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Persisting technological boundaries: Social interactions, cognitive correlations and polarization



Valentine Roux^{a,*}, Blandine Bril^b, Jessie Cauliez^c, Anne-Lise Goujon^a, Catherine Lara^a,
Claire Manen^c, Geoffroy de Saulieu^d, Etienne Zangato^a

^a *Préhistoire & Technologie, CNRS, Nanterre, France*

^b *EHESS, Paris, France*

^c *Traces, CNRS, Toulouse, France*

^d *IRD, Marseille, France*

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ABSTRACT

In this paper, we address the question of the conditions for persistence of technological boundaries. We use field studies to test the predictions generated by a theoretical model in analytical sociology and examine the micro-processes at stake in the non-diffusion of techniques: to which extent techniques contributes to a sharp disagreement between groups and promote polarization? The ultimate goal is to provide archaeologists with an empirically tested model to explain spatial distribution of technological clusters and maintenance of technological boundaries. Field studies examine ethnographic situations in four countries where social groups using different ceramic techniques for making utilitarian vessels live in close geographical proximity. Two situations enable us to examine the conditions under which technological boundaries persist, while two others enable us to analyze, through a boundary-making perspective, how differences in craft techniques contribute to polarization. Our data suggest that in a context where different techniques are used for different types of object there is a cognitive bias which fosters technological polarization. This cognitive bias develops in the course of interactions between actors living in close geographical proximity. Polarization increases when technological standards are used by different social groups, thereby favoring negative influence and persistent technological boundaries.

1. Introduction

In archaeology, the study of technological changes has two sides: the adoption (invention and spreading) of new techniques and the non-diffusion of techniques (or non-borrowing whether considering the actor or the technique). Diffusion participates in homogenization of technical traits, whereas non-diffusion maintains technical diversity. The understanding that technical features can diffuse across geographical or social boundaries (as shown in history, geography, sociology, anthropology) makes the persistence of diversity problematic because movements of people, objects, ideas will tend to homogenize material culture, in particular when substantial benefits are at stake. One salient example of this problematic is the non-diffusion of the potter's wheel in the Mediterranean for hundreds of years and still today in several parts of the globe even in highly competitive situations and despite the advantage of the wheel in terms of time manufacturing (Roux, 2013; Roux and Jeffra, 2016).

Non-diffusion of cultural traits is particular visible at boundaries

between cultural clusters distributed in geographical space. Ethnoarchaeological and anthropological studies have investigated the social dimension of these boundaries (e.g. Dietler and Herbich, 1998; Gosselain, 2002, 2000; Hodder, 1985; Latour and Lemonnier, 1994; Lemonnier, 1993, 1992; Stark, 1998; Stark et al., 2008; Wiessner, 1983). They have highlighted that technological traditions have a tendency to superimpose on social boundaries and to be more resistant to change than easily transmissible traits such as style (shapes and decor of objects) (Gallay, 2007; Gelbert, 2003; Gosselain, 2000; Hegmon, 1998; Mayor, 2010; Roux, 2015; Stark et al., 2000). This difference between the two cultural traits has been explained in terms of learning modalities. Techniques are socially learned and culturally transmitted (e.g. Kuhn, 2004; O'Brien and Bentley, 2011). Their mastery requires learning through long lasting contacts, generally with socially close relatives (e.g. Bril, 2002; Gosselain, 2000; Shennan, 2013; Shennan and Steele, 1999). As a result, the generated population level pattern links technological traditions with producers' social group and are strong identity markers. Stylistic patterns relate not only to

* Corresponding author.

producers', but also to object and consumers' history. Stylistic boundaries are therefore more fluctuating and their link with social boundaries, less marked (David and Kramer, 2001). Since the mechanisms underlying the diffusion and persistence of cultural traits may vary according to the nature of these traits, each trait should be considered separately; in this article, only the persistence of technical traits is examined.

In anthropology and sociology, the co-existence of distinct technological systems, without exchange of traits, has been mainly explicated in terms of social affiliation/ differentiation. Under the 'technological choice' approach, at the group level, technical practices are considered as social facts, made in accordance with social strategies and meanings, their underlying and embedded representations fitting into a wider symbolic system (Dobres, 2000; Latour and Lemonnier, 1994; Lemonnier, 1992, 1993). Consequently, at boundaries, they resist the homogenizing effects of interactions through the process of affiliation/ differentiation. At the individual level, affiliation with the group practicing the same way has been shown to be the result of social learning which implies a learner and a tutor, with the outcome of learners practicing the same way than the tutors (Bril, 2002; Dietler and Herbich, 1998; Tehrani and Riede, 2008), having preferentially close ties with them and therefore developing a sense of affiliation with the tutor's group (Gosselain, 2011). These studies partially draw on Lave and Wenger's work (Lave and Wenger, 1991) on communities of practice. The latter are made up of individuals who exert or have exerted together their craft, given or not family relationships; shared learning process acts as a mechanism of affiliation to the group. Under the evolutionary approach, affiliation has been explained by the psychological bias according to which, in marked groups (here technologically), individuals feel close to individuals who are marked the same way (McElreath et al., 2003, p. 128). As a consequence of affiliation, individuals tend to conform to the norms of the group, while conformism exacerbates differentiation (Henrich and Boyd, 1998; Moscovici, 1984). This combined effect of conformism/ differentiation would favor non-borrowing of techniques.

Addressing cultural boundaries, the affiliation/differentiation process is thus recognized as particularly cogent to explain why non-diffusion of cultural traits may persist and why it should be stronger at boundary region as suggested for ethnic differentiation (McElreath et al., 2003). In the cultural evolution approach, assumptions are made using evidence from analytical sociology. Simulation models have tested the conditions of preservation of cultural diversity. As a first step, diversity has been shown to be preserved when differences between cultural groups are too large; in these cases there is a preference to interact with those who are similar, called homophily (Axelrod, 1997). Going one step further, Flache and Macy (Flache and Macy, 2011) have recently proposed that diversity and differentiation between groups is a result of polarization through the combined effect of long-range and short-range ties, the former connecting "local clusters in the network that are not directly linked otherwise" (Flache and Macy, 2011, p. 147), the latter describing frequently activated relationships (such as family/ kin ties) (Collar et al., 2015, p. 23). Polarization is defined as the division of population "into a small number of factions with high internal consensus and sharp disagreement between them" (Flache and Macy, 2011, p. 149). Simulation with an agent-based model shows that, in a small connected world, polarization occurs when "actors who are connected with a long-range tie are more likely to differ sharply from each other than are actors connected with a short-range tie" (Flache and Macy, 2011, p. 172). More precisely, long-range ties bridging otherwise disconnected clusters can promote cultural integration. However, these long-range ties can have the opposite effect when homophily is combined with differentiation. In this case long-range ties foster cultural polarization rather than integration. In other words, in well-connected networks, inter-group interactions can promote cultural integration but not when the differences between these groups are higher than the differences within the group. In this latter case, the

combination of intra- and inter-group interactions promotes affiliation/ differentiation and polarization.

This sociological model could well explain persistence of technological boundaries in the past, technological clusters supposedly correlating with social clusters and therefore technological boundaries with social boundaries. In these conditions, interactions between technologically marked groups would favor polarization.

In order to test the assumptions and predictions generated by this theoretical model, we propose to use field studies and examine the micro-processes at stake in the non-diffusion of techniques: to which extent techniques contributes to a sharp disagreement between groups and promote polarization? It will be dealt with following a multilevel analytical framework aimed at relating the individual level (micro-level, i.e. the role of techniques in differentiation), the group level (meso-level, i.e. the polarization phenomenon), and the cultural historical specifics emerging from the later (macro-level, i.e. the persistence of technological boundaries) (e.g. Manzo, 2007; Mesoudi, 2007). The ultimate goal is to provide archaeologists with an empirically tested model to explain spatial distribution of technological clusters and maintenance of technological boundaries.

The present research examines ethnographic situations in four countries (Ethiopia, Cameroon, Ecuador and India) where different social groups live in close geographical proximity and use different ceramic techniques for making utilitarian vessels. Two situations will enable us to examine the context under which technological boundaries persist, while two others will enable us to analyze, through a boundary-making perspective (Wimmer, 2013), how differences in craft techniques contribute to polarization. In the four cases, the boundary ceramic techniques present advantages over each other, thus seriously begging the question of the non-integrative effect of contacts.

As we shall see, interactions between groups living in close proximity and using different technological standards favor polarization given "negative" influence, namely influence reinforcing differentiation rather than integration. Technological standards are here defined as specific ways of making specific ranges of vessels and whose transmission over several generations makes them traditions. A cognitive bias makes that they contribute directly to a sharp differentiation between groups. The main consequence of technological polarization is the failure of technical traits to spread between technologically marked groups, even when these groups belong to the same social community as is the case in Ecuador.

