piggy bank) and *Ashtray* (ashtray) (Fig. 2). Each of the three shapes was produced in five specimens; each potter therefore produced a total of 15 pots. In order to respect the usual conditions of practice, potters relied on their practical experience of the required shape and no visual model was presented. All potters used the same wheel and clay. No additional tools were used, except a basin of water to wet the clay. No limit of time was fixed and each potter threw all 15 pots in a single session. The experimenter was present during the experimental task to monitor progress and ensure procedural consistency.

***** Fig. 2 about here *****

All finished pots were marked on the bottom with a number representing the specific potter and the pot number in the series; then they were put to dry for two days. After the drying process, we used a Canon PowerShot-SX270 camera to photograph all pots (together with a calibration object) under standardized conditions. From the pot photos we extracted the (x,y) coordinates of the cross-sectional right profiles using Gimp® and Matlab® software. The profile coordinates were converted from pixels to centimeters using a calibration factor

obtained from the dimensions of the calibration object present in each image. Next, the profiles were re-sampled to generate an equal number of points (256 in total) at regular height intervals along the (vertical) y-axis and finally the coordinates were smoothed with a low pass filter (cf., Gandon et al., 2013, 2014a). Because wheel-thrown vessels are typically axisymmetric, profiles were subsequently converted to full pot outlines by multiplying the x coordinates by -1 to create the corresponding left edge.

To characterize the geometry independently of the size of the pots produced, the analysis proceeded in several steps. First, the ensemble of profiles was submitted to an elliptical Fourier analysis (McLellan and Endler, 1998). The resulting Fourier coefficients were then normalized to the first harmonic to remove differences in size and orientation according to the method proposed by Kuhl and Gardiena (1982). Finally, the normalized Fourier coefficients were submitted to a Principal Component Analysis (PCA). The first two Principal Components always captured over 75% of the variance. Therefore, the variation in geometry of each pot could be adequately represented as a point in the two-dimensional PC1-PC2 space. A Permutation Test (Mielke and Berry, 2007) was carried out on the PC scores for each of the three shape classes separately using the *adonis* function in the R package *vegan* (Oksanen et al., 2016). This analysis tested for heterogeneity of shapes among the potters within shape types; if significant this test indicates the presence of individual influences on ceramic shapes. If not significant, then the test cannot detect any differences among the potters for a given shape. Finally, using the between-trial variabilities over the five specimens thrown by each participant (for each of the three shapes), the standardization of production was assessed via the coefficients of variation ($CV = 100\% * \text{standard deviation}/\text{mean}$) computed on the maximal diameter (centimeter precision) of the pots.

In a complementary experiment, following the drying period we asked each of the five participants to identify their own productions and those of their four colleagues within the assemblage. To this end, we selected, for each of the five potters and for each of the three shapes, the best four specimens (allowing elimination of pots with manufacturing defects). This was done to prevent a potter recognizing his pot because of the presence of a noticeable defect (for example a fingerprint in the wall, or a little rock in the clay). The pots were then organized by groups of 4 pots per shape (x3) and per potter (x5), thereby obtaining a total of 15 groups of 4 pots (Fig. 3). Each potter was individually asked to identify the different producers of the 15 groups of pots. In other words, looking at the total 60-pot assemblage, each potter was to identify his own pots, and those of his four colleagues. The pots were solely observed from a distance. No feedback or any other type of clue was given. In total, each potter had to provide 15 answers (five producers to be identified, for each of the three different shapes), which were entered into an Excel file.

***** Fig. 3 about here *****

3. Results

Figure 4 presents the geometrical distributions in PC1-PC2 space of each of the five specimens thrown by each of the five potters for the Anchora (top panel), Money-Bank (middle panel) and Ashtray (bottom panel) shapes. As can be seen from Table 1, for each shape the Permutation Test revealed significant heterogeneity among potters, indicating that different potters produced vessels with slight but systematical morphometric variations. We therefore conclude that, while they all threw the same three traditional shapes, potters did indeed imprint individual signatures on the vessels thrown.

For the Anchora PC1 (66.0%) and PC2 (19.0%) explained 85.0% of the observed profile variation. Inspection of Fig.4 (top panel) indicated that differences were mostly to be found in the width and position of the indentation below the lip. The Anchora profiles of SAN were close to those of SHI. For the Money-Bank PC1 (60.1%) and PC2 (18.7%) explained 78.8% of the observed profile variation. The differences among potters primarily concerned the width and height of the central bulge and to a lesser extent the height of the mouth (Fig. 4, middle panel). The Money-Bank profiles of SAN were clearly distinct from those of the four other potters, while the Money-Bank profiles of RAM were in between those of LAX and DIN. For the Ashtray PC1 (86.2%) and PC2 (8.4%) explained 94.6% of the observed profile variation. For the Ashtray, variation was considerably larger than for the other two shapes; the profiles differed in the steepness of the sides, the roundness below the lip, and the shape of the lip (Fig. 4, bottom panel). The Ashtray profiles of LAX were close to those of DIN.

