



HAL
open science

A preliminary study of rotation velocity regulation in pottery wheel-throwing: Fieldwork with Indian potters using the low-inertia kick-wheel

Enora Gandon, Thelma Coyle, Frédéric Pous, Franck Buloup, Reinoud J. Bootsma

► To cite this version:

Enora Gandon, Thelma Coyle, Frédéric Pous, Franck Buloup, Reinoud J. Bootsma. A preliminary study of rotation velocity regulation in pottery wheel-throwing: Fieldwork with Indian potters using the low-inertia kick-wheel. *Journal of Archaeological Science: Reports*, 2021, 37, pp.102987. 10.1016/j.jasrep.2021.102987. hal-03475151

HAL Id: hal-03475151

<https://amu.hal.science/hal-03475151>

Submitted on 19 Apr 2022

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.

1 A preliminary study of rotation velocity regulation in pottery wheel-throwing:
2 fieldwork with Indian potters using the low-inertia kick-wheel

3
4 Enora Gandon^{a*}, Thelma Coyle^b, Frédéric Pous^b,
5 Franck Buloup^b, Reinoud J. Bootsma^b

6
7 a. Institute of Archaeology, University College London, 31-34 Gordon Square, London
8 WC1H 0PY, United Kingdom

9
10 b. Institut des Sciences du Mouvement, Aix-Marseille Université, CNRS, 163 av. de
11 Luminy F-13288, Marseille cedex 09, France

12
13
14 * Corresponding author

15
16 Enora Gandon: gandon.enora@gmail.com

17 Thelma Coyle: thelma.coyle@univ-amu.fr

18 Frédéric Pous: frederic.pous@univ-amu.fr

19 Franck Buloup: franck.buloup@univ-amu.fr

20 Reinoud J. Bootsma: reinoud.bootsma@univ-amu.fr

21
22
23
24
25
26
27
28
29

Abstract

30
31
32
33 The present study examined rotation velocity regulation in pottery wheel-throwing.
34 Long assumed to be a key parameter in the control of the centrifugal force, we interpret its role
35 rather as a means to control the linear velocity at the point of hand-clay contact. To test this
36 hypothesis, we set up a field experiment with Indian potters working with a low-inertia kick-
37 wheel. Six expert potters were asked to produce eight types of pots (four shapes × two masses),
38 each type in five specimens (in total each potter threw 40 vessels). We measured the rotation
39 velocity during the pre-forming and forming fashioning phases, as well as the maximal vessel
40 radii at the end of both phases. Results demonstrated that potters reduced the rotation velocity
41 from the pre-forming phase to the forming phase, but also for the large clay masses compared
42 to the small clay masses, and -uniquely during the forming phase- for the shapes characterized
43 by the largest diameter. Overall, the observed decreases in rotation velocity corresponded to
44 increases in mean vessel diameter, suggesting that the potters were applying a limit on the linear
45 velocity. Our results thus provide empirical evidence supporting the role of linear velocity as a
46 key functional parameter in wheel-throwing. Directly relating to the potter-vessel interaction,
47 it indicates both when and by how much the rotation velocity deceleration caused by the
48 exertion of manual pressure forces should be compensated, as well as how to avoid the risk of
49 velocity-induced collapse. While only preliminary, our results also suggest that large-sized
50 ancient wheel-thrown vessels were most likely produced using low-velocity and high-inertia
51 wheels. Future work, examining rotation velocity regulation over different types of wheels, is
52 needed to allow definite conclusions to be drawn.

53
54
55 **Key words:** pottery wheel-throwing, [potter's wheel](#), rotation velocity, linear velocity, motor
56 skill, expertise, field experiment, low-inertia kick-wheel

61 **1. Introduction**

62

63 In pottery, fashioning is the process of deforming a lump of clay into a desired container
64 shape. While the resulting vessel will eventually be solidified by firing, during fashioning the
65 clay remains elastoplastic, meaning that deformations caused by small forces are elastic and
66 hence reversible, whereas deformations caused by larger forces are plastic and hence
67 permanent. Fashioning thus requires the application of sufficient force levels to give rise to
68 plastic deformation of the clay to attain the desired shape. At the same time, however, the
69 evolving mechanical structure (i.e., the pottery vessel) must continuously remain sufficiently
70 strong to avoid collapse (Gandon et al., 2011a). Potters must therefore deftly control the
71 deforming manual pressure forces exerted on the clay surface.