2. Technological boundaries

Analysis of the persistence of technological boundaries first implies understanding how they are generated and how they may be superimposed on social boundaries. Two case studies are examined. They report on situations where ceramic production is in the hands of different groups of potters living in close geographical proximity and having contact with each other. Two questionnaires were designed. The first one aimed at mapping the pottery traditions (questionnaire on manufacturing process and range of vessels) of the region, and at recording the identity of the potters, their numbers, the distribution of the potters' villages, their interactions, their knowledge of each other's techniques, as well as the organization of the production and the distribution of ceramic crafts. The second questionnaire focused on the learning and transmission process. Full details are not here reported systematically, only those related to the issue addressed.

2.1. Transmission and technological boundaries

This section examines how the learning and transmission process of technological standards participate to their reproduction within one's social group, and as a result, create technologically marked clusters that superimpose on social boundaries.

Two situations of different degrees of complexity are considered in

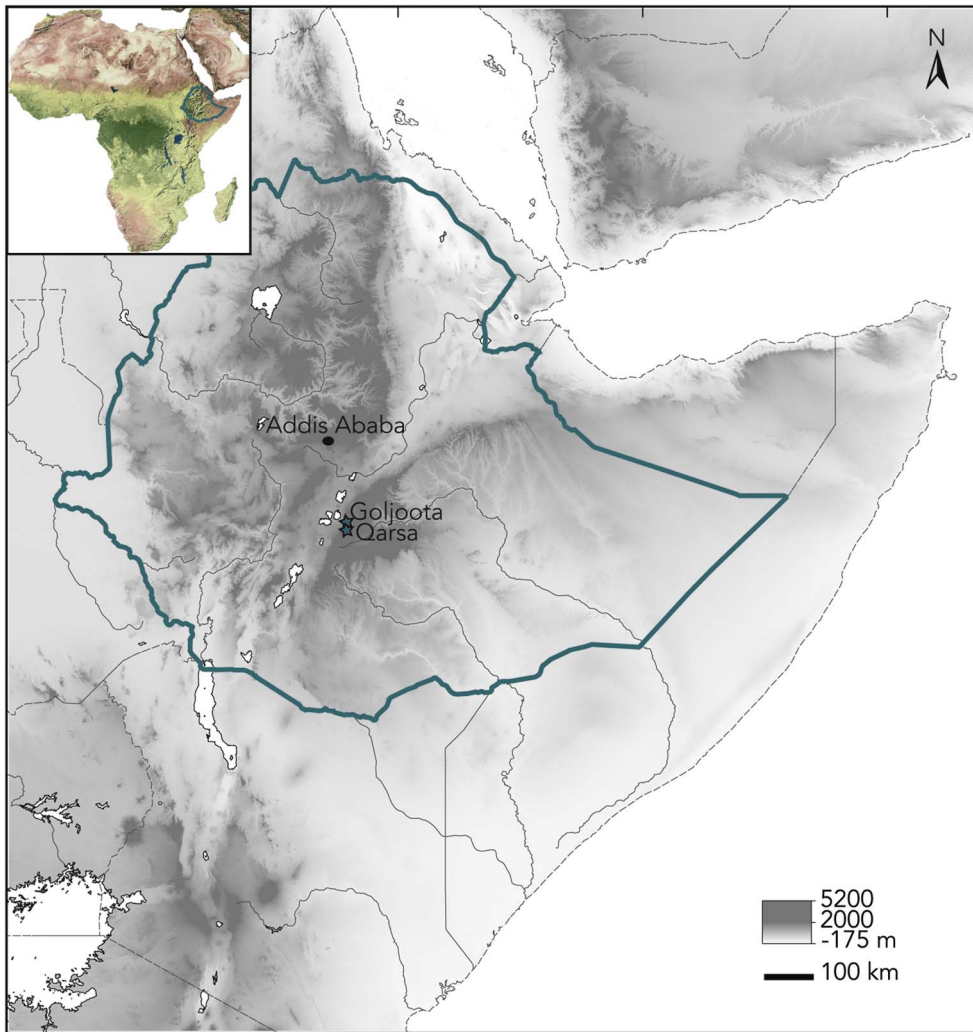


Fig. 1. Map of the Oromiya Region (Ethiopia) locating the two towns surveyed – Goljoota and Qarsa – in the Arsi and West Arsi Zones.

order to assess the role of matrimonial alliances in the contour of the technological boundaries:

- One simple situation which involves two ethnic groups and the transmission of technological standards through women only; it takes place in Ethiopia.
- One complex situation which involves four ethnic groups and the transmission of technological standards through men and women; it takes place in Cameroon.

2.1.1. A “simple” situation: Ethiopia

The Ethiopian case study shows that the learning and transmission process participates to the superimposition of technological boundaries on social boundaries despite variability in the modalities of learning.

The investigations have taken place in the Rift Valley, in the Oromiya region (Fig. 1). This region is inhabited by different ethnic groups (which include the Oromo, Woloyta, Gurage, Sidama, Amhara, Kambata, and Tigrayan) due to movements of populations in the past (Freeman and Pankhurst, 2003). Nowadays, pottery is practiced mainly by two ethnolinguistic groups: the Oromo who speak Afaan Oromo, the vehicular language in the region, and the Woloyta who, apart from the vehicular language, speak Woloytania and are migrants having arrived in the region forty years ago.

The Woloyta and the Oromo are patrilineal (ethnic affiliation depends on patrilineal filiation), virilocal (living at husband’s village) and exogamous communities although in the potter community studied, inter-ethnic marriages are rare. Pottery production is a specialized



Fig. 2. Vessels made by the Woloyta and the Oromo. Note- On the left, the Woloyta flat dish for cooking bread (called *Bashe*); on the right, the Oromo cafetiere (called *Jabana*) to make coffee.

activity conducted by women exclusively on a domestic scale. It is still a dynamic activity. It represents the main source of income for the Woloyta. Their rates of production depend on the season: around 200 vessels per month during the dry season against 80 during the wet season. Among the Oromo, the rates are more variable because pottery is not their sole economic revenue, though they are generally high, particularly among divorced women relying mainly on this revenue.

Two places have been investigated. One is Goljoota, a town including 31 Woloyta and 4 Oromo families of potters, out of which 20 Woloyta and 2 Oromo have been interviewed. The other place is a town, Qarsa, where 30 Oromo families of potters live and out of which



Fig. 3. The Oromo *Chaîne opératoire* for making the cafetiere (called *jabana*). (A) Starting with a thick coil. (B) Drawing the walls with upward discontinuous pressures. (C) Shaping by scraping with a bone spatula. (D) Closing the bottom. (E) Adding a coil for making the shoulder of the cafetiere. (F) Shaping the shoulder. (G) Adding a coil for making the neck. (H) Shaping the neck. (I) After finishing the neck, attaching the handle. (J) Incising decors with a comb on wet surfaces. (K) Coating the *Jabana* with a polish made out of red clay slip mixed with water and vegetable oil or diesel. (L) Open firing; combustible includes wood, twigs and dried dung. (M) Coating the outer surface with carbon by smoking it out; this is done by plunging the hot cafetiere into straw.

9 have been interviewed. Qarsa is 45 minutes' drive from Goljoota. Potters from Qarsa regularly go to Goljoota where a large market takes place several days a week bringing together potters from different places. The Woloyta sell their production directly to the consumers, whereas the Oromo sell their production both directly (as in Goljoota) and indirectly, through middlemen who sell their production in several marketplaces, some as remote as Addis Abeba (200 km from Qarsa).

Woloyta and Oromo make utilitarian vessels. Among them, there are types which are common to both groups. However, in the markets frequented by both groups, there are types exclusive to each of them and particularly successful sales-wise: the Woloyta flatbread dish, and the Oromo cafetiere (Fig. 2). The consumers consider each type to be typical of each ethnic group's production whereas potters themselves consider each type to be proper to each group, and to be sold as such on the market.

The manufacturing process differs between these vessels (Figs. 3 and 4):

- The making of the Woloyta flatbread dish involves the following operations: modeling by drawing, burnishing, organic coating (on the inner face successive coating of a red slip and a mix of water with banana tree roots, on the outer side coating of the edge with dung). The dung coating, used by the Woloyta, is highly popular among consumers because it symbolically gives to the pots the value

attributed to cattle.

