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1 Cultural transmission and perception of vessel shapes among Hebron potters

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30 1. Introduction

31

32 Among the processes underlying human cultural transmission, fidelity copying (action
33 imitation) has been frequently presented as particularly important (Miton and Charbonneau,
34 2018, Lewis and Laland, 2012; Tennie et al., 2009; Tomasello, 1999). Yet, this process has
35 been recently challenged by empirical evidence from wheel-throwing pottery. Gandon et al.
36 (2020a) showed that Nepalese potters used cultural, cross-cultural and individual-specific hand
37 positions (repertoires and sequences) for the fashioning of familiar pottery types. Their results
38 confirmed that the potters' skills are imprinted by the cultural context in which they have been
39 learnt although these skills are not determined by a cultural model copied during learning (Bril,
40 2018). A complementary study with Indian Prajapati and Indian Multani potters tracked the
41 vessel morphogenesis defined as the potter-induced morphological changes in the clay body,
42 from its initial pre-formed stage following centring and opening operations, up to the moment
43 that the final form is reached (Gandon et al., 2020b). Results showed that, in both Prajapati and
44 Multani groups, potters reliably followed individual-specific vessel morphogenesis towards
45 culturally homogenous vessel types. This demonstrates that, at the level of the elementary
46 fashioning gestures, individual learning rather than simple model copying of elders' gestures is
47 required for the acquisition of a complex motor skill such as throwing pottery.

48

49 This is not, of course, to say that cultural transmission plays a minor role in handicrafts.
50 As highly specialized motor behaviours, handicrafts are unlikely to be acquired on the basis of
51 individual learning alone (Boyd et al., 2011; Bril, 2002). In traditional craft workshops, novices
52 learn by deliberate practicing in socially structured environments (with the presence of typical
53 tools and materials, finished vessels, etc.) under the guidance of elders (Boyer and Bril, 2001;
54 Bril, 1986; Crown, 2014; Lave and Wenger, 1991; Minar and Crown, 2001; Rogoff, 1995; Roux
55 and Corbetta, 1989). The social channeling provided by the - material and human -
56 environments educates the novices' attention towards the useful sensorimotor information for
57 achieving the task (Gibson, 1979). This social bias influencing the learning process of novices'
58 skills corresponds to the cultural transmission of handicrafts and leads to culturally inherited
59 traits (Ingold, 2001a, 2001b). As explained by Bril (2015), the elders and the socially structured
60 environment simply organize the novices' experience, while the novices are alone responsible
61 for acquiring a particular skill. The culturally inherited traits are not *given* through the
62 transmission, they *develop* through the socially mediated individual learning. The skills of

63 craftsmen are therefore likely to contain both cultural traits inherited from the cultural
64 transmission (i.e. social biased traits) and individual traits resulting from the individual
65 learning, as illustrated in the study with the Nepalese potters (Gandon et al., 2020a). Accounts
66 of handicraft apprenticeship as a process involving both individual learning and cultural
67 transmission is essential to recognize that craftsmen behaviors - and their subsequent object
68 traits - can be modified through their transmission across generations (Mesoudi, 2017;
69 Wiessner, 1983).

70

71 While craft apprenticeship can be understood as socially mediated individual learning,
72 the ensuing prediction of individual and cultural object traits within craft communities has so
73 far not been investigated in traditions such as pottery throwing. A major issue remains in that
74 we do not know to what extent the objects produced by learners vary from those of their
75 trainers. Previous experimental fieldwork with modern Indian and Nepalese potters indicated
76 subtle individual and social group signatures on ceramic shapes (Gandon et al., 2018; Harush
77 et al., 2020; Roux and Karasik, 2018). Yet, there is still a lack of systematic analysis of object
78 variations among members of crafting families where the transmission takes place. This lack of
79 knowledge limits the understanding of cultural transmission and evolution, thus depriving
80 archaeologists of a valuable framework for interpreting the variability of ancient objects and
81 their temporal evolution. The first goal of this study is to fill up this gap by measuring the vessel
82 shape variation among members of a pottery-making community including different families.

83

84 A related question concerns the visual perception by the craftsmen of the variations in
85 the shape of ceramics. As acknowledged by Crown, it is evident that potters perceive the shapes
86 of the distinctive vessel types they produce: *“The potter then forms the vessel before the clay
87 dries out. These steps require knowledge of culturally appropriate vessel shapes and
88 proportions and the ability to perceive or measure these.”* (Crown, 2014: 74). But visually
89 perceiving (without using any kind of measurement tool) the barely discernible variations in
90 same-type vessel assemblages is less evident. If craftsmen do not identify the slight differences
91 between the vessels produced by distinct members of their community, then the process of
92 selection of certain shape variants would not be guided by the craftsmen choice, and the
93 evolution of ceramic shapes would be caused by other factors. Preliminary results from five
94 Nepalese potters indicated the opposite; certain participants perceived the individual signatures

95 on ceramic vessels (Gandon et al., 2018). The second goal of this study is to verify this
96 preliminary result with an experiment involving a larger sample of craftsmen.

97

98 Here we bring an experimental approach to explore these issues, with the aim of
99 providing an assessment of both (i) the vessel shape variations occurring through cultural
100 transmission and (ii) their perception by the craftsmen. We did so by setting up two field
101 experiments with 26 potters belonging to the pottery-making community of Hebron (Palestinian
102 Territories), with a clear identification of the family relationship between them.

103 In the first experiment participants were asked to throw series of customary pottery types
104 in their familiar conditions of practice. We captured the 2D profiles of their axisymmetric
105 productions. The participants' behavioral reproducibility was analysed by computing the
106 standardization of the vessel assemblages through the coefficient of variation of the vessels'
107 absolute dimensions. We used the Elliptical Fourier method to analyze vessel shape variation
108 among the productions (Gandon et al, 2013; 2018; 2020b; McLellan and Endler, 1998).
109 Following the view of handicraft learning outlined above, our first operational hypothesis is
110 that the complete assemblage of vessels produced by the 26 potters would contain both
111 individual and cultural shape traits, these latter being culturally inherited from the familial
112 transmission unit. If this hypothesis is verified, we could conclude that each transmission (from
113 a trainer to a learner) modifies the ceramic shape, the culturally transmitted traits being
114 combined with new individual traits. Beyond the question of shape variation occurring during
115 the transmission, we also want to understand how individual and cultural shape traits could
116 affect the evolutionary trend of the ceramic shapes. Do the cultural traits propagate through
117 generations of craftsmen or are they diluted in the individual traits resulting from each
118 transmission? We assume that the ceramic shapes evolved through the successive transmissions
119 with the integration of individual traits and the conservation of cultural traits inherited from the
120 familial transmission unit. Hence, our second operational hypothesis is that the shape variations
121 in the complete assemblage of vessels will reflect not only the transmission units but also larger
122 family relationships. If it is the case, it would imply that cultural morphological traits in
123 ceramics propagates through generations of craftsmen at the scale of a pottery-making
124 community including different families.

125

126 In a second experiment, we asked the participants to visually identify their own
127 productions and those of five other potters. Based on the preliminary result found with the

128 Nepalese potters, our third operational hypothesis is that participants will perceive, at least to a
129 certain extent, individual signatures in ceramic shapes. Testing this hypothesis will allow us to
130 evaluate whether potters detect the slight shape variations, and could thus select the individual
131 variant they prefer, notably disseminating it by reproduction. We could then conclude for a
132 possible influence of the potters' choice in the selection and evolution of ceramic shapes.

133

134

135 2. Materials and Methods

136

137 2.1. Experimental setting

138

139 2.1.1. Cultural context

140

141 In the southern Levant, the throwing method as practiced in Hebron dates back to the
142 early Ottoman period (16th century). In the 20th century, the city of Hebron used to be a large
143 center of pottery production. Currently only a few pottery-making families (locally called
144 'Fakhuri', meaning potters) remain. They constitute learning lineages of specialized craftsmen
145 whose craft has been transmitted over many generations. These families work in the
146 neighbourhood of Hebron, 'Al-Fahs' (Palestinian Territories). Changes in their tradition mainly
147 occurred in the type of containers as a result of market evolution. Contemporary customers
148 demand decorative vessels rather than utilitarian traditional vessels (Table 1). Among the latter,
149 the water jug called "Ebreeq" and the cooking pot called "Fokhara" are still commonly used by
150 the Palestinian population. The main part of the production is represented by flowerpots (from
151 15 cm to 1 m high) and small tourist vessels (oil lamp, water pipes, incense burners, etc.), sold
152 both in the Palestinian territories and in Israel, very occasionally in Europe or the United-States.
153 All vessels are produced using an electrical wheel which replaced the kick-wheel since the
154 1980s. Vessels are thrown at high production rates. Potters throw for example 300 small vessels
155 or 30 large vessels in one day. The production is organized in family workshops, with members
156 practicing the wheel-throwing in co-working area (Fig. 1). These family workshops are
157 sometimes in the same compound, this is the case when they belong to a given extended family.
158 They then house the sons and grandsons of the grandfather who originally bought the
159 compound. The different workshops included in a compound can share the clay preparation and
160 drying areas while usually, each workshop has its own kiln. The craft skills are transmitted

161 vertically from father to sons, the eldest sons can also teach their young brothers. These latter
162 are generally the assistant of their elder brothers and father, they throw vessels occasionally but
163 mostly prepare the clay, participate to simple decoration tasks, carry the vessels from the drying
164 area to the kiln, and help for the firing. The family workshops constitute the transmission units,
165 which change through the lifespan of craftsmen. When the sons become adult, they leave their
166 father's workshop and set-up their own workshop with their own sons, so the roles of learner
167 and trainer are held successively by a craftsman.

168



169

170 **Figure 1. Co-working area with elder experts and youngsters.** Left photo: P8 (Potter 8) with his son P6; right
171 top photo: P4 (left) and his elder brother P13 (right); right bottom photo: P15 (in the middle) with his two sons P1
172 (left) and P19 (right). Becoming an expert potter requires sitting for hours at the wheel close to those of the elders.
173 While sitting next to his mentor, the apprentice can observe his mentor' fashioning gestures.

174

175

176 2.1.2. Participants

177

178 Our study involved 26 participants from the Hebron pottery-making community. The
179 participants belong to three families: HAL (16 participants), NAI (7 participants), and NAF (3
180 participants) (Table 1, Fig. 2). As shown in the Figure 2, we worked with two generations,
181 unfortunately the first generation passed away. The NAF family is not related to the two other
182 families, it is made up of four brothers working in an isolated workshop (i.e. not integrated to
183 an extended family compound). These four brothers learnt the skill in the same transmission
184 unit (with their father NAF). The HAL and NAI families have kinship ties, the grand-fathers
185 (HAL and NAI) were brothers, the sons and grand-sons are thus cousins. The compounds of

186 these two families are located a few hundred meters apart. The HAL family members who
187 participated in our experiments are currently distributed between five workshops housing five
188 transmission units made up of the father and his sons (only one father, SAL, did not wish to
189 participate). The five fathers of each workshop are brothers and learnt the skill in the same
190 transmission unit (with their father HAL). In the NAI family, the members who participated are
191 six brothers who learnt the skill in the same transmission unit (with their father NAI), and one
192 son of them (P26) which constitutes (with his father) another transmission unit. The six brothers
193 of the NAI family are currently distributed between three workshops, each of them housing
194 respectively three, two and one brother(s) and their sons (when old enough to work). In total,
195 our dataset encompassed nine transmission units which are labelled U1 to U9 (see caption of
196 Fig. 2). Among them eight transmission units are distributed between two extended families
197 (HAL and NAI's ones) (Fig. 2). The participants were all men, aged from 18 to 72 yrs ($37.9 \pm$
198 12.4 yrs) and with different wheel-throwing experience (years of practice: 27.8 ± 12.7 yrs) as
199 well as different pottery type specialization (Table 1). The specialization is not fixed but
200 changes over time, depending on the market. As P12 said: "*My brothers HAKA and ISS*
201 *perfectly know how to throw big flowerpots, but they did not produce them for several years*
202 *because the demand of customers is mainly for small tourist items.*" The level of practice of the
203 participants (young learner, advanced learner, and expert) was defined by the vessel types they
204 usually produce (Table 1). Among the 26 participants, one was a young learner (P12), three
205 were advanced learners (P18, P14 and P26), all the 22 others were experts. The learners P12,
206 P18, and P14 begun to learn the throwing skill early (at 8, 10, and 14 yrs old respectively) but,
207 as the last sons of their family, they mainly assist their elders and do not produce a lot of vessels.
208 The learner P26 also begun early to learn how to throw pots on the wheel (at 7 yrs old) but, as
209 the eldest son of P25, he throws vessels at high production rates for several years. Three
210 participants (P3, P11, P17) were left-handed and the 23 other right-handed. The participants
211 gave their written consent to participate in the field experiments after having been informed
212 through an informative sheet.