***** Table 1 about here *****

***** Figure 4 about here *****

Finally, visual inspection of the dispersion of the points in Fig. 4, revealed comparable degrees of intra-individual variability for all five potters. This observation was corroborated by the CV results presented in Table 2. Bearing in mind that these CVs were uniquely based on each vessel's maximum diameter, the CV values were generally quite similar for the five potters and the three shapes (Table 2), for an overall mean of $2.9 \pm 1.6\%$. However, as can be seen from Table 2, the shape with the highest CV varied over potters; that is, amongst them they differed to a certain extent in the ability to standardize each of the different shapes.

***** Table 2 about here *****

Table 3 presents the answers given by each of the five potters when trying to identify their pots and those of their four colleagues. Inspection of this table shows that – for the three shapes – one potter (SAN) identified correctly all the pots (15 correct answers); another potter (SHI) identified correctly more than half of the assemblage (11 correct answers); and the three remaining potters identified correctly only third of the assemblage (6, 5, and 4 correct answers for RAM, LAX and DIN respectively). We examined whether incorrect answers (given notably by RAM, LAX and DIN) were caused by confusion between pots with similar features. We noted, for example, in the top panel of Fig. 4 that the Anchora profiles of SAN (potter 2) were close to those of SHI (potter 3). However, these profiles were never confused (see Table 3). By the same token, the Money-Bank pots produced by LAX (Potter 1), RAM (Potter 3), and DIN (potter 5) had very similar profiles (Fig.4, middle panel) but on a total of 12 incorrect answers not even one corresponded to a confusion between RAM and DIN profiles (see Table 3). As for the Ashtray profiles, those of LAX were close to those of DIN but they were only confused one time for a total of 10 incorrect answers. Hence, it appeared that when potters were not able to recognize the producers of the pots the answers provided were not systematically related to potters' particular shape characteristics.

***** Table 3 about here *****

4. Discussion

The shape variability in ancient ceramic assemblages represents a rich source of material to explore the cultural evolution. Interpreting this variability requires the contribution of field experiments, allowing researchers to benefit from the expertise of both craft people and established analysis techniques. Based on our ethnographic observations, we assumed that, in the course of learning, potters develop their own style of practicing wheel-throwing. In doing so, they would mark the shapes of their pots with personal features that could lead over time to an evolution of the traditional ceramic shapes. In this contribution, we analyzed the variability of three traditional ceramic shapes produced by five Nepalese experts, potters raised and trained within the same cultural niche, in order to examine whether the experimental productions presented individual features. In a second step, we explored the ability of potters to visually identify these individual features in the experimental assemblage.

As expected, the traditional context of production and the level of expertise of the participating professional potters gave rise to highly standardized assemblages at the individual level. The values of the CVs – that we interpret as quantifications of copying error – were close to the 3% reported in previous studies (Roux, 2003; Gandon et al., 2011b; Gandon et al., 2014b). On the other hand, the Permutation Test on vessel shapes revealed significant differences among potters, for each of the three shapes. Moreover, different potters threw different shapes with different degrees of precision. These inter-individual variations in the traditional shapes thrown were clearly distinguishable in the PCA space (Fig. 4). The present results thus corroborated those reported by Roux and Karasik (in press) and suggest that individual styles may also be identifiable in ancient ceramic assemblages. The patterned geometrical distribution highlighted in our study (Fig. 4) could be used in archaeology to provide benchmarks for attributing minor shape variations to individual signatures rather than to other factors. Identifying individual signatures in an archaeological

assemblage could help determine the number of artisans involved in a standardized production, which in turn would lead to a better understanding of the social context of the production (Costin and Hagstrum, 1995; Creese, 2012; Hill, 1978; Morris, 1993; Roe, 1980; Thomas, 2009).