- The making of the Oromo tradition cafetiere involves the following operations: coiling by drawing, polishing with a polish made out of a red slip mixed with linseed oil and sometimes post firing carbon coating (smudging). The polish and the carbon coating give to the cafetiere a shiny black aspect which makes them very attractive to the consumers. Smudging is found on different types of vessels (vessels for grilling coffee and meat) and is used only by the Oromo.

As a general rule, the Woloyta vessels have the reputation of being solid, whereas the Oromo vessels have the reputation of being thin and aesthetic (knowing that slip and smudging affect permeability and heating effectiveness, but not strength, Longacre et al., 2000).

The learning and transmission process participates directly to the reproduction of the tradition within each group.

Among the Woloytas, the learning process is pre-marital and the transmission of the craft takes place within the family. It is mainly vertical¹ through the mother to the offspring or, in some exceptional

¹ Vertical transmission: from parents to offsprings; oblique transmission: from institutions or adults others than parents to children; horizontal transmission: within generation (Berry et al., 2002).



Fig. 4. The Woloyta *Chaine opératoire* for making the flatbread dish (called *bashe*). (A) Mixing of clay. (B) Modeling from a lump of clay by horizontal drawing. (C) Addition of clay in the centre of the dish. (D) Shaping the rim with continuous pressures. (E) The dish after shaping. (F) Shaving the outer surface with a metal knife. (G) Smoothing the inner face with a piece of cloth soaked in water. (H) Sun drying before pre-firing. (I) Burnishing the inner face with a small pebble for facilitating the adherence of coatings. (J) Pre-firing. (K) Open firing; combustible includes wood and straw. (L) Coating the inner face with a red slip. (M) Coating the inner face with a mixture of water and Abyssinian banana tree roots. (N) Coating the edge of the dish with animal dung.

cases, oblique, from the aunt (when living as a child with her) or the mother-in-law (when married as a child). According to this process, the Woloyta girls are taught the Woloyta tradition and only this tradition. The learning process encompasses several stages. It starts early by playing and observing informally the adults, followed at the age of 8–11 by their involvement in the preparation of the clay material and the finishing operations, and at 12 by their learning of the fashioning process. Responsibility for sales and firing comes once married. Becoming an accomplished artisan is said to require 6–8 years.

Among the Oromos, when the learning process is pre-marital, the transmission of the craft takes place within the family and is vertical or oblique. However, half of the interviewed potters were not born in a potters' family and did not marry a potter. They learnt the pottery from family or neighbors, often after marriage, but always from the Oromo group. More precisely, until recently pottery was practiced exclusively by one of the Oromo clans and relatively in secret. Therefore, the ones who decided to learn the craft in order to improve their revenues started in secret by watching their neighbors, or their relatives who had learned from watching their neighbors. The pre-marital learning follows the same steps as described for the Woloyta. The post-marital learning occurs over shorter periods with the apprenticeship starting directly at the fashioning stage.

The differences in the learning process between Woloyta and

Oromo, -whether pre- or post-marital, within or outside the family, vertical, oblique or horizontal -, illuminate the fact that these do not play on the transmission process: whatever the modalities of the learning process, it takes place within the learner's social group which favors the reproduction of the tradition within each social group. As a result, in the Oromiya region, the technological traditions reflect the ethnic affiliation of the potter, whether the tutor is from the family or from the social group in the case of non-potters' families, technological boundaries conforming then to social boundaries.

2.1.2. A "complex" situation: Cameroon

In contrast, the Cameroon case study indicates inter-ethnic alliances between potters' families. The learning and transmission process explains that in all cases technological boundaries mirror distinct social learning networks related, not to the potter's ethnic group, but to the tutor's ethnic filiation.

The investigations have taken place in the Tikar plain (North-West of Cameroon) (Fig. 5). This region is nowadays inhabited by eleven different ethnic groups given numerous movements of populations in the past (Blench, 1993; Williamson, 1971). Pottery is still practiced but as a minor secondary activity - ceramic production taking place only 4 months a year. It comes mainly as a complement to other economic activities, chiefly agriculture. The demand is for storage pots for liquids



Fig. 5. Map of the Tikar plain (Cameroon) locating the nine villages surveyed.

Table 1

Subjects interviewed in the Tikar Plain (Cameroon) distributed per village, ethnic group (husband's affiliation), technological tradition, age and sex.

Village	Ethnic group	Tradition	Age	Subjects	Sex
Bankim	Kwanja	T4	76	ELH-4	F
Bankim	Tikar	T3	55	ELG-3	F
Bankim	Tikar	T4	55	MAD-4	F
Bankim	Tikar	T4	68	MAR-4	F
Bankim	Tikar	T3	65	MAM-3	F
Bankim	Tikar	T4	65	VIC-4	F
Dicki	Yamba	T1	77	MOU-1	M
Kinguizom	Mambila	T2	59	HAD-2	F
Kinguizom	Mambila	T2	56	FAT-2	F
Kinguizom	Mambila	T2	46	MAE-2	F
Lam	Yamba	T2	50	MAY-2	F
Mbéto	Tikar	T3	62	YVO-3	F
Mbéto	Yamba	T1	68	HAM-1	M
Mgbanji	Tikar	T3	40	CHR-3	F
Mvou	Mambila	T2	71	LEC-2	F
Nyamboya	Mambila	T4	63	HAB-4	F
Nyamboya	Mambila	T4	70	TOB-4	F
Nyamboya	Mambila	T2	60	MAIM-2	F
Tiké	Mambila	T2	57	FAN-2	F
Tiké	Mambila	T2	62	FAA-2	F
Tiké	Yamba	T2	73	SAB-2	F

(water) and solids (flour, grains, meat, medicines, and spices), very rarely for cooking pots. The potters are specialized and carry out their activity on a domestic scale. They sell or exchange their products directly to consumers, either in villages or at markets, rarely through intermediary salespersons.

All in all, 21 potters were interviewed (Table 1). They live in nine different villages, all located along the main road over a 30 km distance (Fig. 5). The potters are between 40 and 77 years old with an average of 61 years. They are the remaining present-day community of the potters of the region. The rate of production varies between ethnic groups. It is medium (between 10 and 20 vessels per week, 4 months a year) or low

(less than 10 vessels per week, 4 months a year).

The potters of the Tikar plain belong to six ethnic groups: Yamba, Mambila, Tikar, Kwanja, Tumu and Bamiléké, though, as we shall see, they were taught their craft from tutors of Yamba, Mambila, Tikar and Tumu filiation only. These groups are organized in lineages, each carrying the name of the founding ancestor. They are exogamous, patrilineal, patrilocal or virilocal (living at father's village for men, and at husband's village for women). From a linguistic point of view, they are divided between the Ubangian languages (Tikar), belonging to the Niger-Congo family, and the Bantoides languages (Yamba, Bamiléké) that encompass the Eastern and Grassfield Mambiloïdes languages (Mambila, Kwanja, Tumu). Alongside these local languages, there is a lingua franca namely the Fula or Fulfulbé, which had spread by the mid-19th century with the arrival of the Fulani herdsmen and the spread of the Islamic religion.

The main salient technical features differentiating the main technological traditions practiced in the Tikar plain are the clay processing and the forming technique. Four forming techniques are used (described in detail in Gosselain, 2002) (Fig. 6).

1. Modeling by pinching, abbreviated Mp (also called "pinching"). A clay mass is transformed into a hollow volume by punctual discontinuous digital pressures.
2. Coiling by pinching, abbreviated Cp (also called "coiling by vertical superposition"). Coils are superimposed on top of each other and joined by punctual discontinuous digital pressures.
3. Coiling by spreading, abbreviated Cs (also called "coiling by internal apposition"). Short coils are placed against the inner wall and spread in a discontinuous horizontal translation movement.
4. Modeling by drawing, abbreviated Md (also called "drawing from a lump of clay"). Clay mass is transformed in a hollow volume by vertical upwards discontinuous inter-digital pressures.

Each forming technique is performed traditionally by a separate ethnic group. Modeling by pinching is practiced by Yamba men, coiling



Fig. 6. The four forming techniques used in the Tikar plain. (A) Modeling by pinching (Mp, Yamba). (B) Coiling by pinching (Cp, Mambila). (C) Coiling by spreading (Cs, Tikar). (D) Modeling by drawing (Md, Tumu).

by pinching is practiced by Mambila women and men, coiling by spreading by Tikar women and men, and modeling by drawing is practiced by Tumu filiation women. These forming techniques are different in terms of skills and time manufacturing. The Cp is the slowest one and the Md and the Cs the fastest (Fig. 7). The Md is of particular interest because it is practiced by a higher number of potters than Cs, which could have been a factor in favor of a positive influence for its borrowing. This applies, in particular, to the Mambila who have the highest rate of production and at the same time the slowest forming technique (Cp).