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N°	Name	Age	Experience	Family	Most usual production
P1	HEL	31	23	HAL	Ebreeq, big flowerpots
P2	HAK	33	23	HAL	Ebreeq, Fokhara, cooking pots, small tourist items (water pipes, incense burners,...), flowerpots in all sizes
P3	HUS	57	43	HAL	Ebreeq, Fokhara, cooking pots, small tourist items (Money-Bank, water pipes, incense burners,...)
P4	ISS	31	21	HAL	Ebreeq, Fokhara, small tourist items (Money-Bank,..)
P5	EIA	34	20	HAL	Ebreeq, Fokhara, cooking pots, small tourist items (water pipes, incense burners,...)
P6	MOH	25	15	HAL	medium flowerpots
P7	SAL	51	44	HAL	Ebreeq, Fokhara, big flowerpots and big water jars
P8	HIS	49	42	HAL	Ebreeq, Fokhara, flowerpots in all sizes
P9	AHM	27	17	HAL	big flowerpots (part 1) and big water jars (part 1)
P10	MUS	35	25	HAL	small tourist items (Money-Bank,..)
P11	MUST	37	26	HAL	small tourist items (Money-Bank,..)
P12	MOH-1	23	15	HAL	small flowerpots
P13	HAKA	40	32	HAL	Ebreeq, Fokhara, small tourist items (Money-Bank,..)
P14	AMM	24	10	HAL	small tourist items
P15	WAH	72	63	HAL	Ebreeq, flowerpots in all sizes
P16	MOH-2	37	28	NAF	flowerpots in all sizes
P17	HAMA	35	23	NAF	flowerpots in all sizes
P18	ALI	18	8	NAF	small tourist items
P19	ANA	40	31	HAL	flowerpots in all sizes
P20	ALA	44	34	NAI	Ebreeq, Fokhara, flowerpots in all sizes
P21	SHU	47	39	NAI	Ebreeq, Fokhara, flowerpots in all sizes
P22	MOH-3	33	18	NAI	Ebreeq, Fokhara, Money-Bank, flowerpots medium size
P23	NUM	39	31	NAI	Ebreeq, Fokhara, flowerpots in all sizes
P24	SHAK	48	38	NAI	Ebreeq, Fokhara, Money-Bank, flowerpots in all sizes
P25	SHA	54	40	NAI	Ebreeq, Fokhara, Money-Bank
P26	HAM	21	14	NAI	Ebreeq (part 1), big flowerpots (part 1)
	mean	37,9	27,8		
	sd	12,4	12,7		

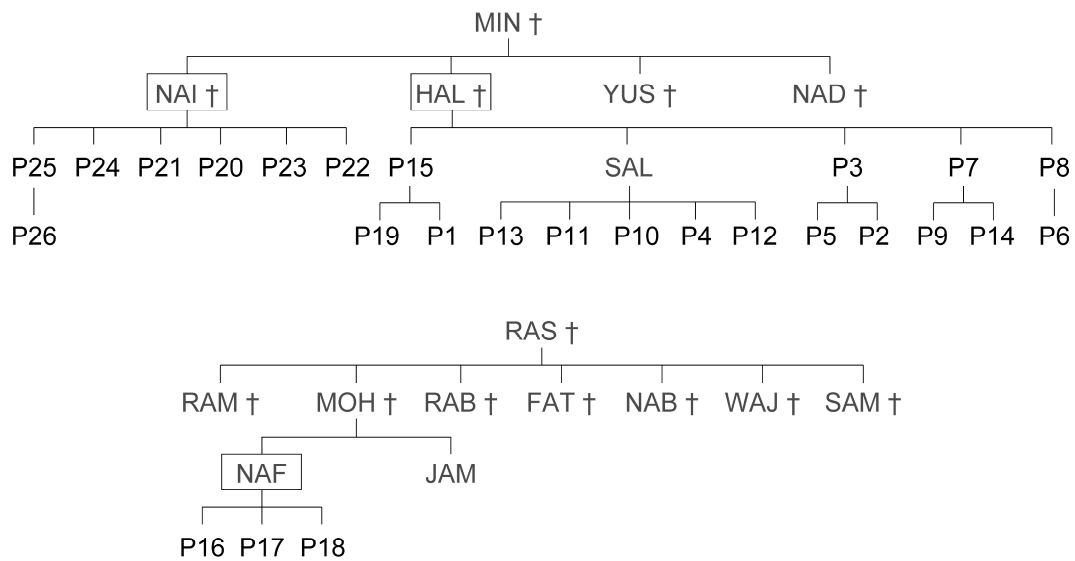
219

220 **Table 1. The 26 participants of the study.** Each potter was asked about his age, experience (i.e. years of practice),
 221 family (HAL, NAI or NAF), and most usual production. The big flowerpots and the big water jars are produced
 222 with the two stages method of throwing (Fig. S1). The most usual production includes the vessel types that the
 223 participants were producing during the last months preceding our study. It does not necessarily include the different
 224 pottery types mastered by a potter, as the production changes throughout the year, depending on the market
 225 demand. For instance, P6 produces mainly medium flowerpots but he also produces Ebreeq and Fokhara in series
 226 for exceptional periods. The potters over 40 years old generally master the entire repertoire of pottery types.

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229



230

231 **Figure 2. Family trees of the families HAL, NAI, and NAF participating in the experiments.** Filial relations
 232 are indicated by vertical lines, and sibling relations are indicated by horizontal lines in which potters are sorted in
 233 an age-descending order from left to right. HAL and NAI were brothers, so their sons and grand-sons are cousins.
 234 Our dataset included nine transmission units (U1: consisting of potters P15, P19, P1; U2: P3, P5, P2; U3: P13,
 235 P11, P10, P4, P12; U4: P8, P6; U5: P7, P9, P14; U6: P16, P17, P18; U7: P25, P24, P21, P20, P23, P22, U8: P15,
 236 P3, P7, P8; U9: P25, P26). Among them eight transmission units are distributed between two extended families
 237 (HAL and NAI's ones). SAL, NAF, and JAM did not participate, NAF and SAL are partially retired, and JAM's
 238 workshop is in another area of Hebron. In the different transmission units, only the potters who participated in the
 239 study are represented.

240

241

242 2.1.3. Production task

243

244 In a first experiment, participants were asked to produce three customary pottery types:
 245 Ebreeq, Fokhara, and Money-Bank (Fig. 3, left). The two first types are traditional vessel types
 246 known since centuries while the latter is a modern vessel type which dates to the late 20st
 247 century. The Ebreeq and the Fokhara were thrown in two stages as potters usually do for those
 248 types (Fig. S1). All the 22 expert participants produced the three types. They were all used to
 249 them even if they produce each type in different quantities depending on their most usual
 250 production (Table 1). The learner P12 did not produce the Ebreeq and Fokhara because he was
 251 not advanced enough. The learners P14 and P18 produced the three pottery types with a low
 252 level of practice. The learner P26 produced the Ebreeq and Fokhara with a high level of practice
 253 for the part 1 of the vessels and a low level of practice for the part 2 (Fig. S1), he produced the

254 Money-Bank with a low level of practice. To assess the reproducibility of behavior, five
255 replicates were produced in each of the three pottery types, so each potter produced a total of
256 15 pots (Fig. 3, right). There were some cases where potters produced six replicates instead of
257 five, which were included in our dataset. For each pottery type, a vessel model was presented
258 in front of the potter's working place during the whole fashioning session. The instructions
259 were to make a vessel with the same size as the model, using self-chosen quantities of clay.
260 Potters were not asked to copy the models exactly because we wanted each participant to
261 produce the pottery type following his own way. For seven expert participants (P1, P2, P5, P17,
262 P20, P21, P23) it was the first time they produced the Money-Bank with the specific shape of
263 the model (they usually produce the Money-Bank with different shape variant). Potters used a
264 basin of water to regularly wet the clay during the throwing process, and a metallic scraper
265 during the thinning and/or final fashioning steps. Potters produced the experimental vessels
266 assemblage using their usual wheel and clay, working at their own pace. All finished vessels
267 were marked on one face with numbers indicating the specific potter and the replicate number
268 in the series; then they were put to dry for two days.

269



270

271 **Figure 3. The three models of pottery types (left photo) and an example of a complete assemblage produced**
272 **by one potter (right photo).** The three models on the left photo are (from left to right): Ebreeq, Fokhara, and
273 Money-Bank. For the experiment, the Ebreeq was produced without the handle and the spout. The complete
274 assemblage on the right was produced by P8.

275

276 2.1.4. Vessel identification task

277

278 In a second experiment, we asked 21 participants to visually identify their own vessels
279 and those of five other potters. Among these latter (i.e. the five other potters), one, two, three
280 or four were members of the transmission unit of the participant, and the remaining were
281 members of the extended family of the participant (living in the same compound) or members

282 of another family. Five participants were not available for this second experiment, they are the
283 three members of the NAF Family (P16, P17, and P18), P24 from the NAI family, and P12
284 from the HAL family. For this vessel identification task we selected, for each potter and each
285 pottery type, the best three replicates (among the five produced) eliminating vessels with
286 manufacturing defects (for example a fingerprint in the wall, or a little rock in the clay). This
287 was done to prevent a potter recognizing his own vessels because of the presence of a noticeable
288 defect. The vessels were then organized by groups of three vessels per pottery type (x 3 types)
289 and per potter (x 6 potters), thereby obtaining a total of 18 vessel groups including 3 self-vessel
290 groups (one by pottery type) and 15 others-vessel groups (five by pottery type) (Fig. 4, left).
291 Looking at the six vessel groups for a given pottery type, each potter was individually asked to
292 visually identify his own vessels, and those of the five other potters (Fig. 4, right). When
293 performing the task, the potter had the list of the six producers' names (including himself) in
294 his hands. His task was to find which vessels belong to which producers. The vessels were
295 observed from a one-meter distance without manipulation. No feedback or any other type of
296 clue was given. In total, each potter had to give 18 answers (six producers to be identified, for
297 each of the three different pottery types), which were later entered into an Excel file. The
298 participants could also refrain from answering if they were unsure. To close this experimental
299 session, the experimenter (E. Gandon) gave each potter his performance and asked him which
300 clues he used to identify the vessels' producers.

301



302

303

304 **Figure 4. The vessel identification task.** Here the experimenter (E. Gandon) is working with P11. For the three
305 pottery types (front line: Money-Bank, middle line: Fokhara, and back line: Ebreeq), potters were asked to identify
306 the producer of the six vessel groups. They were invited to identify the producers starting from the leftmost 3-
307 vessels group and subsequently proceeding rightward. They could change their answers if deemed necessary at the
308 final summary given by the experimenter (photograph by W. Alqaraja).

309 2.2. Data recording and analysis

310

311 2.2.1. Morphology of the vessels

312

313 Once the vessels were dried, we used a Canon PowerShot-SX270 camera (resolution
314 2112 x 2816 pixels) to photograph all vessels. A size-calibration object was placed next to each
315 vessel (as in Fig. 3, left). Two vessels were removed from the dataset because they were
316 damaged (P13, one Fokhara and P8 one Money-Bank). In total, 129, 126, and 136 vessels of
317 Ebreeq, Fokhara, and Money-Bank respectively, contributed to the present analysis.

318

319 Using Matlab® software we extracted the x-y coordinates (in pixels) of the complete
320 vessel outline from each vessel photo. A low-pass filter was applied to these coordinates to
321 remove noise from pixellation. The coordinates were then converted from pixels to centimeters
322 using the calibration object present in each photo. The coordinates were subsequently
323 resampled so that the distance between neighboring points was standardized to 1 mm.

324

325 We computed the vessel absolute dimensions: base, aperture, height, maximal diameter,
326 and height of the maximal diameter. The base was not computed for the Fokhara which have a
327 rounded bottom. In order to assess the standardization of production we computed the between-
328 trial variation over the five replicates thrown by each participant, for each of the three pottery
329 types, using the coefficient of variation ($CV = 100 * \text{standard deviation} / \text{mean}$) computed on
330 the vessel absolute dimensions (Eerkens and Bettinger, 2001; Kvamme et al., 1996). A smaller
331 CV indicates a higher standardization of production. To test if the pottery type (Ebreeq,
332 Fokhara, and Money-Bank) influenced the standardization of production we used an ANOVA
333 with equal variance and t-tests for post-hoc. The effects of the participants' ages and
334 experiences were also tested with a linear regression analysis.

335

336 All complete vessel outlines were subjected to an Elliptical Fourier transformation
337 (Gandon et. al., 2013; 2018; 2020b; McLellan and Endler, 1998). The resulting series of 40
338 pairs of coefficients were normalized with respect to the first coefficients to correct for size
339 differences so that pure shape could be analyzed. For graphical representation of the shape, the
340 size-corrected Fourier coefficients were subjected to a Principal Component (PC) analysis. For

341 all vessels, over 70% of the total shape variance was captured by the first three PCs. Each vessel
342 shape could thus be represented as a point in a unique three-dimensional PC shape-space,
343 allowing a visual inspection of the variations within and among participants as well as the
344 variations within and among the transmission units. This mathematical shape description also
345 allowed to reconstruct, for each participant and each pottery type, the mean vessel shapes. These
346 mean vessel shapes were reconstructed from the mean Elliptical Fourier coefficients of the five
347 vessel replicates produced by each participant for each pottery type.