72

73 Fashioning techniques exploiting a wheel-based rotation device can be distinguished
74 depending on the contribution of the wheel's rotational motion to the fashioning sequence. The
75 three general variants of such fashioning techniques, identified in the archaeological record or
76 directly observed in ethnographic studies, are wheel-finishing, wheel-shaping, and wheel-
77 throwing (Ther & Toms, 2016; Roux, 2019). Of these three, only wheel throwing exploits the
78 the wheel's rotational motion over the complete fashioning sequence, which, thereby, poses
79 requirements on rotation velocity in terms of regularity and magnitude. The advent of wheel-
80 throwing, with the clay's surface continuously moving relative to the potter's hands, definitely
81 marked a breakpoint in the evolution of ceramic fashioning techniques (Leroi-Gourhan, 1943;
82 Van der Leeuw, 1993; Pierret, 2001; Roux & Courty, 1998). While, on the one hand, it allowed
83 for considerable gains in production rate and product regularity (Roux, 2012, 2019), it, on the
84 other hand, required the development of specific sensorimotor capabilities for mastering the
85 skill and thereby longer apprenticeship (Roux & Corbetta, 1989).

86

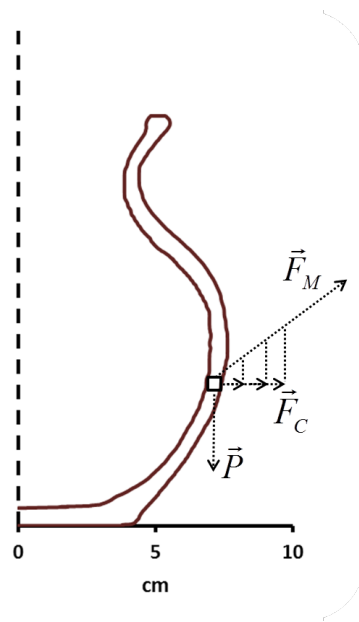
87 Across cultures and time, wheel-throwing has been practiced with different kinds of
88 wheels (often referred to as fast-wheels) that vary in the ways they are activated (Rice, 1987).
89 While variations in rotation velocity in the wheel-throwing process have been noted and the
90 need for regularity has been underscored (RJB: DO YOU HAVE A REF?), to date the
91 regulation of the rotation velocity over the entire wheel-throwing process has not been
92 described for any kind of wheel. This is quite surprising, given that such rotation velocity
93 regulation constitutes the technical trait distinguishing wheel-throwing using the (fast-) wheel

94 from wheel-finishing and wheel-shaping using the turntable and the slow-wheel. The present
95 study provides a first step to filling this gap, so as to allow archaeologists to better understand
96 how ancient rotation devices may have been used. Identifying how potters operated the (fast-
97)wheel will also shed some light on the complex relation existing between the properties of the
98 rotation devices (size, inertia, maximal rotation velocity), the vessels characteristics (size, shape
99 and weight), and the fashioning techniques used by the potter (wheel-finishing, wheel-shaping,
100 and wheel-throwing) (Roux & Miroschedji, 2009; Roux & Jeffra, 2015; Ther et al., 2017).