Regarding the clay processing, three different recipes are used depending also on the ethnic groups: the Mambila use one clay material only, the Tikar and the Tumu mix two clay materials, and the Yamba mix clay material with termite mound earth.

Two situations of craft transmission were encountered: either the craft is practiced within the family and the transmission is vertical, from parents to offspring (children or grand-children), or the craft is not practiced in the family and the transmission is horizontal, done at the post-marital stage by members of the family in-law.

When the craft is practiced within the family the tendency is that the offspring practices the tradition taught by the tutor who can be the mother or the father. As an example, Tumu women who perform the Md, married men from different ethnic groups: three married Tikar, one married a Kwanja, two other ones Mambila. In these different cases, whoever they married, they kept teaching the Md to their children. As a result, Md is practiced in different ethnic groups (Tikar, Kwanja, Mambila, Bamiléké). In this region at least (Md has a wide expansion in West Africa and its diffusion may have followed different modalities

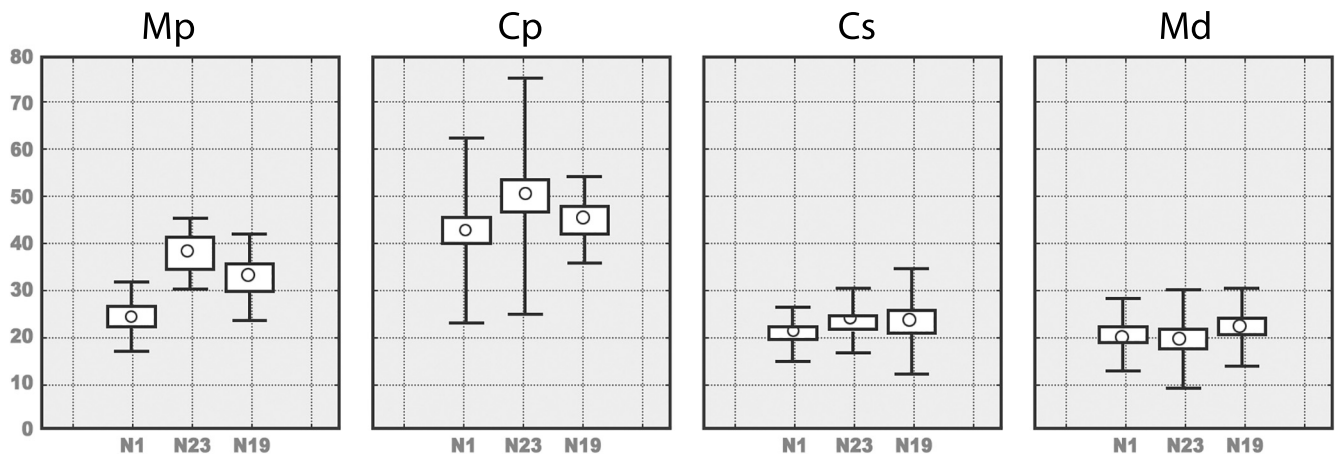


Fig. 7. Manufacturing time per pot depending on forming techniques. The potters made 6 pots of similar size for three different shapes. N1 is a common shape. N23 and N19 are two unusual shapes with different ratios H/DM corresponding to different degrees of difficulty. Coiling by spreading (Cs) and modeling by drawing (Md) are faster than coiling by pinching (Cp) and modeling by pinching (Mp).

which are not discussed here), Md remains thus strongly tied with the Tumu filiation as shown by its transmission over more than three generations.² When there are two tutors, the mother and the father, originating from two different ethnic groups and therefore using different pottery techniques, the two techniques can be taught successively and one individual can practice two traditions. This is rare but it can happen during one life time. In this case, however, only one tradition is taught to the next generation, usually the tradition taught first. For example, one woman learnt pottery first from her grand-mother who was Tumu (Md), and second from her grand-father who was Tikar (Cs) (when she was 15 years old). After marrying a Tikar who was not a potter, she taught only the Tumu technique (Md) to her children (three daughters and one son). In the same way, there are cases where one subject is taught the craft before marriage and arrives in a new family where another tradition is practiced. The subject then may come to learn two traditions. However, when it comes to teaching the offspring, only one tradition is taught. This is a case of a Bamiléké woman whose mother was Tumu and who was taught the Md. She married a Mambila who was a potter practicing the Cp; the potter taught her his tradition so that she could help him. However, she taught her daughter (Mambila by her father) the Md and when her husband died, she abandoned the Cp definitely.

When women originate from families who are not potters or who pass the craft on to men only, they are taught the craft after marriage by the in-laws. The technique they practice corresponds then to their in-laws tradition. Thus a Yamba woman had not been taught the craft because, among the Yamba, pottery-making is a male activity. When she married a Mambila, she learnt the Cp (Mambila) which she passed on her offspring.

In summary, and in line with Gosselain's observations (2000), in the Tikar plain, the technological traditions reflect, as a general rule, the ethnic filiation of the tutor, knowing that the tutor can be the mother, the grand-mother, the father, the grand-father, or the in-laws in the case of post-marital learning, and knowing also that the tutor and the learner can be affiliated to different ethnic groups (in the case of inter-ethnic marriages). In general, the tutors teach the technique they were taught initially, and not the technique they might have learned later in the course of their life. This tendency points to the importance of the learning process in the transmission of the tradition. According to this process the potter progressively integrates the knowledge and the skills involved in the making of the vessels taught by his (her) tutor. At the end of the learning process, the technological standards proper to his (her) tutor's group are deeply embodied as suggested by the Tumu potters who keep transmitting the initial technique they learnt despite marriages with men practicing other techniques and children whose ethnic affiliation depends on the father's affiliation.

To conclude, the examples of Cameroon and Ethiopia show well that because learners learn from tutors, and because tutors are always selected from close social circles, technological traditions are perpetuated within circumscribed social circles, delimiting technological clusters made up of socially close individuals.

2.2. Interactions and technological boundaries

The conditions under which technological boundaries persist and technological traits do not diffuse can be defined in terms of connectedness and interactions between the potters located within and on either side of the technological boundaries. As we shall see, connectedness within each ethnic group is strong, while degrees of interactions between ethnic groups vary depending on regions, Ethiopia or Cameroon.

² As an example, a Tumu woman married a Kwanja (not a potter); she taught her daughter the Md who also married a Kwanja (not a potter) and who taught her children the Md in turn (2 daughters and one son).

2.2.1. Ethiopia

In Goljoota, the Woloyta know each other well. They are all related by blood ties or marriage (they are distributed between four main families). Moreover they are neighbors, living in houses located in the same neighborhood along the same route. In this regard, they represent a tightly interconnected cluster of potters sharing family relationships and located in the same area of space. They interact on a daily basis, though they say that they do not exchange information about their craft and do not buy from each other.

In Qarsa, the Oromo are less related through blood ties or marriage. They live in scattered houses. However, they are not isolated. They have developed friendship relationships and often meet in everyday spaces (streets and fields) and through the meetings of two existing cooperative (aimed at helping families in need). They buy vessels from each other (the types they do not make they buy directly at each other's homes or on the market). They talk to each other about their craft, mainly for discussing sources of clay rather than forming or finishing techniques. In this regard, even though the Oromo potters are not connected by family relationships they are still tightly connected by social and friendly relationships.

Regarding interactions between the Woloyta and the Oromo, the two groups are in contact on a regular basis in the local markets. The market is a public space where they meet a few times a week (Fig. 8). They stand at distinct places. They talk to each other but rather briefly. They mainly talk about the sales or when asking for change. In some cases, Oromo would question the Woloyta about their techniques. But as a general rule, they do not discuss their craft. They can buy from each other. Besides, Woloyta and Oromo are neighbors in Goljoota. They have friendly relationships, they visit each other and casually discuss over a cup of coffee.

These interactions explain that Woloyta and Oromo know each other's productions well as shown also by their capacity to recognize who manufactured what when we showed them photographs of the different types of vessels made by both groups. When asked about not copying stylistic and technical traits from each other in order to improve their revenues, Woloyta and Oromo give the same sorts of explanations (technical [*our raw material will be inappropriate; our techniques are better for what we do; we do not have the knowledge*], organizational [*our working organization is not the same and therefore we cannot do the same way than the others*] and economic [*consumer prefer the original to the copy; it will take too much time to make them*]) justifying the pointlessness of borrowing.

In summary, in the Oromiya region, potters from each ethnic group entertain close relationships, given family or social ties. In contrast, the connections between the two ethnic groups are rather loose. However, they do exist and imply that each group is well acquainted with each other's ceramic production and technological features.