348

349 Statistical differences among vessel shapes were further examined for each of the three
350 pottery types separately. For that purpose, in a first step we ran nested permutation tests
351 (Anderson, 2001) on the 40 pairs of normalized Fourier Coefficients using the nested.npmanova
352 function in the R package BiodiversityR. This analysis was based on a two-level hierarchical
353 model, in which the individual potters were nested within transmission (family) units. These
354 permutation tests allow us to test our first operational hypothesis, assessing the presence of
355 significant shape variation among individual potters and among the transmission units. Because
356 these tests can be used only with exclusive groups, two rounds of permutation tests were run.
357 The first round tested the presence of significant variation among the transmission units U1,
358 U2, U3, U4, U5, U6, U9 and among the different individual potters (20 individuals for Money-
359 Bank, and 19 individuals for Ebreeq and Fokhara because P12 did not produce these two pottery
360 types). The second round tested the presence of significant variations among the transmission
361 units U6, U7, U8 and among the different individual potters (14 individuals for all three pottery
362 types).

363 To test our second operational hypothesis, we constructed dendrograms presenting the
364 similarities among the participant's mean vessel shapes (Figs. 8, 9, S2, and S3). The mean vessel
365 shapes were used because showing every vessel replicate would make the diagrams too
366 complex. For each pottery type (Ebreeq, Fokhara, Money-Bank) three dendrograms were made.
367 The first dendrogram provides distinct branch colours for the two families MIN and RAS; the
368 second provides this for the three families HAL, NAI, NAF; and the third provides distinct
369 colours for each of the nine transmission units. While the permutation tests assess the presence
370 of individual and cultural traits inside the global set of vessels produced by the 26 participants,
371 the dendrograms illustrate the transmission of the cultural traits across the two generations of
372 participants, taking into account the combination of individual and cultural traits. If cultural
373 traits on vessel shape were conserved through successive transmissions as we expected, there

374 should be reasonably strong resemblance between the family trees (Fig. 2) and these
375 dendrograms (Figs. 8, 9, S2, and S3). The resemblance would appear in the dendrograms
376 through a distinction between the branches of two families MIN and RAS, the three families
377 HAL, NAI, NAF, and the nine transmission units. Dendrograms were produced according to
378 the unweighted pair-group mean arithmetic (UPGMA) method using the R function hclust. For
379 permutation tests and dendrograms, the alternative-Gower distance was used as a dissimilarity
380 measure (Anderson et al., 2006), and 10000 randomizations were used to obtain *P*-values. For
381 all statistical tests, the alpha level used was 0.05.

382

383 2.2.2. Identification of the vessels

384

385 To test our third operational hypothesis, the performance of the participants in the
386 identification task was measured by the number of (i) correct answers, (ii) incorrect answers,
387 and (iii) no answers (when participants refrain from answering). A correct answer was recorded
388 when the vessel's producer was correctly identified by the participant and an incorrect answer
389 was recorded when participant responded another potter instead of the correct one. First, we
390 analyzed if potters correctly identified their own vessels (i.e. self-vessel groups) more than
391 those of the other potters (i.e. others-vessel groups). Then, the Kruskal-Wallis test was
392 employed to test the effect of pottery type (Ebreeq, Fokhara, and Money-Bank) on performance.
393 Pairwise t-tests were used to compare the effect of familial distance (transmission unit vs.
394 extended family) on performance, and linear regression was used to test the effects of
395 experience and age. Results were interpreted in light of the information given by the participants
396 during the interviews closing the experimental session.

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399 3. Results and discussion

400

401 3.1. Morphology of the vessels

402

403 3.1.1. Standardization of production

404

405 Tables S1, S2, and S3 present the mean absolute dimensions of the vessels (in
406 centimeters) produced by each participant, for the Ebreeq, Fokhara, and Money-Bank
407 respectively. The among-participant standard deviations ranged between 0.5 and 1.8 cm for all
408 pottery types (see last line of the Tables S1, S2, and S3), indicating a rather high standardization
409 of the productions at the level of the pottery-making community in line with earlier results
410 (Gandon et al., 2014a). Table 2 presents the vessel standardization (i.e. CVs) for each
411 participant and each pottery type. The values were in a range of 1.7 to 6.3 %, if one excludes
412 P11, specialized in small items. They are within the ordinary coefficients of variation range
413 reported in previous studies with potters throwing familiar pottery types at high production rates
414 (Gandon et al., 2014a; Gandon et al., 2014b; Harush et al., 2020; Longacre, 1999; Roux, 2003).
415 There was a tendency for the vessel standardization to improve (CV to decrease) with the age
416 and experience of the potter, especially for Ebreeq, and for Money-Bank to a lesser degree. But
417 there was no statistically significant relation between the CVs and the participants age (Ebreeq:
418 $r_{24} = -0.35, p = 0.08, CI = [-0.65, 0.05]$, Fokhara: $r_{24} = -0.09, p = 0.67, CI = [-0.46, 0.31]$, Money-
419 Bank: $r_{24} = -0.33, p = 0.10, CI = [-0.64, 0.07]$), and experience (Ebreeq: $r_{24} = -0.38, p = 0.05,$
420 $CI = [-0.67, 0.01]$, Fokhara: $r_{24} = -0.11, p = 0.60, CI = [-0.48, 0.29]$, Money-Bank: $r_{24} = -0.32,$
421 $p = 0.11, CI = [-0.63, 0.08]$). Although the degree to which the vessel standardization is related
422 to the age and experience is somewhat different between shapes, we conclude that, overall, the
423 26 participants all acquired a sufficient expertise to throw standardized vessels. Finally, we
424 found that the CVs of the Ebreeq were significantly smaller than those of the Fokhara and
425 Money-Bank; the latter two were statistically equivalent ($F(2, 48) = 11.42, p < 0.01$) (Ebreeq:
426 3.5 %; Fokhara: 4.5 %; Money-Bank: 4.8 %) (see Table S4 for post-hoc tests). This difference
427 was small but could indicate that the participants produce Ebreeq with a higher frequency than
428 Fokhara and Money-Bank.

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Standardization of production (CVs %)				
Potter	Ebreeq	Fokhara	Money-Bank	Mean
P1	3.1	2.2	3.4	2.9
P2	4.4	4.9	3.4	4.2
P3	3.7	2.8	3.1	3.2
P4	2.2	3.3	5.1	3.5
P5	1.9	3.3	4.5	3.2
P6	2.3	3.7	4.9	3.6
P7	1.7	2.7	4.0	2.8
P8	2.7	2.8	3.6	3.0
P9	2.3	5.5	5.1	4.3
P10	4.6	5.3	3.4	4.5
P11	5.7	8.6	6.9	7.1
P12	-	-	4.0	4.0
P13	2.5	4.2	2.8	3.2
P14	5.2	3.5	4.7	4.4
P15	1.9	3.4	4.3	3.2
P16	3.8	4.5	4.9	4.4
P17	4.9	5.8	6.0	5.6
P18	5.7	4.4	6.4	5.5
P19	5.2	3.4	3.8	4.1
P20	4.1	4.6	5.1	4.6
P21	4.1	6.0	5.1	5.0
P22	3.8	5.1	4.5	4.5
P23	2.9	5.8	6.0	4.9
P24	3.0	6.3	6.1	5.1
P25	3.2	6.3	5.0	4.8
P26	3.8	5.3	7.2	5.4
Mean	3.5	4.6	4.8	4.3

437

438 **Table 2. Coefficients of variation of the productions.** The coefficients of variation were computed over the five
 439 replicates thrown by each participant for each pottery type (Ebreeq, Fokhara, and Money-Bank). They were
 440 computed on each absolute dimension of the vessels and subsequently averaged to obtain a mean coefficient per
 441 participant and per pottery type.

442

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444 3.1.2. Individual and cultural traits on vessel shapes

445

446 Figure 5 presents, for the Ebreeq, Ebreeq neck, Fokhara, and Money-Bank separately,
 447 the morphology of the vessels in the three-dimensional PC shape-space. The shape of each
 448 vessel (and Ebreeq neck) produced by each participant is represented as a point in the PC shape-

449 space, while the distinct transmission units are indicated though different colours. Figure 6
450 presents the mean vessel shape of the five replicates produced by each participant for the three
451 pottery types. Figure 7 presents the Ebreeq necks photos of the five Ebreeq replicates produced
452 by each participant.

453

454 Despite certain overall similarities of the evenly distributed graphical markers, visual
455 inspection of Figure 5-a shows that the Ebreeq vessels produced by the same potter clustered
456 in the PC shape-space, with some participants producing more standardized assemblages
457 (tighter clusters; P7, P8 for example) than others (P16, P10 for example). The specialisation of
458 the participants in certain pottery types (see Table 1) explains the individual differences
459 observed in terms of assemblage standardization: the less a potter is specialized in a pottery
460 type, the less he will produce standardized assemblages for that type. Some of the individual
461 signatures observed in Figure 5-a were detectable in the mean vessel shapes presented in the
462 Figure 6-a: the Ebreeq of P1 were particularly wide, those of P13 had a fine lower part, those
463 of P9 had an oval body, those of P20 had a square outline. Within the five-replicates assemblage
464 produced by each potter, some vessel shapes were different from the others (P3, P23 for
465 instance) (Fig. 5-a), suggesting that a given pottery type can be produced by a single potter with
466 a range of variation (see Photo dataset). A clustering of the vessel assemblages also appeared
467 at the level of the transmission units, indicating culturally inherited signatures which were
468 particularly visible for U2, U4, and U8. In the transmission unit U3, the assemblages of P13
469 and P4 were close, while those of P11 and P10 were farther apart in the PC shape-space and
470 corresponded to atypical mean shapes (Fig. 6-a). This can be explained by the fact that P11
471 and P10 are not specialized in the Ebreeq production, they more often produce small tourist
472 items (Table 1). The assemblage of P26 also occupied a different part of the PC shape-space
473 and corresponded to an atypical shape (Fig. 6-a); P26 being still a beginner in producing this
474 pottery type. The Ebreeq produced by the other two learners P14 and P18 were closer to those
475 produced by the experts, yet they had irregular shapes and a low degree of standardization
476 (Photo dataset and Table 2).

477 As for the Ebreeq complete vessel (Fig. 5-a), individual signatures appeared in the
478 Ebreeq neck through individual clusters in the PC shape-space (Fig. 5-b). Some of these
479 individual signatures appeared clearly in Figure 7, notably two atypical neck shapes produced
480 by P3 and P24, but also the necks produced by P1 which were wider than all others, and those
481 produced by P22 which distinguished through a square-shape lip on the aperture. Some neck

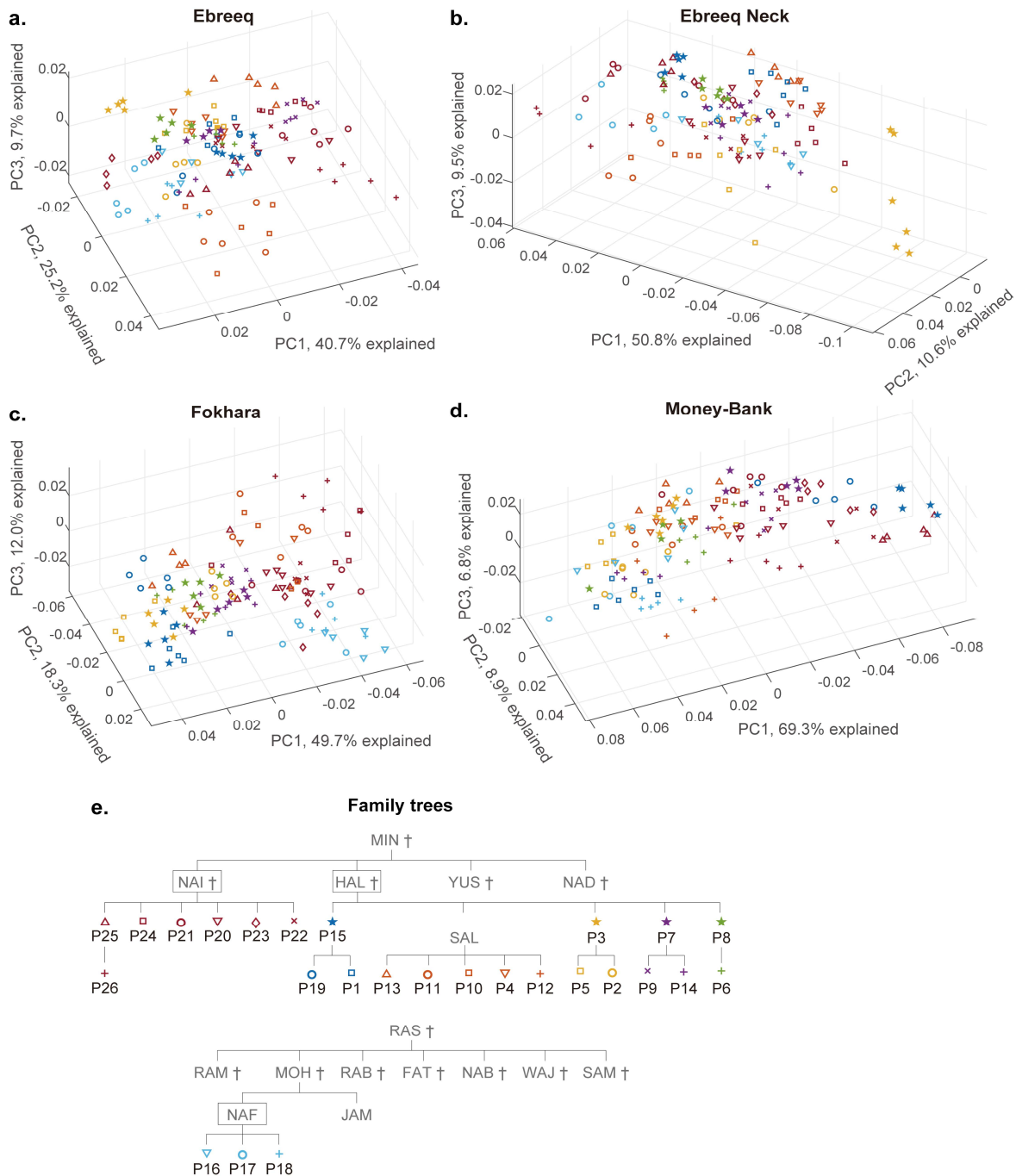
482 assemblages were more standardized (for instance P7, P8, P13) than others (P10, P11, P17, P5).
483 Individual variants were exhibited in the assemblage of single potter, for example P2 who
484 produced the neck with two different styles of lip on the aperture, one style being used for four
485 replicates and the other for one replicate. The same thing was observed with P20 who produced
486 three necks using one style, and two necks using another style (Figs. 5-b and 7). Similarity
487 between the necks produced by the transmission unit members was observable, indicating
488 culturally inherited signatures (Fig. 5-b). Inside each transmission unit, the higher similarity of
489 the necks did not appear between the necks produced by all members but between those
490 produced by two members, brothers (P4-P13, P20-P22, P18-P16) or father and son (P7-P9).