As for the mechanisms underlying the emergence of inter-individual variations in ceramic shapes, we submit that potters do indeed develop individual motor skills despite a highly constrained task (shaping vessels with the use of rotational kinetic energy) and the similarity of the cultural environment (same social group), the intended products (same three vessel shapes), the technical traditions (same clay, and wheels) and the transmission context (same vertical transmission from father to son). Such a development of individual motor skills within the same cultural niche leading to minor variations in shapes is very likely related to the learning process. Learning elementary movements can be viewed as an adaptation to the constraints of the individual, the task and the (material) environment (Newell, 1986; Reed and Bril, 1996; Bril, 2015). This process takes place under the guidance of the social environment (notably the tutor's observation and teaching) which imprints a cultural mark on motor behaviour (Bril, 2002b; Gandon, 2014). However, this cultural influence is not completely dominant. In fact, the role of the tutor is only to guide the novice. Executing a technical movement implies a mixture of common and individual strategies (Parry et al., 2015; Reed and Bril, 1996; Rein et al., 2014). This explains that, despite belonging to the same learning network, the potters produced traditional ceramic shapes whose metric variability corresponds to individual signatures. Let us indeed recall that SAN and DIN learned from LAX, and that LAX, RAM and SHI learned from the same father.

Even if, as demonstrated in the present contribution, characteristics of individual craftsmen affect traditional ceramic shapes, the question to what extent these individual characteristics play a role in the evolution of these shapes remains open. Does the evolution of the types defined by archaeologists indeed originate, at least partially, from inter-individual variability? Given the high reproducibility of expert motor behaviors (Bootsma and Van Wieringen, 1990; Sevrez et al., 2009, 2012; Gandon et al., 2014), the individual shapes may last long enough (at least during the lifespan of the craftsman and of his pots) to constitute a variant that could be transmitted and selected. In this light, we wondered whether craftsmen can detect minor differences between the shapes of the same types of objects made by different producers. If this were the case, they could select the individual variant they prefer, notably disseminating it by reproduction. In turn, this selection would then influence the shape evolution. The preliminary results obtained in the complementary experiment shed some light on this issue. The fact that one potter performed the identification task perfectly indicates that the individual signatures on ceramics assemblages are not only detectable by numerical analysis (Fig. 4), but also visually. Indeed, it is highly unlikely that, for each traditional shape, SAN correctly identified the five producers of the pots simply by chance. Following E.J. Gibson's (1992) lead, we may therefore assume that he developed the perceptual ability to detect the slight shape differences present on each shape assemblage. In the present context we hypothesize a relation between shape discrimination ability and the motivation of craftsmen. Indeed, the best results were obtained by SAN who, in discussions, demonstrated a special interest for esthetic performance in his daily work. This kind of interest could lead craftsmen like him to become more aware of the stylistic aspect of the artifacts. In his attempt to produce "beautiful shapes" (in his own words), SAN usually compared his production with those of his colleagues. In this way, we assume that he developed an acute perception of shapes, and consequently of the individual signatures. Such

perfectionist craftsmen could play a key role in the selection and evolution of the traditional artifacts shapes.

5. Conclusion

At the crossroad of archaeology and experimental psychology, we addressed the issue of inter-individual variability in the production of ceramic types. The goal was to explore whether such variability could imply potter signatures. Taking traditional ceramic shapes as a case study, we setup a field experiment with five expert potters from the Kathmandu district. The 2D profiles of the experimental productions (three shapes replicated five times) were analyzed with a geometrical shape analysis method borrowed from biology. In a complementary experiment focusing on shape discrimination, the participants were asked to visually identify their own productions and those of their four colleagues.

Results highlighted an expected level of individual standardization of the productions together with significant inter-individual variations. Hence, although the traditional ceramic shapes are characterized by a strong cultural standardization (Gandon et al., 2014a), these shapes are also characterized by individual styles. Our results corroborated the original results obtained by Roux and Karasik (in press). We assume that, even though conditions of transmission and shapes produced are homogeneous within a community of practice, during apprenticeship individuals develop their own motor skills, which reflect upon the finished products. Together with those of previous studies showing that the cultural origin of potters influences the direction of the copying errors (Gandon et al., 2014b), these results can be

understood within the framework of ecological psychology as showing how the constraints of the individual, the task, and the environment (both material and social) interact in the shaping of human motor behavior and in its material consequences.

In archaeology, interpreting type variability in terms of individuals could provide supplementary information on the social organization of the production (domestic versus specialized production, size of the workshops, distribution network...), either for modern or ancient periods. Type variability could also explain the evolution of ceramic shapes when considering individual features as a source of cultural divergence. Further work is now required to understand the exact role played by the individual signatures in the evolution of ceramic shapes. In the future, we would encourage field studies of cultural transmission across generations to consider the potters' gestures, the resulting shapes, and the perceptual ability of potters to discriminate the shape variations.

6. Acknowledgments

We are grateful to Sanjay Prajapati for welcoming and allowing us to work in his workshop and Patrick Lecouffe for providing technical assistance.

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