2.2.2. Cameroon

In the Tikar plain, the general situation is that all the potters are connected to each other, either directly or indirectly, thus being aware of each other's technological traditions. These interactions are based on family ties (blood ties or marriage) or on friendly and social relationships.

Family ties are met within each ethnic group. Friendly and social relationships are encountered within and between the ethnic groups. In the latter case, they are visible in the sharing of clay sources and decoration tools. Interestingly, the pattern of connections does not privilege links at the group level (intra-group interactions) or at the technological tradition level (intra-tradition interactions) as we shall see with the example of the interactions between the potters practicing the Md technique, - the fastest forming technique and therefore, the technique likely to be borrowed -, and the other potters using slow forming techniques.

The large majority of the potters practicing the Md live in the same village, Bankim (4 out of 6). Among them, MAR-Md³ has regular direct

³ Abbreviation of the first name followed by the abbreviation of the technique used.



Fig. 8. Woloyta and Oromo potters meeting regularly in market places (market of Goljoota – Arsi Zone, Oromiya Region). (A) In the foreground the Oromo Potters, in the background the Woloyta Potters. (B) In the foreground the Woloyta Potters, in the background the Oromo Potters.

interactions with potters using the Md, the Cs and the Cp forming techniques. Her professional and friendly interactions are mainly with EHL-Md and MAM-Cs living in Bankim, and FAN-Cp and SAB-Cp living in Tiké; these occur when these potters visit each other's homes and collect the clay material on MAR-Md's land. MAR-Md is also connected directly with MAY-Cp, living in Lam, with whom she exchanges decoration tools ("roulettes") and with MAD-Md, VIC-Md, and ELG-Cs, three co-wives living in Bankim and who are neighbors. HAB-Md, from Nyamboya, has also direct interactions with Cp potters among whom MAY-Cp, collecting clay on her land, and MAIM-Cp who is a neighbor.

Furthermore, indirect interactions between potters using the Md and the other potters exist through the Cp potters who have direct interactions on the one side with Md potters and, on the other side with most of the Mp and Cp potters. This is the case of SAB-Cp, from Tiké, who has direct interactions with MAR-Md and informs most of the potters about clay sources (FAN-Cp, FAA-Cp and SUZ-Cp her daughters; FAT-Cp, MAE-Cp and HAD-Cp, from the same household in Konguizom; LEC-Cp, from Mvou; and MOU-Mp, from Dicki). This is also the case with Cs potters who have both interactions with Md, Cs and Mp potters (MAM-Cs, a close friend of MAR-Md, is YVO-Cs's sister, living in Mbeto and in close interactions, either for clay or decoration tool sharing, with HAM-Mp, a neighbor).

In summary, in the Tikar plain, there are strong interactions on the one hand between the potters belonging to the same ethnic group given family ties, and on the other hand between the potters belonging to different ethnic groups given friendly and social relationships.

2.3. Cognitive correlations and technological boundaries

In the previous examples, the groups of potters differ socially and in their craft. In the polarization issue, one of the questions is about the features participating to both a high consensus within the groups and a sharp disagreement between them. Social origin is one. Technological standard is another one that we propose now to examine in the light of human cognitive limitations. The cognitive limitation considered here is the one in which individuals use a "covariation principle" to assess causality. The "covariation principle" states that "if event A accompanies outcome B, and if event A is absent when outcome B is absent, then people tend to attribute A as the cause of B" (Carley, 2001, p. 181;

Kelley, 1967, 1973). According to this principle, if technique A accompanies product B, and if technique A is absent when product B is absent, then people may tend to attribute technique A as the cause of product B, or product B as the cause of technique A.

As we shall see, this cognition principle has major repercussions, among which polarization even within a same social group. This will be first exemplified by a case study in Ecuador where ethnographic investigations were conducted according to the same questionnaires designed for Ethiopia and Cameroon. A second case study in India will enable us to explain how this "covariation principle" comes into play when technological standards are used by different social groups.

2.3.1. Ecuador

The situation in Ecuador is a case in point because it shows that, all other things being equal, technological standards have contributed directly to polarization.

The case study takes place in the canton of San Miguel de Porotos (south of the Cañar province) (Fig. 9). This region is inhabited by potters who are of indigenous origin (cañari) and speak Spanish, but whose parents or grandparents used to speak Quichua (language of pre-Hispanic origin related to the Quechua of Peru). Pottery is a specialized activity conducted by women or men on a domestic scale during half of the year (Sjöman, 1992). It is a source of income in addition to agriculture.

The potters' eleven houses in the canton of San Miguel de Porotos are distributed between three hamlets: Pacchapamba (5 potters), Chico Ingapirca (3 potters) and San Juan Bosco (3 potters). Nine potters were interviewed (Table 2). In each hamlet transmission is vertical, from parents to their offspring.

The three hamlets are separated by only a few hundred meters (10–20 min walking distance). Each hamlet is home to families who have no kinship ties; whereas members of a same family or members with strong ties can be living in different hamlets (example of one family whose members live in San Juan Bosco and in Chico Ingapirca; example of a godfather living in Chico Ingapirca and his godchild in Pacchapamba).

Regarding ceramic production, the potters from Pacchapamba and San Juan Bosco are specialized in the manufacture of utilitarian wares (cooking pots, jars, tortilla dishes), whereas the potters from Chico

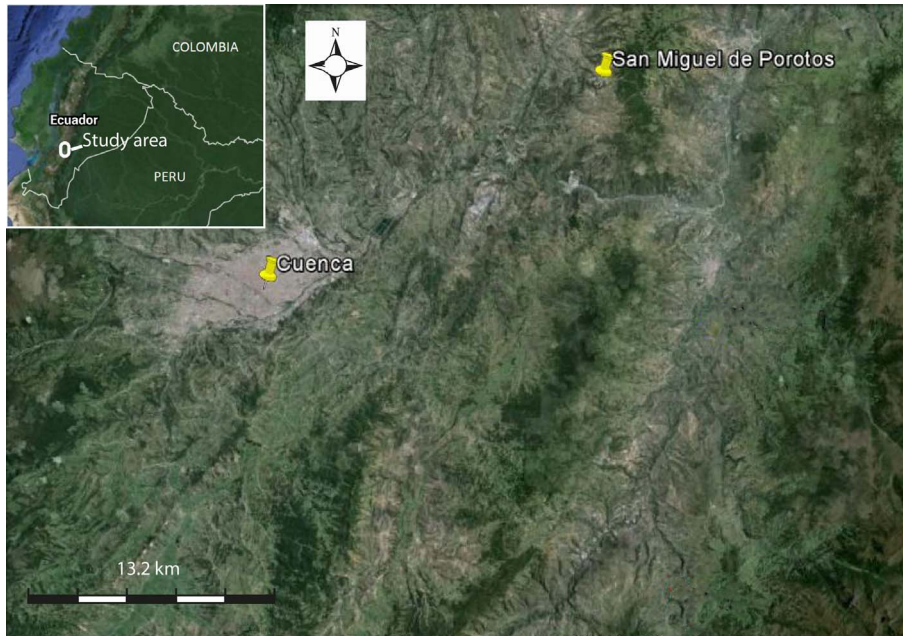


Fig. 9. Location map of San Miguel de Porotos (Ecuador).

Table 2

Subjects interviewed in the three hamlets of the canton of San Miguel de Porotos (Ecuador).

Hamlet	Family	Subjects
Pacchapamba	Pérez Zimbaña	María Pérez
		María Zimbaña (María's daughter)
	Fernández	Margarita Fernández
		María Fernández (Margarita's sister)
Chico Ingapirca	Suquinagua	Edelina Suquinagua
	Inga	Francisco Inga (Godfather of Margarita's son)
		Maríana Inga (Francisco's sister)
San Juan Bosco	Tenenpohuay	Teolinda Tenenpohuay
	González	Remigio Gonzalez (Teolinda's son-in-law)

Ingapirca are specialized in ornamental or specialized wares (birthday pots, plates for flower pots). The annual production is slightly lower in Pacchapamba (550 items a year against 750 in San Juan Bosco and Chico Ingapirca).

Now, in the canton of San Miguel de Porotos three open firing structures coexist: open firing in Pacchapamba, walled firing in San Juan Bosco and kiln in Chico Ingapirca (Fig. 10). The kiln presents objective advantages when considered in terms of thermal performance characteristics - maximum temperature achieved, temperature variation within the kiln load and control of the rate of temperature increase - and in terms of control of firing atmosphere - protecting the load from gusts of wind and reducing the incidence of fire clouds in oxidized pottery kilns (Arnold, 1991; Pool, 2000; Rice, 1984). The kiln presents also advantages in terms of combustible and working hours (Table 3).