491

492 The Fokhara vessels results were similar to those of the Ebreeq. Individual signatures
493 appeared through systematic clusters of the assemblages produced by each distinct potter (Fig.
494 5-c). Some of those individual signatures were obvious in the mean vessel shapes: the Fokhara
495 produced by P1 had a wide lower part, those of P13 had an elongated body and a rounded lower
496 part, those of P19 had an elongated body (Fig. 6-b). The standardization of the individual
497 assemblages varied between the participants, for instance the assemblages of P15 and P3 were
498 less variable than those of P10 and P11. The assemblage of P4 exhibited two variants, three
499 vessels were close to those of his brother P13, while the other two vessels were in a different
500 region of the PC shape-space. Two Fokhara produced by P4 were more elongated than the
501 other three vessels in the photos (see Photo dataset). A similarity between the assemblages
502 produced within each transmission unit was observed, and particularly noticeable in U4, U5,
503 and U8. As for the Ebreeq, in U3, the assemblages of P13 and P4 were close while those of P10
504 and P11 were distant and corresponded to atypical mean shapes (Fig. 6-b). This result is
505 certainly due to the specialization of P10 and P11 in small tourist items (Table 1). The
506 assemblage of P26 stood out from all others and corresponded to an atypical mean shape
507 reflecting that P26 was a learner. Although they were not skilled at producing Fokhara, the
508 vessels of the two learners P14 and P18 had a similar shape to that of the experts' vessels.

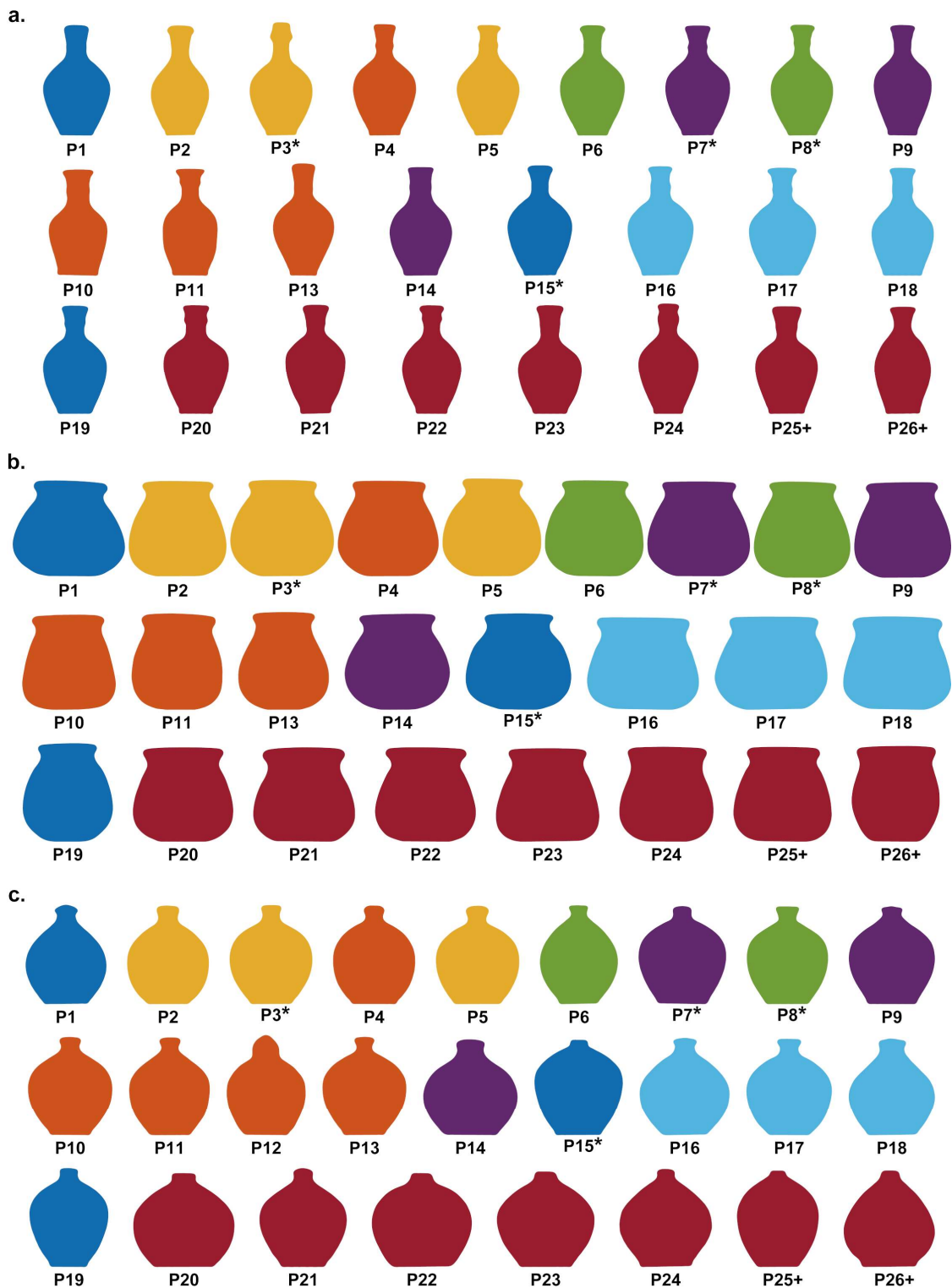
509 Results of the Money-Bank vessels were qualitatively similar to those of the Ebreeq and
510 Fokhara. We observed individual signatures through distinct clusters in the PC shape-space for
511 the different potter assemblages (Fig. 5-d). In Figure 6-c we can see for instance that the Money-
512 Bank of P15 were distinguished by wide shoulders, those of P8 had a narrow neck bellow their
513 bud, and those of P19 had an elongated lower part. Some assemblages were more standardized
514 (those of P1 and P13 for instance) than others (those of P16 and P17 for instance). Individual

515 signatures did not exclude individual variants, for example we saw that for P7 and P23 the five
516 vessels were separated in two clusters (two vessels being in a distant area of the three others).
517 Similarity at the level of transmission unit appeared for U2, U4, and U6. It appeared also
518 between the four brothers of the U3 transmission unit (P4, P10, P11, and P13), with the fifth
519 brother P12 assemblage being far from the others and corresponding to an atypical mean shape
520 (Fig. 6-c) signing the learning of this young potter. The learning was also observable in the
521 vessels of P14 which were far from those of his father (P7) and brother (P9) (Fig. 5-d) and
522 corresponded to an atypical mean shape (Fig. 6-c). The Money-Bank produced by the learner
523 P18 had also an atypical mean shape (Fig. 6-c) and were in an extremity of the PC shape-space
524 (Fig. 5-d). Surprisingly, in the transmission unit U1, although the assemblages of the father
525 (P15) and the eldest son (P19) were close, the one of the youngest son (P1) was in a distant area
526 of the PC shape-space, this difference being also observable in the mean shape (Fig. 6-c). In the
527 U7 transmission unit, the assemblages of the five youngest brothers were close, and that of the
528 older brother (P25) was distant. The assemblage of P26 (son of P25) was distant from all others
529 and corresponded to an atypical mean shape (Fig. 6-c) signing the learning of this young potter.
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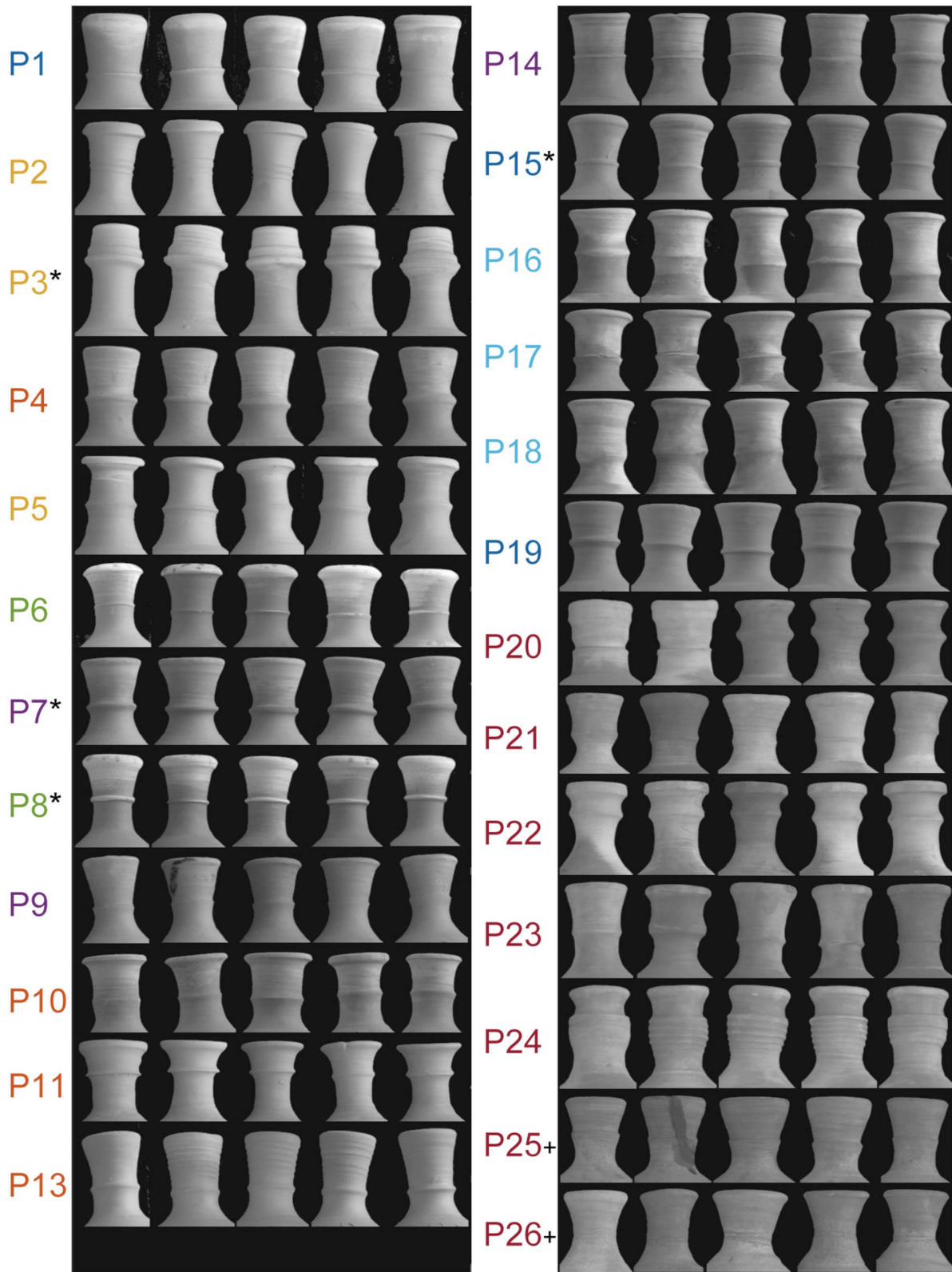
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Figure 5. Vessels morphology represented in the three-dimensional PC shape-space. a. Ebreeq, b. Ebreeq neck, c. Fokhara, and d. Money-Bank, e. Family trees. All the vessels produced by the participants are presented. The three principal components (PC1, PC2, PC3) in the x, y and z axis are derived from principal component analysis on 40 sets of Elliptical Fourier coefficients of each pot shape. For all vessels, over 70% of the total shape variance was captured by these first three PCs. Potters from the same transmission unit are represented in the same colour, except those from the U8 who are represented by star-shaped markers. P26 is represented using the same colour as the transmission unit of his father and uncles. Family relations are represented in the bottom panel (e), where filial relations are indicated by vertical lines, and sibling relations are indicated by horizontal lines in which potters are sorted in an age-descending order from left to right. The potters under 25 years of age are represented by the markers “+”.