101

102 Among archaeologists, the rotation velocity in wheel-throwing has commonly been
103 regarded as a parameter controlling the resultant centrifugal force, which, in turn, has widely
104 been considered as an active agent in the clay deformation process (Foster, 1959; Jeffra, 2011;
105 Méry et al., 2010; Orton et al., 1993; Rice, 1987). While novice potters may regularly
106 experience collapse of their vessel during fashioning, due to insufficiently-controlled force
107 balances, this should not be taken to imply that expert potters face the same problems. Indeed,
108 a recent finite-element mechanical modelling exercise (Gandon et al., 2019) demonstrated that
109 in expert potter wheel-throwing the centrifugal forces generated by vessel rotation
110 systematically remained far below the force threshold for plastic deformation. For experts, the
111 centrifugal force is not, therefore, an active agent in the sense of plastically deforming the clay
112 by itself. However, like the (downward-acting) gravitational forces, the (outward-acting)
113 centrifugal forces do affect the pressure forces the potter must apply to fashion the desired
114 vessel: In order to control the net deforming force applied to the clay, the potter needs to
115 modulate the (muscular) manual pressures forces exerted in the vertical and radial directions as
116 a function of the magnitude of these non-muscular forces (Fig. 1). Still, as follows from Gandon
117 et al.'s (2019) demonstration, in wheel-throwing the operative centrifugal forces resulting from
118 wheel rotation remain small relative to the pressure forces exerted by a competent potter.
119 Therefore, for expert potters at least, regulation of rotation velocity during wheel-throwing
120 should be considered from another angle.

121



122

123 **Fig 1. The forces applied over the clay surface during wheel throwing.** \vec{F}_M : the manual
 124 pressure force exerted by the potter, \vec{P} : the weight of the clay, \vec{F}_C : the weight of the clay. The
 125 pressure forces exerted by the potter can be resolved into vertical, radial and tangential
 126 components (the tangential component, not represented in this 2D figure, is oriented orthogonal
 127 to the page). When the potter fashions the clay outwards, the centrifugal force is added to the
 128 radial component of the pressure forces. When we consider the clay together with the wheel,
 129 we use the expression ‘wheel-throwing system’ (Pierret, 2001).

130

131 In fashioning a vessel by wheel-throwing, two main phases can be distinguished. The
 132 process begins with a *pre-forming phase* in which the potter centers the mass of clay on the
 133 wheel and sets the stage for the subsequent forming process by opening (i.e., hollowing) the
 134 centered lump of clay. During the *forming phase*, thinning the clay (known as “pulling”) brings
 135 out the initial form as the vessel rises from its base, while the ultimate form is attained during
 136 the final shaping. These two fashioning phases involve different pressure forces in terms of
 137 magnitude and orientation. In the pre-forming phase large pressure forces are required to
 138 constrain the mass of clay into a centered lump. As Roux and Corbetta (1989) have
 139 experimentally shown, this step of centering is rarely mastered by apprentices before the age of
 140 14 years because of a lack of strength. During hollowing, the pressure forces required to dig
 141 into the lump of clay will also be high when a large mass of clay is to be deformed. From pulling

142 to final shaping (i.e., during the forming phase), the thickness of the vessel walls decreases
143 progressively, reducing the magnitude of the pressure forces the potter can safely apply.

144

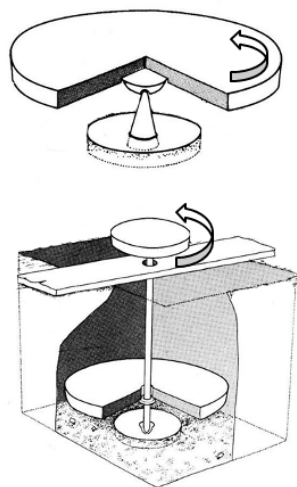
145 As the clay is continuously moving relative to the hands, the exertion of any manual
146 pressure forces normal to the clay surface creates friction, adding to the inherent, but usually
147 small, friction operating at the wheel's fulcrum. Being a resistive force, friction represents a
148 kinetic energy loss, leading the wheel to decelerate. When potters use an electrical wheel, this
149 energy loss is constantly compensated by the electrical energy injected into the system via the
150 motor. This is not the case, however, for the traditional wheels used in ancient pottery
151 communities and which can be still seen in use today (Fig. 2). For non-electrical wheels, the
152 rotational kinetic energy of the wheel-throwing system is maintained by human effort. A stick-
153 wheel requires the potter to interrupt the fashioning process to accelerate the wheel with the
154 help of a hand-held stick. Because of this process-disrupting characteristic, a stick-wheel
155 typically has a large moment of inertia allowing minimization of the deceleration caused by the
156 friction forces. A foot-operated kick-wheel, on the other hand, allows the potter to insert energy
157 by modulating the frequency and/or intensity of kicking, allowing the fashioning activity to
158 continue with only short interruptions.