The presence of the kiln in Chico Ingapirca has been attested for a long time. There is no memory of its introduction. On the basis of oral narratives the kiln was already used in the sixties by the three households of potters who were then in activity.

The potters of Pacchapamba and San Juan Bosco never borrowed the kiln because at first they say that the open or the walled firing is their method, that it works well and therefore that they have no interest in changing it. But they also give other reasons (technical, organizational and economic) among which the more frequent is that the kiln is appropriate only for decorative items and inappropriate for utilitarian vessels.

As potters say: "The kiln is used by Francisco whose production is famous and different from ours; we do not make the same items and therefore we do not need the kiln" (a potter from San Juan Bosco); or "Kilns are for potters who make special items like the "decorated figurines" made by Francisco or the "birthday vessels" made by Edelina" (a potter from Pacchapamba); or "Our pots are well fired, with a nice color and sell well" (a potter from San Juan Bosco).

With reference to the "co-variation principle", these explanations given for the non-borrowing of the kiln highlight that the potters make a strong cognitive correlation between the firing structures and the products to be fired: they link the kiln with the firing of decorative items and no other items than these ones. Inter-marriages between hamlets are particularly telling examples of this cognitive correlation. Thus, two potters of San Juan Bosco married men of Chico Ingapirca. When they moved there, they left behind the walled firing and adopted the kiln along with the manufacture of small decorative items under the guidance of the mother-in-law. They never made any more big vessels because, as they say, the kiln is for firing small items only. Another example is provided by a woman from Pacchapamba who married a man from Chico Ingapirca and then adopted the kiln along with the manufacture of small decorative items. When her husband died, she returned to Pacchapamba, gave up the kiln and the small decorative item production, and used open firing again which she liked better because, as she said, it allows her to fire bigger vessels.

As a result of this cognitive correlation, technological boundaries were formed differentiating the three hamlets: the kiln is found only in Chico Ingapirca and is used to fire decorative items only; open firing and walled firing are found respectively in Pacchapamba and San Juan Bosco and are used to fire utilitarian vessels only.

In summary, in San Miguel de Porotos, at first the three hamlets were making the same types of vessels that they fire using two firing structures (the story of the walled firing is not known). Then, in the course of adopting the kiln the kiln users specialized in the production of specific types of objects. As a consequence of the principle of rationality favoring correlations between techniques and finished product, groups with no family tie got formed, each of them using different technological standards. These differences in technological standards have divided the potters into three groups, fostering polarization to the extent that on the one hand the kiln has not been borrowed despite its advantages over the open and walled firings, on the other hand potters of San Miguel do not feel they belong to the same community, as shown



Fig. 10. Firing structures in San Miguel de Porotos. (A) Open firing. (B) Vertical updraft kiln. (C) Walled firing.

Table 3
Comparative costs between kiln, open firing and walled firing in Ecuador (in 2014).

Capacity (100 pots)	Fuel	Working hours to prepare the firing	Cost of the kiln
Kiln	1 bundle of wood and 6 muleloads of straw	2	410 \$
Open firing	7 muleloads of wood and 20 muleloads of straw/ eucalyptus leaf	4	–
Walled firing	5 muleloads of wood and 3 muleloads of straw	4	6 \$

by their refusal to form an association which required a minimum of ten potters and which would have helped them in increasing their sales.

2.3.2. India

The case study in India (North West India, Bulandshar district, Fig. 11) illustrates not only the intrinsic value of technological standards in the polarization process, but also how this process integrates progressively social differentiation. The principle of rationality correlates, in this case, potter's tools and preforming techniques and potter's tools and social groups.

The ethnographic situation has already been described elsewhere (Roux, 2013). The craft production is distributed between Muslim and Hindu potters, two endogamous groups (Kramer, 1991) who live in the same villages or in different villages. Each of them uses different

technological systems which present strong differences in terms of cost and benefit. The Muslim potters use the foot wheel, the kiln and glaze; the Hindu potters use the fly wheel, the open firing and do not glaze their vessels. Like the kiln as opposed to open firing, the foot wheel presents clear advantages over the fly wheel. The foot wheel is operated with the foot and enables the control of the speed all throughout the forming process. In contrast, the fly wheel is launched with a stick and the speed of the fly wheel cannot be controlled. It decreases progressively once launched. As for the glazing technique, it is mainly applied on cooking pots, which are then less permeable and have better thermal properties than the unglazed ones. However, neither the kiln, nor the foot wheel and glaze have ever been borrowed by the Hindu community, except for a few cases not discussed here. This is all the more noticeable since Hindu potters interact regularly with Muslim potters in a professional (sharing customer orders) and friendly framework (visiting each other), and therefore know well the Muslim techniques (they could draw the Muslim kiln and explain how it works).

In order to investigate how technological differences enhanced polarization we interviewed 50 Hindu and Muslim male and female teenagers of different age groups (from 8 to 19 years old) living in nine different villages (30 male teenager potters including 17 Hindus and 13 Muslims; 20 female teenager potters, including 9 Hindus and 11 Muslims, Table 4). The interviews included questions about manufacturing process, properties of the techniques and tools, technological system used by the other group, advantages or disadvantages of each technological system, and at last who uses which system. For this purpose, the subjects were shown photographs of each community's

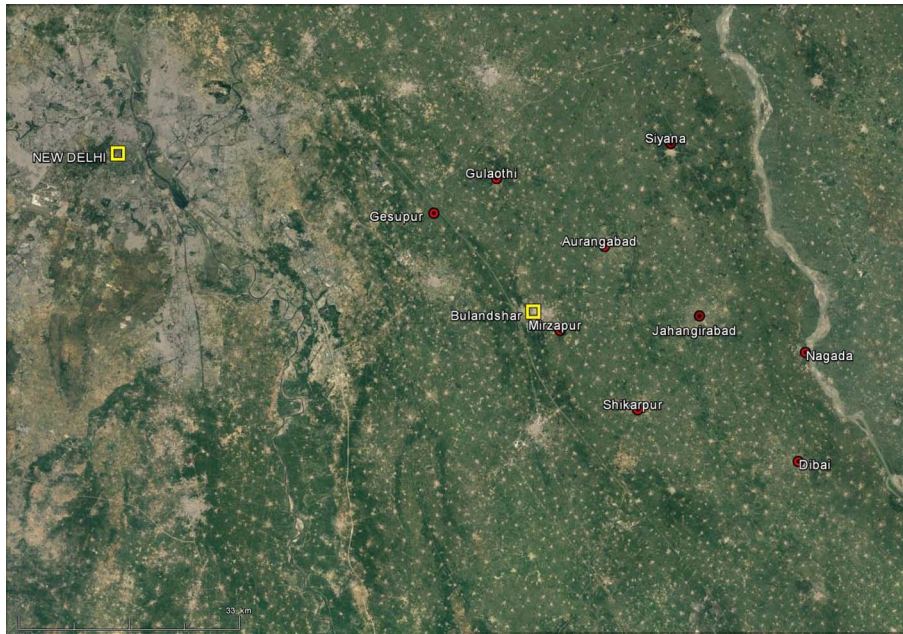


Fig. 11. Location map of the villages surveyed in Bulandshar district (Uttar Pradesh, NW India).

instruments so that they could make precise comments (Fig. 12). We will focus on the comments given about the potter's wheels. Two main results obtain: (a) cognitive correlations evolve depending on one's experience and contribute progressively to link technique and social group; (b) interactions between actors using different techniques are necessary for correlation between technique and social group.

The first result reports on the correlation between instruments and finished products, and between instruments and preforming techniques. We asked the male potters (30) about the differences between the fly wheel and the foot wheel. Out of 30 subjects (13 Muslims and 17 Hindus), 24 knew about both instruments, 13 Muslims and 11 Hindus. When they knew, they could attribute each instrument to each community.

In the Muslim community, when asked about the advantages of the foot wheel over the fly wheel, 6 out of 13 indicated that the foot wheel is good for big vessels, and the fly wheel for small vessels only. They include three boys aged 10–11 from Shirkapur and Jahangirabad where both communities are settled and the Hindu potters specialized in the making of small vessels; and three teenagers aged between 15 and 18 from Gesupur, Aurangabad and Mirzapur. The two latter villages are inhabited by Muslim potters only, but the teenagers had seen Hindu potters from Bulandshar (a nearby town) specialized also in the making of small vessels. The Muslim teenagers who did not correlate the wheel with specific finished products considered the fly wheel not as good as the foot wheel because it could not be operated with the foot, it needed to be restarted every time the rotation slows down or it might be tiring for the arms.