542

543 **Figure 6. Mean individual shape of the vessels.** a. Ebreeq, b. Fokhara, and c. Money-Bank. These shapes are
 544 reconstructed from the mean Elliptical Fourier coefficients of the five vessel replicates produced by each
 545 participant for each pottery type. Potters from the same transmission unit are represented in the same colour (U1:
 546 blue, U2: yellow, U3: orange, U4: green, U5: purple, U6: light blue, U7: red) or by the same symbol (U8: *, U9:
 547 +). Family relations are represented in Figure 2 and 5.



548

549 **Figure 7. Photos of the Ebreeq necks.** All the necks thrown by the participants are presented. The five necks
 550 thrown by one potter are presented in a row, with a label on the left side indicating the potter's number. Let's us
 551 recall that P12 did not produced the Ebreeq. Potters from the same transmission unit are represented in the same
 552 colour (U1: blue, U2: yellow, U3: orange, U4: green, U5: purple, U6: light blue, U7: red) or by the same symbol
 553 (U8: *, U9: +). Family relations are represented in Figure 2 and 5.

554 Hierarchical permutation tests run on the normalized Elliptical Fourier coefficients were
555 used to interpret the results presented in Figures 5, 6, and 7. In line with our first operational
556 hypothesis, these tests revealed a significant vessel shape heterogeneity among individuals and
557 among the transmission units for the three pottery types (Table 3). Hence, even though the
558 standardization of the productions at the level of the pottery-making community was high
559 (Tables S1, S2, S3), there was still room for significant variation. Corroborating the results of
560 earlier work (Roux & Karasik, 2018; Gandon et al., 2018), these results showed that potters left
561 subtle but identifiable individual signatures on ceramic shapes, even on typical traditional
562 pottery types produced for a common consumer market. The presence of individual signatures
563 demonstrated that the vessels produced by the novices are not perfect copies of those produced
564 by their trainers, although the transmission unit also affected the vessels. We conclude that the
565 learning process modifies the ceramic shape, the culturally inherited traits being combined with
566 new individual traits. We should stress that the individual signatures did not prevent individual
567 shape variants within a single pottery type. For the modern vessel type Money-Bank these shape
568 variants most likely correspond to the various customers preferences as explained by the
569 participants; for the traditional vessel types Ebreeq and Fokhara, it is still unclear if these shape
570 variants result from potter personal styles or from the existence of traditional shape variants
571 transmitted by the previous generations of craftsmen.

572 To our knowledge, our results demonstrate for the first time the existence of familial
573 signatures within the same community of potters made up of a few families of craftsmen. These
574 signatures likely resulted from the social channelling occurring inside the transmission unit
575 during the learning of the skill. In this respect, these signatures represent the cultural part of the
576 potters' skill, which supposedly propagates across generations. Interestingly, these cultural
577 signatures were non-significant for the Ebreeq necks which were marked only by individual
578 signatures (Table 3, Fig. 7). We can then assume that the necks are the more relevant part of
579 the vessel to be analyzed on ancient assemblages in order to detect individual signatures which
580 has also been shown by Harush et al. (2020).

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Permutation tests on U1, U2, U3, U4, U5, U6, and U9				
Pottery type	Parameters	Df	F	P
Ebreeq	Transmission unit	6	1.50	0.0429
	Individual	13	12.27	<0.0001
Fokhara	Transmission unit	6	3.28	0.0007
	Individual	13	6.83	<0.0001
Money-Bank	Transmission unit	6	2.01	0.0433
	Individual	14	10.49	<0.0001
Ebreeq Neck	Transmission unit	6	1.51	0.09049
	Individual	13	9.38	<0.0001
Permutation tests on U6, U7, and U8				
Ebreeq	Transmission unit	2	1.97	0.0496
	Individual	10	11.46	<0.0001
Fokhara	Transmission unit	2	9.25	<0.0001
	Individual	10	3.64	<0.0001
Money-Bank	Transmission unit	2	2.88	0.0405
	Individual	10	10.59	<0.0001
Ebreeq Neck	Transmission unit	2	0.95	0.5302
	Individual	10	11.57	<0.0001

586

587 **Table 3. Permutation tests results.** Hierarchical permutation tests were run on the 40 size-corrected coefficients
 588 resulting from Elliptical Fourier analyses of the vessels. For each pottery type, within-potter effects are based on
 589 the five replicates thrown by each participant. The tests were run separately for each vessel type (Ebreeq, Fokhara,
 590 and Money-Bank) and the Ebreeq necks. In the first round, the analysis tested the presence of significant vessel
 591 shape variation among the transmission units U1, U2, U3, U4, U5, U6, U9 and among the different individual
 592 potters (20 individuals for Money-Bank, and 19 individuals for Ebreeq and Fokhara because P12 did not produce
 593 these two pottery types). In the second round, the analysis tested the presence of significant vessel shape variation
 594 among the transmission units U6, U7, U8 and among 14 individual potters (for all three types).

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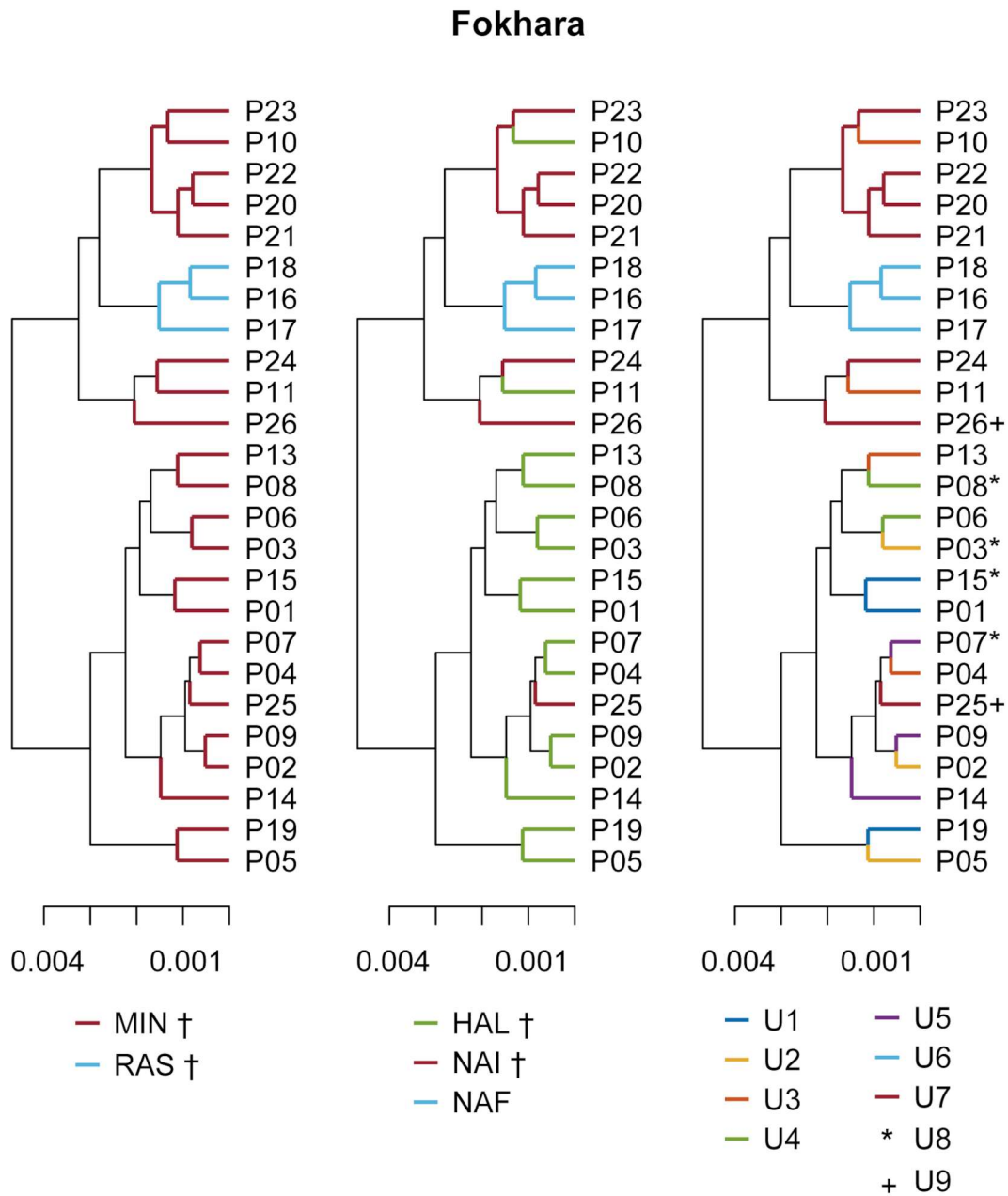
596 3.1.3. Conservation of cultural traits through transmission

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598 Figures 8, 9, S2, and S3 present the dendrograms of the participants' mean vessel shapes,
 599 for the Fokhara, Ebreeq neck, Ebreeq, and Money-Bank respectively. These graphs indicate
 600 that the differences between the two families MIN and RAS, the three families HAL, NAI,
 601 NAF, and the nine transmission units varied across the three pottery types. Differences appeared
 602 between the two families MIN and RAS and between the three families HAL, NAI, and NAF,
 603 especially for the Fokhara and to a lesser extent for the Ebreeq and Money-Bank, corroborating
 604 the results of the permutation tests (Table 3). At the level of the transmission unit, the
 605 differences were predominantly blurred by the individual signatures on vessel shapes, for the
 606 three pottery types. Yet, several clustering units stood out, indicating that the transmission units

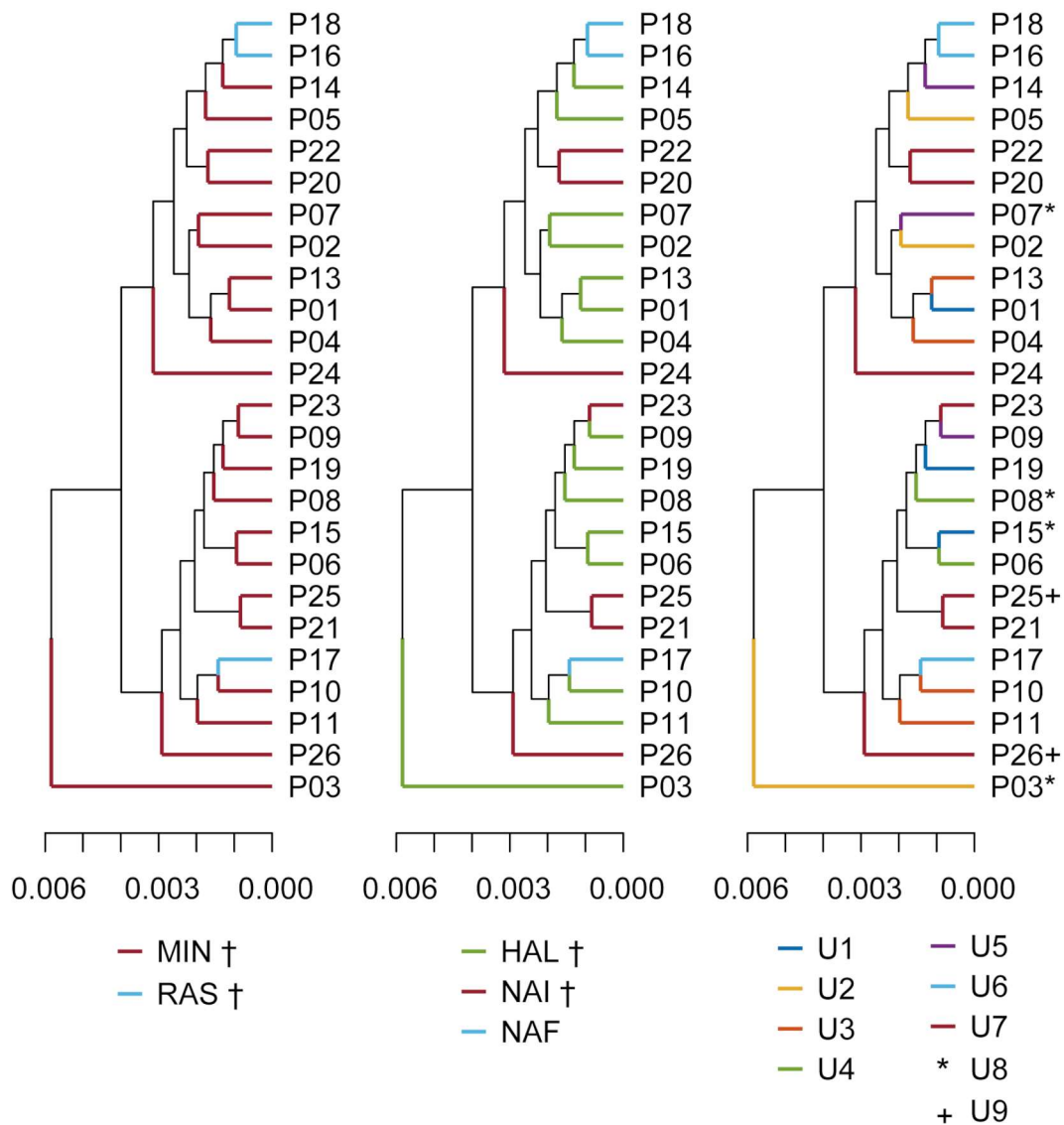
607 still left some traces on the vessel shapes: for the Fokhara the potters from U4 and U6 produced
608 mean vessel shapes similar to each other within each unit, while the mean vessel shapes
609 produced by potters from U1, U2, U5, U7, and U8 were similar to a less extent; and the mean
610 vessel shapes produced by potters from U3 and U9 mainly diverged within each unit. For
611 Money-Bank, contrary to Fokhara the potters from U3 produced similar mean vessel shapes.
612 This can be explained by the fact that the five brothers of this transmission unit produced
613 Money-Bank in a high rate (except the youngest one P12) (Table 1). For the transmission units
614 U1, U2, U5, U6, U7, and U9 a partial clustering was noticeable, while no significant clustering
615 appeared in U4 and U8. For Ebreeq, the potters from U1, U2, and U6 produced similar mean
616 vessel shapes within each transmission unit. By contrast, the mean vessel shapes produced by
617 potters from U4, U7, and U8 were less similar, and those produced by potters from U3, U5, and
618 U9 even less. When we focus on the Ebreeq neck only, although there were a few pairs close
619 to each other from the same transmission unit (e.g., P18 and P16, P22 and P20, P25 and P21,
620 P10 and P11, P4 and P13), most of the neck shapes were distinct between individuals, showing
621 the strong effects of idiosyncrasy in producing the neck of Ebreeq (see also Table 3). Overall,
622 the resemblance between the family trees (Fig. 2) and the dendrograms (Figs. 8, 9, S2, and S3)
623 was present but weak, and the strength of resemblance within each family and transmission unit
624 differ according to the vessel type. For example, the family resemblance found in Fokhara was
625 not apparent in the neck of Ebreeq. And the potters from U3 produced similar Money-Bank
626 shapes, but dissimilar Fokhara shapes. These original findings do not support our second
627 operational hypothesis and we conclude that cultural traits on ceramic vessel shape do not
628 automatically propagate within the transmission chain. While we found with the permutation
629 tests that the variability within each transmission unit was significantly smaller than the
630 variability among the different transmission units, in terms of the distance between each potter's
631 mean shape, some potters from the same transmission unit were similar, while others were not
632 (Figs. 8, 9, S2, and S3). The same pattern of results was visible in the PC shape-space: while
633 some potter's vessel shapes from the same transmission unit were close to each other, others
634 were closer to potter's vessel shapes from other transmission unit (Fig. 5). Hence, even if
635 cultural traits were inherited from the family and the transmission unit, they were diluted by
636 individual traits which came to the fore. As for biological evolution, a given vessel shape is a
637 combination of culturally inherited traits (i.e. the social bias occurring through learning) and
638 both random and non-random effects. Random effects (like genetic drift in evolution) come
639 from random idiosyncrasies among potters, and non-random effects (like natural selection in
640 evolution) come from environmental effects such as the market demand. These observations