159

160

161

162



163

164

165 **Fig 2. Two kinds of non-electrical wheels in use in northern India.** Top panel: the high-
166 inertia stick-wheel used by the Prajapati Hindu potters. Bottom panel: the low-inertia kick-
167 wheel used by the Multani Muslim potters. We have measured equivalent maximal rotation
168 velocities during fashioning in these two wheels: 222 and 230 rpm for the stick-wheel and kick-
169 wheel respectively. The left-side drawing is adapted from Orton et al. (1993). (color for the
170 online version)

171

172 Neither the rotational kinetic energy of the wheel-throwing system nor its rotation
173 velocity are directly perceived by the potter. What the potter perceives, via haptic and visual
174 sensations, are the thickness of the vessel walls and the linear velocity at which these walls pass
175 through the hands. Linear velocity (v) is defined as $v = \omega r$, where ω is the rotation velocity of
176 the wheel-throwing system and r the distance between the wheel's rotation axis and the walls
177 of clay. During fashioning, energy loss due to friction can be perceived in the ensuing
178 deceleration of the linear velocity; the potter can then respond by accelerating the wheel-
179 throwing system. To gently deform the clay and maintain axial symmetry, the linear velocity
180 should be regular and sufficiently high to allow the pressure forces to be continuously applied
181 over the complete circumference of the vessel. This requirement sets a minimal linear velocity
182 necessary for the fashioning process. According to Hulthen (1974), such minimal velocity
183 would be on the order of 0.7 m/s, but one should note that it varies with vessel diameter. One
184 may also expect an upper limit on the linear velocity, beyond which the potter can no longer
185 control the fashioning process because of incompressible delays in human sensorimotor
186 capabilities. At high velocities, the centrifugal force may also come into play, increasing the
187 risk of vessel collapse. Hence, the linear velocity at the point of clay-hand contact may well be
188 a key functional parameter in wheel-throwing. It is the parameter that would indicate how much
189 and when to compensate the deceleration caused by the friction forces, and how to avoid risk
190 of collapse. Indeed, in a previous study we have shown that potters maintain the linear velocity
191 within a certain range, measuring values comprised between 0.3 and 1.2 m/s for an average of
192 0.7 m/s (Gandon et al., 2011b), thus partly corroborating Hulthen's hypothesis (op. cit.). What
193 still needs to be demonstrated is how the linear velocity is controlled by the potter. If it is a key
194 functional parameter in wheel-throwing as we suggest, it should be controlled to adapt to the
195 operative task constraints that vary as a function of fashioning phase and vessel characteristics
196 (mass and shape).

197

198 To test this hypothesis, we set up a field experiment with expert potters in northern India
199 (Uttar Pradesh). We recorded the rotation velocity of a low-inertia kick-wheel which requires
200 frequent driving (acceleration), and thus provides a privileged means to study a potter's 'on-
201 line' regulation of the rotation velocity. Participants were asked to produce pots of four different
202 shapes, each shape being thrown with two different masses. The experimental requirement to
203 produce vessels of different mass and shape implies that the vessels produced will differ in
204 diameter. Directly recording the linear velocity of the clay wall during fashioning was not
205 possible without interfering with the hand-clay interface . Instead, we developed a method to
206 measure the rotation velocity throughout the fashioning process. Given the direct (radius-
207 mediated) relation between the linear velocity and the rotation velocity, we expected that the
208 changes in the rotation velocity would be coherent with the control of the linear velocity. This
209 lead to the operational hypothesis that the control of the linear velocity should be observable
210 through a decrease in rotation velocity as the diameter of the vessel increases: from the pre-
211 forming to the forming phase, for the large mass compared to small mass, and in the forming
212 phase for the largest diameter shapes. We emphasize that compensating for the kinetic energy
213 loss is energy-consuming and thus tiring for potters using a non-electrical wheel. Traditional
214 craftsmen usually produce a large quantity of pots per day (hundreds of middle size pots for
215 example) and, in line with the energy efficiency characteristics of motor skill experts **RJB:**
216 **REF?**), we assume that they have developed a low (muscular) energy consuming behavior. We
217 postulate therefore that expert potters throw vessels with the wheel at a rotation velocity
218 allowing the linear velocity to remain within an optimal range, keeping it as far as possible
219 below the values where the centrifugal forces would threaten the structural integrity of the pot.
220 Prior to presenting our main, rotation velocity related results, we will present the
221 standardization of the vessel assemblages (i.e., variability of vessels' absolute dimensions)
222 which accounts for the reproducibility of the participants' fashioning behavior.