In the Hindu community (11), one potter (17 years old) correlated the fly wheel with small vessels and the foot wheel with big vessels; he is from Shirkapur where the Muslim potters make bigger vessels than the Hindus. Another (18 years old) correlated the foot wheel with the throwing of big lumps of clay. He is from Nagara where the Hindu potters make a wide range of vessels and are not specialized in small vessels. These two Hindu potters have never seen the foot wheel but have heard of it. Seven others, who are younger, estimated that the foot wheel was not as good as theirs because it was operated with the foot which might be tiring. Two older ones estimated that the use of the foot wheel would bring them bad luck because the wheel is the *chakra* of Vishnu and should not be touched with the foot.

In addition, we asked a few Hindu senior potters why they did not adopt the foot wheel. The majority of them outlined that the flywheel is

very well suited for what they produce, namely thick vessels whose body is then paddled and can reach up to 50 liters capacity. In contrast they said that the Muslim potters throw thinner vessels whose body is not paddled but whose bottom is pounded, and therefore require a more stable wheel. In other words, senior potters correlate the type of wheel and the finished products under the rational explanation that the fly wheel is good for thick vessels and the foot wheel is good for thin vessels because the fly wheel is less stable and therefore less appropriate to throw thin vessels. There are also senior potters who invoked that foot wheels were not good instruments because wheels should not be touched with the foot.

From these answers, it can be seen that the young teenagers explain the differences of properties of the two instruments either in terms of the skills they require (with the foot, with the arm), or in terms of the type of vessels made by each community. The answers given by the Hindu seniors correlate the instruments with the preforming techniques (paddling versus pounding): in their words, paddling requires thick vessels whose throwing needs less stability than thin pounded vessels. Paddling is a preforming technique used by the Hindus, pounding by the Muslims. In this regard, the fashioning *chaînes opératoires* differentiate both groups with the result that, given the principle of rationality, the two groups perceive the properties of their instruments in the light of these *chaînes opératoires*, and only these.

These results highlight that perception of the properties of the tools is constructed in the course of learning but is not taught as shown by the teenagers' answers which focus on correlations between tools and body postures or between tools and finished products. Only seniors propose correlations between tools and *chaînes opératoires*. Only the older teenagers and seniors attribute a symbolic value to their wheel. This shows on the one hand how the cognitive bias is exerted depending on one's experience and one's age, how then it influences the perception of a technique's properties and how, eventually, it disfavors transfers of techniques from one technological system to the other. On the other hand, it shows that correlations between tools/techniques and social groups is not straightforward; the explicit correlation is mainly between finished products and social groups (they are the Hindus *versus* the Muslim who make small *versus* big vessels); in this regard, it does not play directly on the perception of the properties of the techniques; it comes after to enhance differentiation between both technological systems ("in our group, we do like that" as opposed to "in their group, they do like that").

Table 4
Subjects interviewed in India distributed per village, caste, sex and age.

Village	Caste	Sex	Age
Aurangabad	MK	M	16
Aurangabad	MK	M	12
Aurangabad	MK	M	12
Aurangabad	MK	M	10
Dibai	MK	M	16
Dibai	MK	M	12
Dibai	PR	M	13
Dibai	PR	M	12
Dibai	PR	M	10
Gesupur	MK	F	19
Gesupur	MK	F	9
Gesupur	MK	M	15
Gesupur	MK	M	8
Gesupur	PR	F	12
Gesupur	PR	M	12
Gulaothi	MK	F	15
Gulaothi	MK	F	10
Gulaothi	MK	M	14
Jahangirabad	MK	F	19
Jahangirabad	MK	F	15
Jahangirabad	MK	F	14
Jahangirabad	MK	F	11
Jahangirabad	MK	M	11
Jahangirabad	MK	M	11
Jahangirabad	PR	F	15
Jahangirabad	PR	M	15
Jahangirabad	PR	M	14
Jahangirabad	PR	M	11
Jahangirabad	PR	M	11
Jahangirabad	PR	M	9
Jahangirabad	PR	M	9
Mirzapur	MK	F	10
Mirzapur	MK	M	18
Nagada	PR	F	15
Nagada	PR	M	18
Nagada	PR	M	18
Shikarpur	MK	M	10
Shikarpur	PR	F	15
Shikarpur	PR	F	19
Shikarpur	PR	M	19
Shirkapur	PR	F	18
Shirkapur	PR	F	18
Shirkapur	PR	F	14
Shirkapur	PR	F	10
Shirkapur	PR	F	9
Shirkapur	PR	M	17
Siyana	PR	F	9
Siyana	PR	M	15
Siyana	PR	M	15
Siyana	PR	M	10



Fig. 12. Young potters commenting on photographs showing Muslim and Hindu kilns.

The second result indicates that the individuals who do not have interactions with the other community do not know about the other's technological system. This is the case of most of the girls who know about the whole manufacturing process which takes place within the household and in which they participate (helping in clay preparation, painting and firing the vessels), but who are not used to leaving their neighbourhood and therefore are not exposed to other ways of working (Fig. 13). This is also the case of six Hindu potters (out of 17; they are 10, 12, 15, 17 and 19 years old) who are not involved in pottery sales. Consequently, they do not know who uses what and therefore do not make any correlation between the instruments and the finished products or the social groups. In contrast, all the Muslim potters knew about both technological systems because, unlike the Hindus, they have all been involved in the craft since childhood, accompanying their father to sell or buy the pots, preferring, as a general rule, to learn pottery rather than to go to school. In brief, it is not enough to belong to the same village and have parents socializing with each other's communities, one also has to interact, directly or indirectly, for differentiation to develop.

3. Discussion

We started by raising the question of persisting technological boundaries and diversity on the basis of ethnographic cases. These cases include social groups who use techniques presenting different properties in terms of cost and benefits.

3.1. Context of persisting technological boundaries

At first, data from Ethiopia and Cameroon illustrate how technological boundaries get formed and are superimposed on social boundaries. In both cases the learning and transmission process explains that craft learning requires a tutor, and that the tutor is always selected within one's social group. Comparison between both countries shows that this process of the tutor's selection within one's group occurs whatever the learning modalities (pre- vs. post-marital), the potters' gender (male vs. female) or the matrimonial alliances (alliances between technologically marked groups). As a result, technological traditions reflect social groups and technological boundaries conform to social boundaries, i.e. the tutor's social group boundaries, or put it another way the learning network boundaries. The conformity between technological boundaries and learning networks has been acknowledged for some time now and explains why in archaeology technological traditions are cogent proxies to identify past social groups (e.g. Bowser and Patton, 2008; Dietler and Herbich, 1998; Gosselain, 2000; Hegmon, 1998; Herbich, 1987; Longacre, 1991; Stark et al., 2000) and why they can be regarded as coherent units amenable to evolutionary analyses (e.g., implying a phylogenetic link between cultural groups) (Manem, 2008; Shennan, 2013; Shennan et al., 2015).

As a second step, the context into which technological boundaries persist has been defined in terms of connectedness and interactions between the potters located within and on either side of the technological boundaries. Data show that technological boundaries persist in a context where the different groups interact on a regular basis, no matter the nature of the interactions, distant (Ethiopia) or close (Cameroon), or the nature of the ties within each group, social (Ethiopia) or family (Cameroon) relationships. We add that the persistence of technological boundaries takes place in two different demographic situations. In Ethiopia, pottery activity is still very alive and potters are numerous. On the contrary, in Cameroon, pottery activity is dying and potters are very few in number.