641 predict frequent evolutionary divergence of vessel shapes over time, both within and among
 642 potters (Futuyma, 2005; Nielsen and Slatkin, 2013). We also observed on Figure 9 the two
 643 atypical Ebreeq neck shapes produced by P3 and P24 (Fig. 7), and on Figure S2 the atypical
 644 Ebreeq shape produced by the learner P26 (Figs. 5-a and 6), this latter showing the initial
 645 learning difference which presumably is the source of future variation and even evolution of
 646 shapes.



647
 648 **Figure 8. Dendrograms of the mean vessel shapes for the Fokhara.** The mean vessel shapes of Fokhara
 649 produced by all participants are presented. The similarity between the mean vessel shapes of the different
 650 participants is indicated by the point at which the branches diverge. The distance of the divergence between the
 651 branches is indicated in the horizontal axis. The further right the diverging point is, the more similar are the mean
 652 vessel shapes in the corresponding branches.

Ebreeq Neck



653

654 **Figure 9. Dendrograms of the mean vessel shapes for the Ebreeq necks.** The mean vessel shapes of Ebreeq
 655 necks produced by all participants are presented. The similarity between the mean vessel shapes of the different
 656 participants is indicated by the point at which the branches diverge. The distance of the divergence between the
 657 branches is indicated in the horizontal axis. The further right the diverging point is, the more similar are the mean
 658 vessel shapes in the corresponding branches.

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3.2. Identification of the vessels

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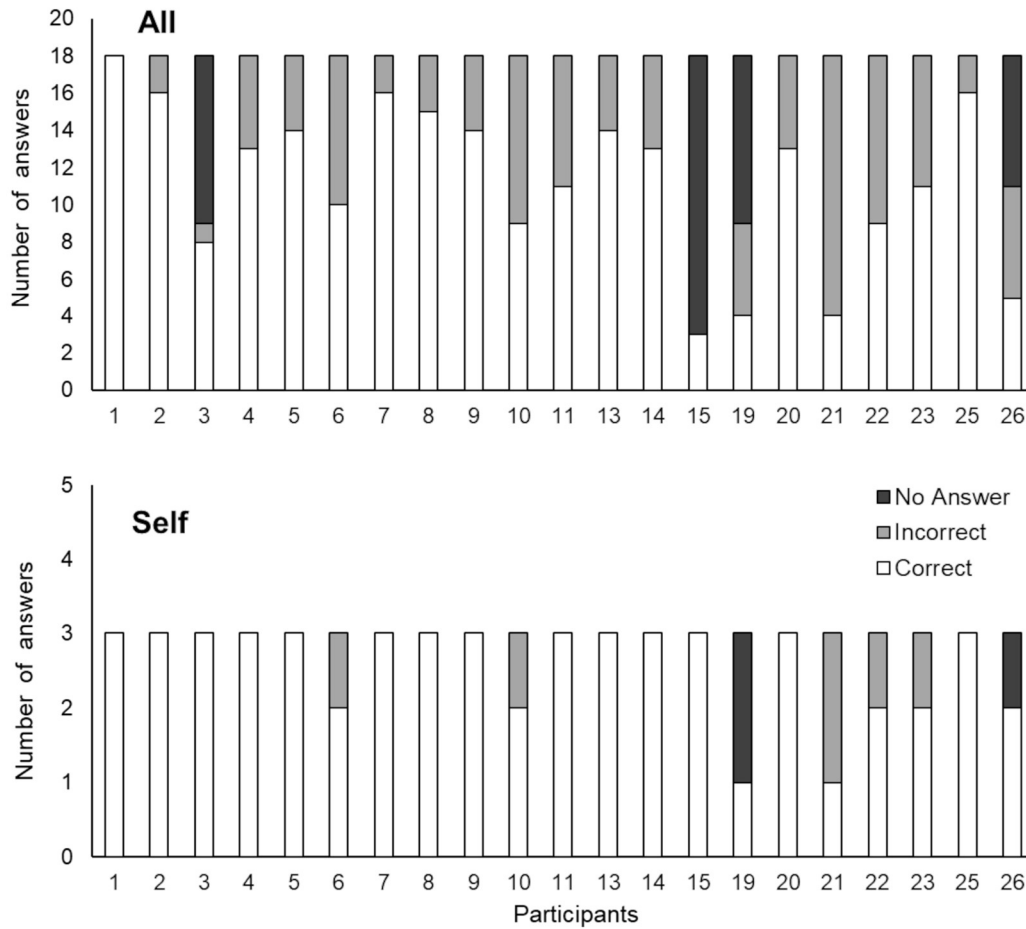
667 Figure 10 presents the performances of the potters when they were asked to recognize
668 their own vessels and those of their colleagues. The among-participant mean number of correct
669 answers was 11.2 ± 4.4 , which represents more than half of the total 18 vessel-groups examined
670 (62%). Hence, as we expected in our third hypothesis, potters do perceive to some extent the
671 individual signatures on ceramic shapes. Differences among the participants were observed:
672 one potter correctly identified all the 18 vessel-groups, three potters correctly identified 16
673 vessel-groups, 13 potters identified more than 9 vessel-groups, and four potters correctly
674 identified less than 6 vessel-groups. These performances were not significantly related to the
675 age of the potters ($t(19) = -0.95$, $p = 0.34$), nor their experience ($t(19) = -0.98$, $p = 0.32$) and no
676 tendencies of relation were observed. A factor which could influence the vessels' identification
677 is the potters' personalities, such as perfectionism or curiosity which would enhance the
678 observation of the vessels from the different individual and workshops. For example, P7
679 explained: *"I like to observe, this is not the case of everyone."* The participants identified their
680 own vessels proportionally better than those of their colleagues: 2.6 ± 0.7 (87%) correct answers
681 in average for a total of 3 vessel groups examined (Fig. 10, bottom panel). Because the sample
682 size of the two groups (self-vessel vs. others-vessel) was different (3 and 15 respectively), we
683 cannot provide a statistical test of this result. Yet, we assume that the identification of self-
684 vessels is easier for the potters because of a longer exposure, as it is easier for pianists to identify
685 their own musical performances (Repp and Knoblich, 2004). Pottery Type did not influence
686 statistically the performances ($KW(2) = 3.54$, $p = 0.17$) (Ebreeq: 4.1 ± 1.8 ; Fokhara: 3.9 ± 2.0 ;
687 Money-Bank: 3.2 ± 1.7). But the lower identification score for the Money-Bank is probably
688 due to its limited frequency of production (Table 1). Finally, the transmission unit vessels were
689 not significantly better identified than the extended family vessels: $4.7 (\pm 2.7)$ and $4.0 (\pm 2.7)$,
690 for the transmission unit and extended families respectively ($t(20) = 0.85$, $p = 0.40$). This can
691 be explained by the tight relations existing between members of extended family.

692

693 The fact that participants identified to some extent the vessels' producers confirms our
694 third operational hypothesis and leads to the conclusion of a possible influence of the potters'
695 choice in the selection and evolution of ceramic shapes. The interviews done with the potters
696 just after their participation in the task revealed that they detected the vessels' producers through
697 different visual characteristics including the vessel size, the colour of clay, and the shape of the

698 whole vessel. Other characteristics allowed them to identify specifically each pottery type:
699 Ebreeq were mainly identified by their neck, Fokhara by their aperture, and Money-Bank by
700 their bud. In fact, because of curvature changes and the presence of lips, these vessel parts
701 concentrate morphological information, and thus potential morphological variations
702 constituting possible individual or family styles. Sustaining this interpretation, recent accounts
703 of social group signatures in Indian water jars showed that the distinction between the Hindu
704 and Muslim communities depended upon the jar rim curve length and neck curve (Harush et
705 al., 2020). Participants also noticed the similarity between the vessels of different individuals:
706 *“The vessels of HIS and his son MOH are highly similar”* (P13), *“My vessels look like those of*
707 *my brother HAKA”* (P4). The vessels aesthetic and the standardization of vessel-groups were
708 also underlined and attributed to a specific potter (P8). In contrast, the vessels with
709 imperfections were attributed to the less advanced potters (P14, P26, and P10 for the Ebreeq).
710 As a test, the experimenter (E. Gandon) performed the vessel identification task under the
711 instructions of her assistant (W. Alqaraja). Because she observed the production of all vessels,
712 photographed them all, and manipulated them for the setup of the identification task, it was
713 expected that she could detect the different vessels’ producers. Her performance was 14 correct
714 answers for a total of 18 vessel-groups examined (78%). Overall, these results suggest that an
715 exposure to the vessels in their context of production can be sufficient to recognize their
716 producers, even by outsiders. As P2 and P5 said: *“I recognize the vessels of my father and those*
717 *of my brother because I’m used to seeing them.”* Importantly, this exposure to the vessels of
718 others depends on the life history of potter who can change their usual workshop for economic
719 reasons. For instance, at the end of our field work, P2 left his father (P3) workshop because he
720 did not have enough work and joined the workshop of his uncle P7. The potter P19 also
721 explained that he could easily identify the vessels of his cousin P2 because he worked with him
722 a few years ago.

723



724

725 **Figure 10. Performances of the participants in the vessel identification task.** Top panel (All): number of correct
 726 answers, incorrect answers, and non-answers given by each participant when trying to identify the producers of
 727 the 18 vessel groups (3 self-vessel and 15 others-vessel groups); bottom panel (Self): number of correct answers,
 728 incorrect answers, and non-answers given by each participant when trying to identify his own productions (3 self-
 729 vessel groups). The participants P12, P16, P17, P18, and P24 were not available to perform this task.

730

731 4. Conclusion

732

733 Many studies have addressed the selective forces operating in cultural evolution
 734 (Dunnell, 1980), but the production of variation occurring through the transmission has not
 735 received much experimental attention. How much are the objects produced by learners different
 736 from those of their trainers? Do inherited cultural traits propagate through the successive
 737 transmissions across generations? Do craftsmen perceive individual morphological signatures
 738 within traditional object assemblages? We tackled these questions in examining the range of
 739 variability in vessel shapes produced by 26 potters from the pottery-making community of
 740 Hebron. As a long-standing crafting tradition, this community represents a valuable case study.

741 The participants – all men – belonged to three distinct families and were distributed through
742 nine familial transmission units (Fig. 2). All participants were asked to produce, in controlled
743 conditions, five vessels of three different pottery types (Ebreeq, Fokhara, and Money-Bank),
744 then 21 participants were invited to visually identify their proper productions and those of five
745 other potters.