223 ***2. Materials and methods***

224





225 ***2.1. Experimental setting***

226

227 Six professional potters gave their written consent to participate in the field experiment.
228 The participants (right-handed men) were all over 25 years old (31.3 ± 4.5 yrs) and had a

229 minimum of ten years of wheel-throwing experience (16.5 ± 6.4 yrs). They all originated from
 230 the village of Jahanjirabad (Uttar Pradesh, India) and belong to the Multani-Khumar
 231 community. In India, the wheel-pottery handicraft is learned within endogamous castes which
 232 throw standardized traditional objects at high production rates (Kramer, 1997; Roux &
 233 Corbetta, 1989; Saraswati & Behura, 1964). The experiment took place in a traditional pottery
 234 workshop in the participants' village. All fashioning was performed on the same low-inertia
 235 kick-wheel (Fig. 2, bottom panel) using soft red clay (1.7 kg/cm^2 indentation hardness).
 236 Participants were asked to reproduce four different model shapes using two different quantities
 237 of clay, leading to a total of eight experimental conditions (Table 1). To assess the
 238 reproducibility of behavior, five specimens were produced in each of the eight experimental
 239 conditions, so that each potter produced a total of 40 pots. The shapes (referred to as cylinder,
 240 bowl, sphere and vase) were presented as drawings without providing indication of absolute
 241 size to be produced. The quantity of clay provided for each trial corresponded to a mass of
 242 either 0.75 kg or 2.25 kg. The participants were instructed to accurately reproduce the
 243 proportions of the models, to throw vessels with the thinnest walls possible, and to refrain from
 244 embellishment operations at the end of the fashioning. No tools were used but a basin of water
 245 to wet the clay. Potters produced the 40 vessels working at their own pace. The experimenter
 246 was present during the experimental task to monitor progress and ensure procedural
 247 consistency. Participants freely practiced the task one day before the experiment. Data
 248 acquisition relied on non-invasive methods detailed in the following sections (Fig. 3).

249
250
251
252
253
254

Shape	Cylinder		Bowl		Sphere		Vase	
2D drawing								
Mass of clay (kg)	0.75	2.25	0.75	2.25	0.75	2.25	0.75	2.25

255

256 **Table 1. The eight experimental conditions.** Potters were asked to produce four different
257 shapes (cylinder, bowl, sphere and vase) with two different clay masses (0.75 and 2.25 kg).

258

259



260

261

262 **Fig 3. The non-invasive experimental setting.** The potter performed the task while wheel
263 rotation velocity and vessel profiles were recorded with a computer and a video camera
264 respectively. A thin insulated cable connected the rotation velocity measurement device (fixed
265 to the wheel) to the computer acquisition system. (color for the online version)