3.2. Technological standards as differentiation markers

As a third step, we took a boundary-making perspective in order to assess better the polarizing effect of interactions between groups using

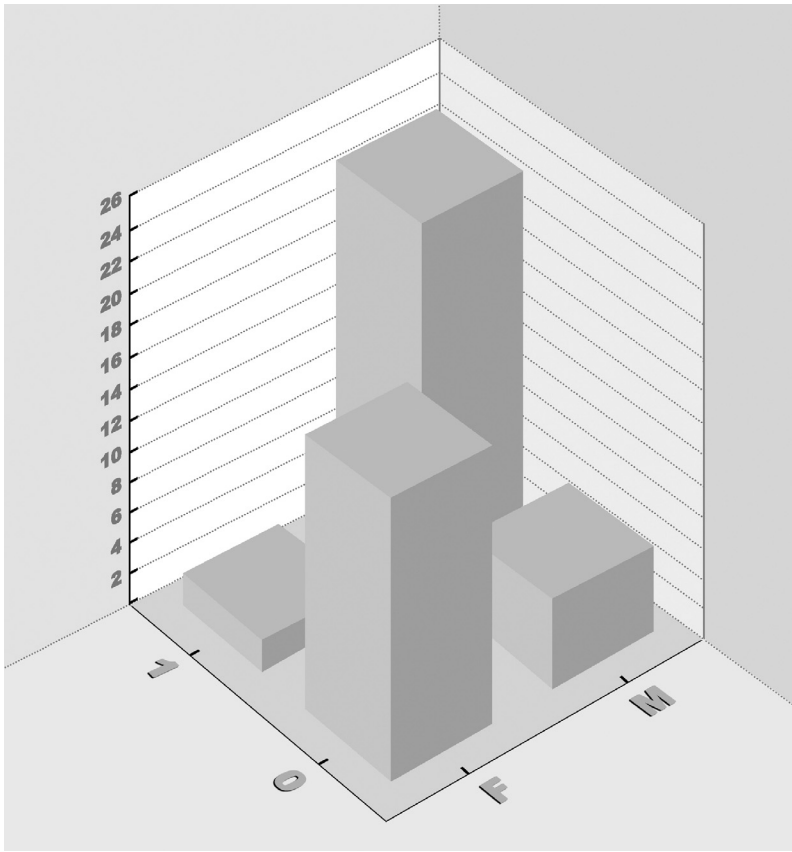


Fig. 13. Number of potters distributed per gender (F, M) and between those who know about the foot-wheel (1) and those who don't (0).

different technological standards.

Our data show that technological standards participate in polarization given first a cognitive bias correlating techniques and finished products. In Ecuador, this cognitive bias makes that the kiln is attributed to small decorative items and the open firing to big vessels. The case of Ecuador is not an isolated one. In India, it has been observed too that the covariation principle linking finished products and kiln influences the potters' perception of the functional properties of the firing structures. Thus, in the region of Jodhpur, in the town of Pachpadra inhabited by Hindu potters, the kiln was introduced in 1998 to make small glazed items and capture a new market (Roux and Gabriellini, 2016). The kiln was built in the house of one of the potters involved in the project. But the latter failed. It took then seven years for the potter to think enlarging the kiln and using it for firing his own production composed of plain utilitarian vessels. For seven years, he perceived the kiln as only good for firing small glazed items. The influence of the finished product in the perception of the properties of the kiln has also been observed in two other Indian places (Roux and Lara, 2016). In one of them (Jahangirabad, Bulandshar dist.), a few Hindu families use the kiln for big vessels, while firing small vessels in open firings. The Hindu potter who first adopted the kiln borrowed it from a Muslim friend who was making only big vessels. As a consequence, he considered that the kiln was unsuitable to fire small vessels. The other Hindu families living in the same town (same sub-caste) are not interested in the kiln because they say they make only small vessels and that small vessels cannot be fired in kilns. In a nearby village, Siyana, five Hindu families use also a kiln. But, unlike in Jahangirabad, the kiln is small and used for small vessels only (the history of the adoption of the kiln is different); the big vessels are fired in open firings. The other Hindu families (same sub-caste) use open firings only, explaining that they make big vessels and that big vessels cannot be fired in kilns. In summary, in Northern India, the same type of vertical updraft kiln is perceived as good for firing big or small vessels depending on the type of vessels fired in the kiln which

was originally adopted. This relative perception of the kiln properties makes that potters do not transfer the new firing technique even to their own production.

The field experiments in India explain how this cognitive bias is constructed at the individual level in the course of learning: young potters develop progressively, by reference to their experience, their own understanding of the properties of the techniques in relationship with the properties of the finished products (*I use the kiln because I make decorative items; I use the fly wheel because I throw big pots*). They use obvious indicators of what they think should be causing their practice. This causality process is studied in social psychology and has been well described within the framework of the attribution theory which is about how people make causal explanations (Kelley, 1967, 1973). These causal explanations prevent individuals from transferring their skills to new situations because they do not understand the properties of the task. In experimental psychology, capacities of transfer of skills to new situations is used to characterize degrees of expertise (e.g. Bril et al., 2010).

In Ecuador, where two technological standards are used, this cognitive bias has promoted polarization despite absence of social differentiation - individuals belong to the same social group - and close ties between the potters. Consequently, the potter community is distributed between those who use the kiln and make decorative items and those who use open firings and make utilitarian vessels. It perceives itself as composed of two technologically marked groups and for this reason, refuses to form an association despite economic advantages.

Differentiation created by technological standards increases when they are in the hands of different social groups. The field experiments in India show how young potters correlate progressively techniques and social groups: correlation between techniques and finished products gets combined with the correlation linking finished products and social groups. The result is twofold: a strong link between techniques and social group (technique t is correlated to product p , product p to group

G, then technique *t* to group G), and a sharp disagreement between the social groups - not the same technique, not the same finished products, not the same social group - as seen in Ethiopia, Cameroon and India. This disagreement promotes differentiation while, at the same time, affiliation is reinforced in the course of learning, communities of practice and cultural process of identity construction shaping each other (Lave, 1991, p. 80).

Interactions are of a major importance in the polarization process. Indeed, interactions are required for actors to correlate techniques and social groups as shown by Indian teenagers. These interactions can be of different nature, as exemplified by the four case studies, but they always take place between actors who live in close geographical proximity and who in this regard are strongly connected.

3.3. Conditions for persistence of technological boundaries

The four case studies show that independently of the organization of production, interactions between actors belonging to different well connected groups are not sufficient for positive influence when the differences between the groups are higher than within the groups. The technological standards are strong markers of differences, creating inter-group disagreement (even within a same social group). As a consequence, these technological standards contribute directly to enhance and add differentiation between interacting communities, especially if those belong to different social groups. It explains that persistence of technological boundaries has been systematically observed in situations where different communities live in close geographical proximity and use different technological standards. Whatever the cultural context and the local social situation, these interactions have promoted negative influence.

Lastly, let us note that there may be exceptions to this regularity. One example takes place in Cameroon where one Mambila potter (FAN-Cp, whose mother SAB-Cp taught her Cp) adopted recently Md, after visiting MAR-Md and ELH-Md and practicing with them, from the preparation of the clay paste to the forming of the vessel. As a result, there has been a positive influence and an integrative effect. This positive influence reveals:

- (a) The role of the cognitive bias correlating here clay material and fashioning technique; the potter did not borrow only the forming technique, but also the clay material, linking both features which, in the case of Cameroon, appear to have played a role in the differentiation process between the four groups, each of them using different clay materials and recipes.
- (b) The role of social learning. Borrowing new practices has implied social learning between individuals from the Md and Cp social groups through common practice, from the preparation of the clay until the forming of the pot. In a situation of technological polarization, such a situation is rare. It goes with exceptional close relationships. This has been observed in Cameroon, and in India, in the town of Jahangirabad (Bulandshar dist.) where a Hindu potter and a Muslim potter had developed exceptional friendship followed by a unique case of borrowing of the kiln by the Hindu potter.

4. Conclusions

Field studies have enabled us to test empirically the predictions of the experimental model elaborated by Flache and Macy (2011) while examining the micro-processes at play in the non-borrowing of techniques. They highlight that interactions between groups using different technological standards and living in close geographical proximity represent conditions in favor of the persistence of technological boundaries. Technological standards add to differentiation between groups due to a cognitive bias developed at the individual level. Polarization along with negative influence increases when the technologically marked groups belong to different social groups. The former do not

correspond necessarily to distinctive, bounded, homogeneous social groups; their nature can be expressed by their degree of “groupness”, a term coined by Brubaker and Cooper while debating identity (Brubaker and Cooper, 2000, p. 20). By using the term “groupness”, the point is to take advantage of:

“an analytical idiom sensitive to the multiple forms and degrees of commonality and connectedness, and to the widely varying ways in which actors (...) attribute meaning and significance to them. This will enable us to distinguish instances of strongly binding, vehemently felt groupness from more loosely structured, weakly constraining forms of affinity and affiliation.”

Brubaker and Cooper, 2000, p. 21

Our four case studies illustrate different degrees of groupness, from a weakly constraining form of affinity as in Ecuador, to a strongly sense of groupness expressed by explicit reference to the other group as in Ethiopia, Cameroon and India. The sense of groupness is enhanced when technological boundaries overlap social boundaries, strengthened then by greater differentiation between groups. In archaeology contextual data should help to correlate technological clusters with different degrees of groupness (e.g. Parkinson, 2006).

Polarization and negative influence can last for centuries, as exemplified by the long co-existence of wheel made and hand-made ceramics around the Mediterranean basin (Gauss et al., 2016).

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