746

747 At the scale of individuals, the coefficients of variation of the vessel absolute dimensions
748 were limited, revealing the high level of practice of the participants in the wheel-throwing skill.
749 This intra-individual variation of the vessel dimensions also revealed the irreducible copying
750 error owing to the sensori-motor limits of human performances (Eerkens and Lipo, 2005), and
751 the existence of individual shape variants inside each pottery type. At the scale of the pottery-
752 making community, the vessel shapes produced by novices differed from those of their trainers,
753 reinforcing the view of a socially mediated individual learning in handicraft. Across
754 generations, traditional vessel shapes are not reproduced as perfect copies but with a
755 combination of cultural inherited traits and individual traits. The fact that vessel shapes
756 statistically differed among the 26 participants proved that these individual variants were not
757 simply due to the human copying error but to the idiosyncratic manner with which each potter
758 fashioned each pottery type. We propose that, for potters, traditional pottery types exist not as
759 fixed templates, but as norms with certain range of variation regarding what is appropriate and
760 what is not. The pool of individual shape variants owing to the learning process constitutes a
761 set of appropriate possible variations allowing potters to adapt each pottery type to the current
762 constraints of their socio-economic environment. For example, the Fokhara could have a flatter
763 bottom for customers using gas stove, and the money-bank could have a limited maximal
764 diameter depending upon the clay's hardness.

765

766 Concerning the evolutionary trend of the ceramic shapes, the findings contradicted our
767 assumption that all cultural morphological traits propagate necessarily through artisan
768 generations. Belonging to a familial transmission unit left cultural traits on the vessel shapes
769 but the individual traits prevented the conservation of clear cultural traits across the two
770 generations of participants in the present study. One could say that, from trainers to novices, a
771 transmission of cultural traits exists but is not exclusive, which corroborates the fact that the
772 learning process corresponds more to a socially mediated individual learning than to a fidelity
773 copying. Our quantification of the vessel shape variation indicated that the individual traits

774 overtook cultural ones, which could lead to divergence of vessel shapes within the transmission
775 chain. Hence, without stabilizing mechanisms, we could predict changes of the ceramic shapes
776 over time, exhibiting evolution disconnected from the social organization of their production.
777 However, when we compared the vessel shapes of a given pottery type (Money-Bank) produced
778 by potters originated from four distinct pottery-making communities (Indian Prajapati, Indian
779 Multani, Nepalese, and Palestinian), we observed that the subsets of vessels produced by each
780 community were distinct from each other's ($F(3, 192) = 24.73, p < 0.001$) (Fig. S4). This
781 indicates that ceramic shapes certainly carry inherited cultural traits transmitted through
782 learning lineages. For future research, it would be challenging to develop a more qualitative
783 analysis of the vessel shapes, isolating the various discrete morphological traits interwoven in
784 the whole vessel shape. We hypothesize that certain traits could perpetuate through generations
785 and even historical periods, although they do not constitute the whole shape (Harush et al.,
786 2020). We stress that, if it is the case, our study demonstrated that such cultural continuity in
787 ceramic shapes does not result from fidelity copying in the form of a reproduction, by the
788 novices, of all the trainers' vessel morphological traits. Instead, this shape continuity could
789 result from stabilizing mechanisms such as consumer demand, which directly influences the
790 potters' choice. The results of the identification task supported this view, showing that potters
791 do perceive the subtle same-type vessel shape variations and thereby could select the individual
792 variant they prefer, notably disseminating it by reproduction. Importantly, not only expert
793 potters perceive the morphological variations, but they are also able to produce new shapes
794 without a long training period (Gandon and Roux, 2019). This imply that they can easily modify
795 the shape of a given pottery type following their choice for new morphological traits.

796

797 In brief, the Hebron case offered insights into the cultural transmission and evolution of
798 craft objects. The results highlight the individual part of the learning process and of the
799 subsequent developed skills and vessels (Gandon et al., 2018; Gandon et al., 2020a, Gandon et
800 al., 2020b). This study will help archaeologists to interpret the ancient ceramic shapes variation
801 and to better understand how those shapes have evolved. Now, a new avenue of research is
802 opened in order to disentangle the individual and cultural morphological traits. This is essential
803 in order to obtain a thorough understanding of the evolution of morphological types across time
804 and space. Finally, the craftsmen's ability to perceive shape variations certainly plays a key role
805 in the selection and evolution of traditional objects' shapes. We demonstrated that craftsmen
806 practicing in shared or neighbour workshops developed, probably through simple vessels

807 exposure, the ability to perceive the slight morphological differences characterizing the objects
808 of each individual. The question remains to understand how potters' personalities modulate the
809 development of this perceptive ability.

810

811

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822

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824

825 Dataset reference

826

827 The photos dataset is provided in a Zenodo repository link: <https://zenodo.org/record/4589147>

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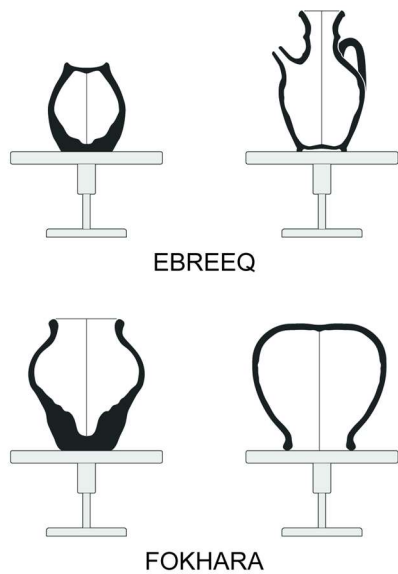
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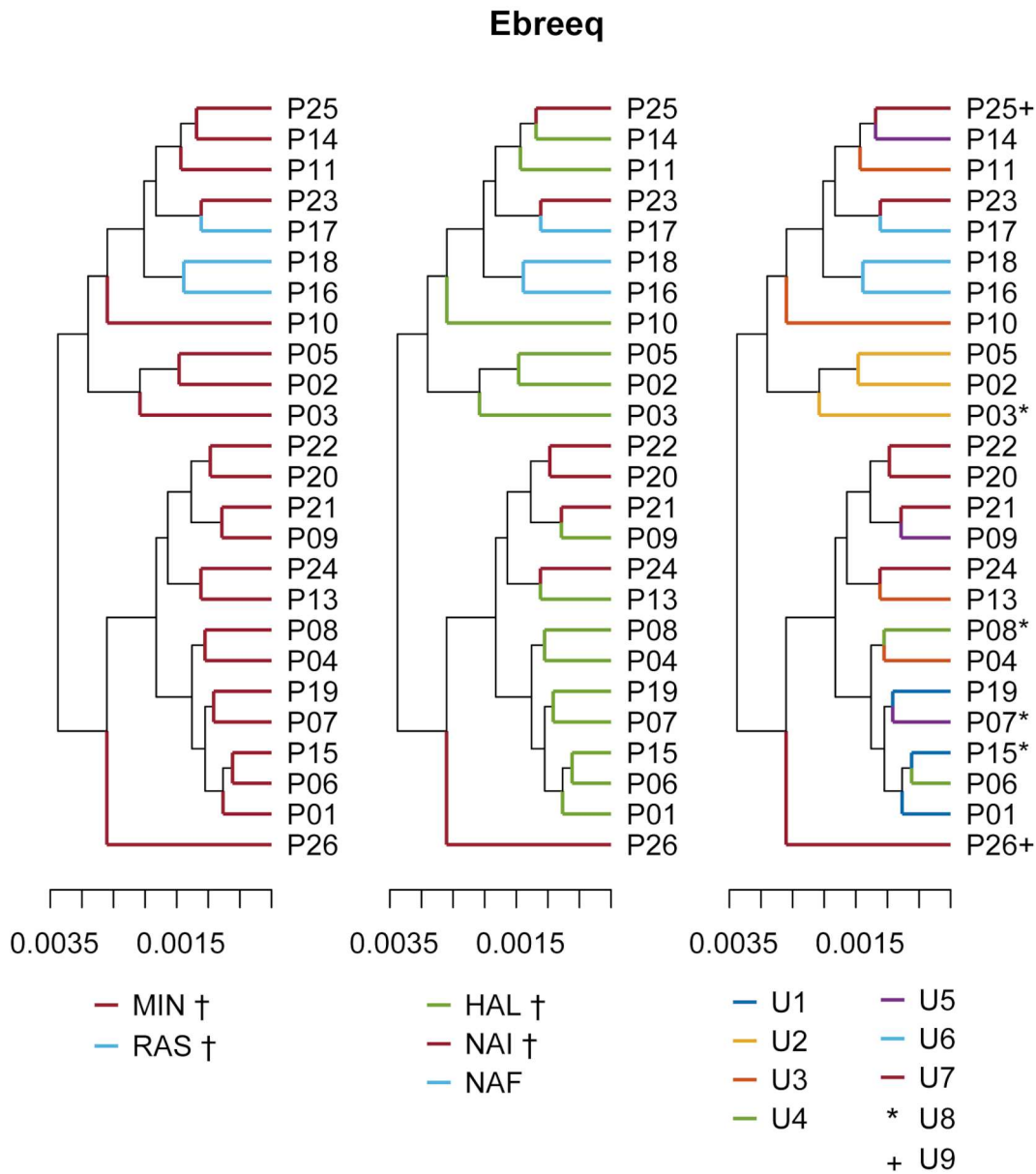


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993 **Figure S1. The two stages method of throwing used for the Ebreeq and Fokhara.** In a first stage, the potter
994 throws the roughout of the vessel keeping the lower part of the wall thick (left drawing). This roughout is then cut
995 from the wheel and left to dry under conditions allowing the lower part to remain wet. In a second stage, the
996 roughout is placed upside-down on the wheel (sometimes in a chuck, made up of leather-hard ring of clay) for the
997 throwing of the final vessel (right drawing). Starting by the base or the upper part depends on the vessel type. For
998 the Ebreeq, the potter starts throwing the base, while for the Fokhara he starts throwing the upper part. Starting by
999 the base or by the opening depends on the location of the maximum diameter and enables the potter to overcome
1000 the risks of collapse while wheel throwing thin walls, from the bottom to the top without further post-throwing
1001 operations (drawings by X. Desormeau).

1002



1003

1004

Figure S2. Dendrograms of the mean vessel shapes for the Ebreeq. The mean vessel shapes of Ebreeq produced by all participants are presented. The similarity between the mean vessel shapes of the different participants is indicated by the point at which the branches diverge. The distance of the divergence between the branches is indicated in the horizontal axis. The further right the diverging point is, the more similar are the mean vessel shapes in the corresponding branches.

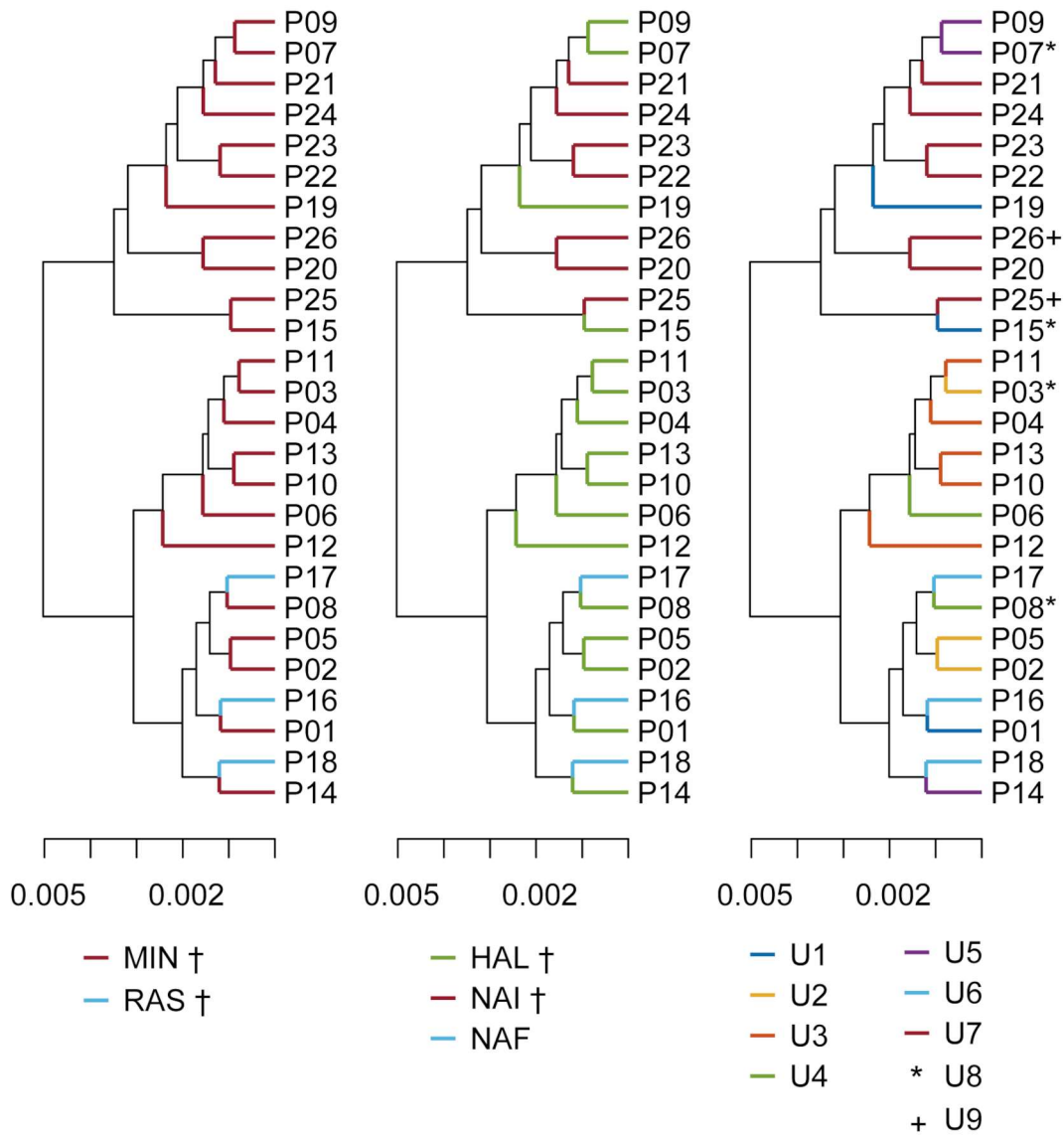
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Money-Bank