266

267

268

269

270

2.2. Data acquisition and analysis

271

272

2.2.1. Vessel assemblages

273

274 Using a Panasonic NV-GS320 camcorder, all behavioral sessions were filmed under
275 standardized conditions: the camera was fixed on a tripod with lens orientation centered on the
276 vertical rotation axis of the wheel. The camera was positioned at 4 to 6 m from the wheel. The
277 lower edge of the video image was aligned with the working surface of the wheel and the image
278 was centered on the vertical rotation axis of the wheel. The plane of the camera was
279 perpendicular to the plane of the wheel working surface (Fig. 3). The zoom was adapted to fully
280 cover a 36-cm high by 42-cm wide calibration object (inverted T-shape) that could be placed
281 on the wheel's working surface. Two images of each vessel were extracted from the films, one
282 after the pre-forming phase (Phase 1: centering and hollowing, during which the large surfaces
283 of both hands are in contact with the clay) and the other at the end of the forming phase (Phase
284 2: thinning and final shaping, during which only one or two fingers of each hand are in partial
285 contact with the clay). The beginning of Phase 1 was defined by the onset of the first manual
286 centering action, generally corresponding to the moment of maximal rotation velocity. Phase 1
287 ended (and Phase 2 began) when the potter initiated the first pulling action. Phase 2 ended when
288 the last final shaping action was completed. These 2D images adequately captured the
289 consistently axisymmetric shape of the vessels. From the images, we extracted the 2D
290 coordinates of the right-side cross-sectional profiles by tracing them out on a Cintiq 21UX
291 Wacom® tablet with integrated screen. The profile coordinates were converted from pixels to
292 centimeters using a calibration factor obtained from the dimensions of the calibration object.
293 Next, the profiles were re-sampled to generate an equal number of points (256 in total) at regular
294 height intervals along the y-axis and finally the coordinates were smoothed with a low pass
295 filter. Because the thrown vessels were typically symmetric, profiles were subsequently
296 converted to full pot outlines by recentering at $x=0$ and multiplying the x coordinates by -1
297 to create the corresponding left edge. Using the between-trial variabilities over the five specimens
298 thrown by each participant (for each of the eight experimental conditions), the standardization
299 of production was assessed via the coefficients of variation ($CV = 100\% * \text{standard deviation} /$
300 mean) computed on the absolute dimensions of the final vessel (height, base, aperture, maximal
301 diameter, and height at the maximal diameter). We also measured the maximal vessel radii at
302 the end of the pre-forming phase and at the end of the forming phase.

303 **2.2.2. Rotation velocity**

304

305 Wheel rotation velocity was measured by means of a magnet fixed to the lower side of
306 the kick-wheel's rotating plateau and a magnetic sensor (NI USB-6008, National Instruments)

Commenté [BR1]: Reported as such in the Results section and Table 2. Is fine to express as percentage.

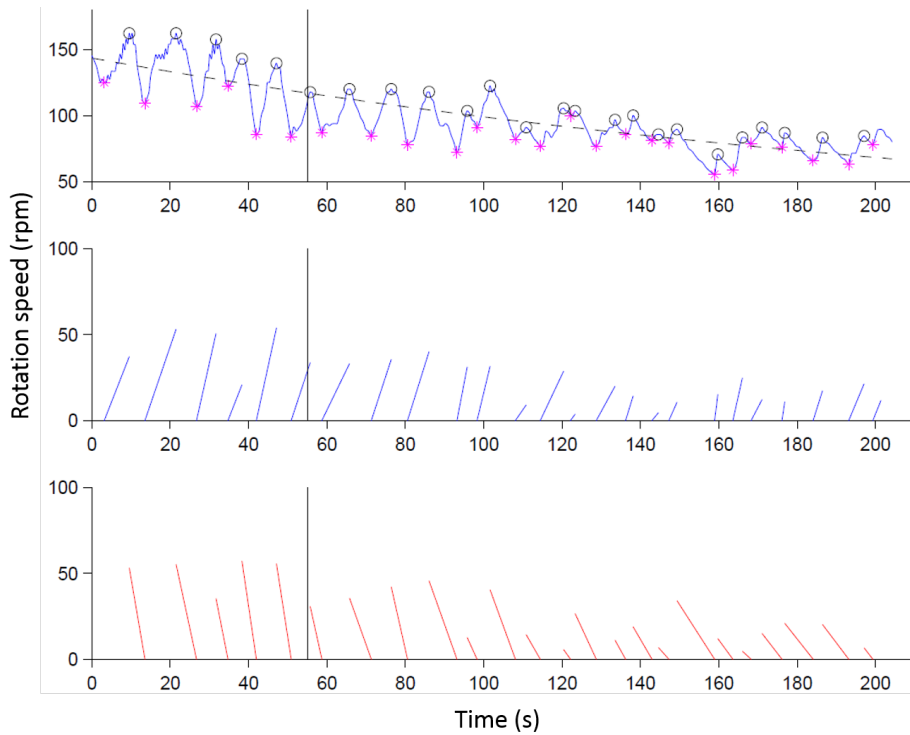
307 attached to the wooden support structure. The magnetic field sampling was performed at 100
308 Hz, with a measure of rotation velocity thus being available after each full turn of the wheel.
309 Acquisition of rotation velocity was synchronized with video recordings of the potter's
310 fashioning behavior (Panasonic NV-GS320) allowing the start and end points of the two phases
311 of the wheel-throwing to be identified (Fig. 3). We focused on fashioning durations and rotation
312 velocities during the pre-forming phase (Phase 1) and the forming phase (Phase 2).