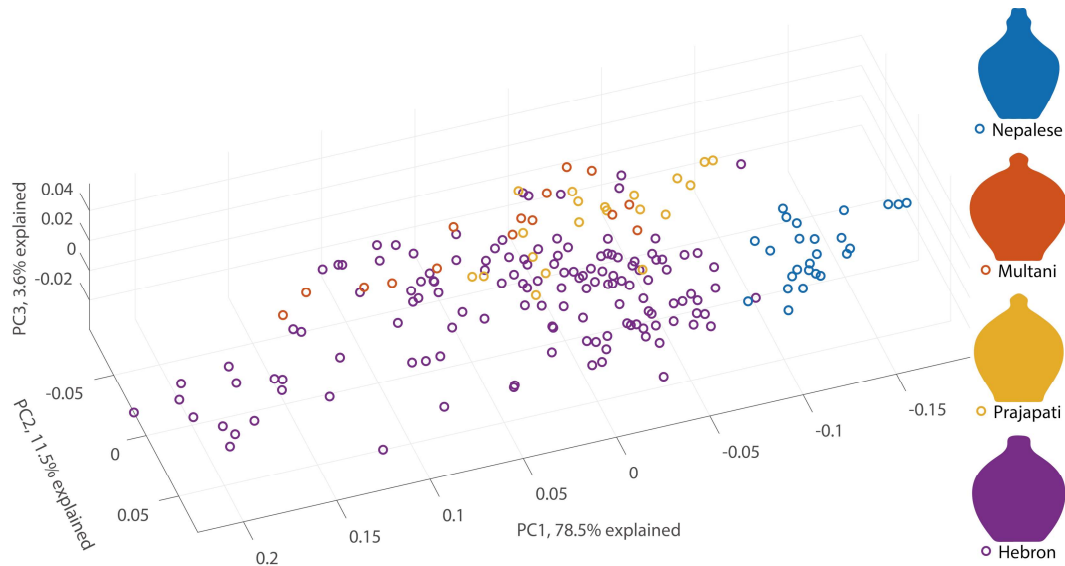
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1010

1011 **Figure S3. Dendrograms of the mean vessel shapes for the Money-Bank.** The mean vessel shapes of Money-
 1012 Bank produced by all participants are presented. The similarity between the mean vessel shapes of the different
 1013 participants is indicated by the point at which the branches diverge. The distance of the divergence between the
 1014 branches is indicated in the horizontal axis. The further right the diverging point is, the more similar are the mean
 1015 vessel shapes in the corresponding branches.

1016

1017



1018

1019 **Figure S4. Geometrical distribution of the Money-Bank thrown by potters of four cultures.** Indian Prajapati:
1020 yellow, Indian Multani: orange, Nepalese: blue, Hebron: purple. The points in the PC shape-space show the
1021 variations among potters, for the four groups, and are based upon Elliptical Fourier coefficients derived from every
1022 pot shape. The pot outlines (right of the graph) are reconstructions of the shapes resulting from the mean
1023 coefficients of each group's production.

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1030 Supplement Tables

1031

Dimensions (cm)										
Ebreeq										
Potter	B		H		A		MD		HMD	
	m	sd	m	sd	m	sd	m	sd	m	sd
P1	8.8	0.5	29.4	0.4	6.7	0.2	17.9	0.3	12.2	0.4
P2	7.8	0.2	29.6	0.9	7.2	0.6	15.8	0.3	11.1	0.7
P3	8.0	0.4	30.4	0.5	5.1	0.4	17.2	0.2	11.7	0.3
P4	8.4	0.2	29.6	0.3	6.0	0.2	16.9	0.3	12.4	0.4
P5	7.5	0.2	29.2	0.8	6.5	0.1	16.7	0.2	12.1	0.3
P6	8.0	0.2	29.2	0.6	7.0	0.2	17.2	0.2	12.5	0.4
P7	8.4	0.1	29.8	0.3	7.1	0.2	17.7	0.4	12.7	0.1
P8	8.1	0.3	31.5	0.6	7.0	0.2	17.8	0.4	12.7	0.4
P9	8.1	0.2	31.2	0.4	7.2	0.2	16.5	0.4	14.1	0.4
P10	10.1	0.5	26.4	1.0	8.0	0.3	14.7	0.6	11.1	0.8
P11	8.4	0.1	25.6	0.4	7.1	0.3	13.3	0.6	10.1	1.7
P13	7.5	0.2	31.1	0.6	6.7	0.1	17.1	0.2	13.3	0.6
P14	8.0	0.6	25.8	0.9	6.3	0.3	15.0	0.3	10.1	0.8
P15	8.7	0.2	29.9	0.5	6.9	0.1	17.6	0.5	13.0	0.2
P16	10.2	0.7	30.0	0.8	6.9	0.3	18.2	0.5	12.7	0.3
P17	9.1	0.7	27.8	1.2	7.9	0.3	17.4	0.5	11.6	0.7
P18	10.4	0.8	29.2	1.4	7.3	0.3	17.0	0.8	11.3	0.9
P19	9.2	0.8	29.9	1.2	7.4	0.4	17.6	0.7	12.9	0.7
P20	8.2	0.3	27.2	1.5	6.6	0.2	16.3	0.5	12.4	0.6
P21	8.0	0.2	29.0	1.0	7.2	0.4	15.9	0.5	13.6	0.7
P22	8.6	0.3	30.3	0.8	6.9	0.2	16.5	0.7	12.6	0.7
P23	8.7	0.2	29.0	0.8	7.4	0.4	17.0	0.5	11.7	0.1
P24	7.7	0.2	29.7	0.6	6.0	0.2	16.2	0.6	13.4	0.4
P25	8.6	0.4	26.4	0.6	7.2	0.2	15.3	0.3	11.4	0.5
P26	8.7	0.2	27.8	0.6	6.8	0.3	14.7	0.4	11.6	0.8
m	8.5		29.0		6.9		16.5		12.2	
sd	0.8		1.6		0.6		1.2		1.0	

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1033 **Table S1. Ebreeq absolute dimensions (centimeters).** The mean and standard deviation are computed over the
1034 five replicates thrown by each participant. B: Base, H: Height, A: Aperture, MD: Maximal Diameter, HMD: Height
1035 of Maximal Diameter. The two last lines of the table present the among-participant mean and standard deviation.

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Dimensions (cm)								
Fokhara								
Potter	H		A		MD		HMD	
	m	<i>sd</i>	m	<i>sd</i>	m	<i>sd</i>	m	<i>sd</i>
P1	16.2	0.4	12.0	0.3	18.9	0.3	8.3	0.2
P2	16.1	0.8	10.7	0.1	15.8	0.7	5.9	0.5
P3	15.0	0.6	12.0	0.2	16.5	0.3	6.5	0.3
P4	14.1	0.6	11.8	0.1	15.8	0.3	6.3	0.4
P5	16.6	0.5	10.9	0.2	17.1	0.4	8.2	0.5
P6	14.4	0.4	11.3	0.3	15.6	0.6	5.7	0.3
P7	16.5	0.3	14.9	0.6	17.0	0.4	6.8	0.2
P8	16.3	0.2	11.7	0.2	16.6	0.3	5.2	0.3
P9	17.8	0.5	13.2	0.7	15.6	0.9	7.0	0.5
P10	13.8	0.8	10.9	0.3	13.7	0.4	3.7	0.4
P11	13.0	0.7	10.2	0.3	12.6	0.3	4.7	1.1
P13	16.8	0.4	10.9	0.8	15.7	0.5	5.6	0.2
P14	12.9	0.2	10.4	0.5	14.2	0.3	4.9	0.2
P15	14.5	0.5	10.7	0.4	16.1	0.6	4.9	0.1
P16	11.9	0.5	12.3	0.4	14.6	0.5	3.6	0.3
P17	12.0	0.5	11.8	0.3	14.7	0.5	4.4	0.6
P18	12.1	0.3	12.0	0.4	14.3	0.4	3.4	0.3
P19	18.0	0.5	11.0	0.3	16.6	0.4	6.2	0.3
P20	13.3	0.7	11.6	0.3	14.4	0.5	4.4	0.3
P21	13.1	0.6	11.8	0.8	14.4	0.6	3.9	0.3
P22	13.7	0.6	11.9	0.6	14.8	0.6	4.3	0.3
P23	13.1	0.8	11.1	0.6	14.7	0.5	3.6	0.3
P24	14.4	0.5	12.5	1.1	14.5	0.5	4.9	0.5
P25	14.9	0.8	11.6	0.4	15.6	0.8	4.4	0.5
P26	15.2	0.9	12.8	0.5	14.2	0.7	6.7	0.5
m	14.6		11.7		15.4		5.3	
<i>sd</i>	1.8		1.0		1.3		1.4	

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1044 **Table S2. Fokhara absolute dimensions (centimeters).** The mean and standard deviation are computed over the
 1045 five replicates thrown by each participant. H: Height, A: Aperture, MD: Maximal Diameter, HMD: Height of
 1046 Maximal Diameter. The two last lines of the table present the among-participant mean and standard deviation.

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Dimensions (cm)								
Money-Bank								
Potter	B		H		MD		HMD	
	m	sd	m	sd	m	sd	m	sd
P1	6.6	0.3	15.3	0.4	12.5	0.2	6.0	0.2
P2	4.9	0.3	11.9	0.2	10.0	0.2	5.0	0.2
P3	4.9	0.2	11.9	0.3	10.0	0.2	5.3	0.1
P4	5.6	0.2	12.5	0.7	10.4	0.4	5.5	0.4
P5	5.4	0.4	11.7	0.4	10.0	0.4	5.1	0.2
P6	5.0	0.3	12.9	0.5	10.3	0.1	5.5	0.5
P7	6.0	0.4	12.1	0.5	10.9	0.3	5.8	0.2
P8	5.3	0.2	12.6	0.4	10.5	0.2	5.9	0.3
P9	6.2	0.5	12.5	0.5	11.1	0.4	5.8	0.2
P10	5.2	0.3	12.9	0.1	11.0	0.3	6.1	0.2
P11	5.4	0.6	13.0	0.8	10.6	0.5	6.1	0.4
P12	5.3	0.1	12.4	0.4	9.8	0.3	5.4	0.4
P13	5.5	0.1	13.6	0.3	11.6	0.3	6.6	0.3
P14	5.7	0.4	10.6	0.4	10.4	0.3	4.3	0.2
P15	5.3	0.2	11.5	0.6	10.6	0.3	6.4	0.4
P16	5.3	0.6	11.6	0.1	10.6	0.4	4.9	0.2
P17	5.1	0.4	12.1	0.4	10.7	0.3	5.6	0.5
P18	5.4	0.4	11.2	0.4	10.0	0.3	4.5	0.5
P19	4.7	0.2	13.1	0.6	10.4	0.3	7.1	0.3
P20	6.3	0.3	10.0	0.3	10.7	0.3	4.5	0.4
P21	4.8	0.3	11.1	0.3	9.7	0.3	5.3	0.4
P22	5.7	0.3	9.4	0.4	10.0	0.2	4.4	0.2
P23	5.7	0.3	10.6	0.5	10.8	0.5	5.3	0.5
P24	5.4	0.3	10.6	0.6	10.0	0.3	4.4	0.5
P25	4.9	0.3	11.6	0.6	9.8	0.3	6.1	0.3
P26	5.8	0.2	10.4	0.8	9.8	0.3	3.7	0.5
m	5.4		11.9		10.5		5.4	
sd	0.5		1.3		0.6		0.8	

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1056 **Table S3. Money-Bank absolute dimensions (centimeters).** The mean and standard deviation are computed over
 1057 the five replicates thrown by each participant. B: Base, H: Height, MD: Maximal Diameter, HMD: Height of
 1058 Maximal Diameter. The two last lines of the table present the among-participant mean and standard deviation.

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Pair	t	df	p
Ebreeq – Fokhara	-3.45	24	0.002
Ebreeq – Money-Bank	-4.21	24	0.0003
Fokhara - Money-Bank	-0.89	24	0.37

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1063 **Table S4. Post-hoc t-test for the effect of pottery type on the coefficient of variation of the production.**