313

314 Observation of the evolution of rotation velocity over time during fashioning revealed
315 both global and local changes (Fig. 4). First, we analyzed the global changes focusing on the
316 fashioning durations and on the average rotation velocities. Next, we focused on the
317 characteristics of local increases and decreases in rotation velocity, defined as acceleration and
318 deceleration bouts, respectively. Acceleration bouts resulted from the potter kicking the wheel
319 with his (right) foot, thereby increasing rotation velocity. Deceleration bouts resulted from the
320 dissipation of rotational kinetic energy due to friction forces, thereby decreasing rotation
321 velocity. Because the friction forces are (to a very large extent) determined by the clay-
322 deforming pressure forces, we can consider the decrease in rotation velocity observed during
323 deceleration bouts as indicative of the pressure force exerted by the potter. Bouts were
324 operationally identified by a peak-finding algorithm that determined the local maxima and
325 minima in the rotation velocity time series. Velocity differences of less than 4 rpm were
326 discarded. Acceleration bouts ran from a local minimum to the subsequent maximum, while
327 deceleration bouts ran from a local maximum to the subsequent minimum. For each vessel
328 thrown, the number of acceleration and deceleration bouts was determined, together with their
329 duration, amplitude and average rate of velocity change (i.e., acceleration or deceleration
330 magnitude).

331 In order to analyze the characteristics of the wheel-throwing process exhibited by expert
332 kick-wheel potters, we used repeated-measures ANOVAs with factors Shape (4 levels), Mass
333 (2 levels), and Phase (2 levels), while local analyses also included the factor Bout Type (2
334 levels, acceleration or deceleration).

335



336

337 **Fig 4. Example of rotation velocity recording over the course of fashioning.** This example
338 is from a potter fashioning a 2.25 kg cylinder. The top panel presents rotation velocity as a
339 function of time, revealing both the global decrease in rotation velocity as well as the alternation
340 between local increases and decreases. The identified minima and maxima in rotation velocity
341 are indicated by asterisks and circles, respectively. The lower panels present the local increases
342 (acceleration bouts, middle panel) and decreases (deceleration bouts, bottom panel) in
343 linearized form. Each line's slope corresponds to the corresponding bout's magnitude of
344 acceleration or deceleration. For ease of comparison between bouts, deceleration is expressed
345 in absolute values. The vertical line crossing the graphs indicates the end of Phase 1 and the
346 beginning of Phase 2. (color for the online version)

347

348

349 **3. Results and discussion**

350

351 **3.1. Vessel assemblages**

352

353 To quantify participants' consistency in final vessel shape produced Table 2 presents
 354 the coefficients of variations of the final vessels' absolute dimensions, for each of the four
 355 shapes (cylinder, bowl, sphere, and vase) and the two masses (0.75 and 2.25 kg). As expected,
 356 the traditional context of production and the level of expertise of the participants gave rise to
 357 highly standardized assemblages. The values of the CVs were close to the 5% reported in
 358 previous studies with expert potters (Gandon et al., 2014a; Gandon et al., 2014b; Roux, 2003).
 359 This result indicates that the participants succeeded in the experimental task. They produced
 360 the experimental assemblage with a high level of standardization reflecting expert performance.

361 Table 3 presents the average maximal radius of the vessels at the end of the Phase 1
 362 (pre-forming) and 2 (forming), for each of the eight experimental conditions. We observed that
 363 the maximal radii at the end of phase 1 were limited and dependent on the Mass only (on the
 364 average 4.1 and 5.8 cm, for the 0.75 and 2.25 kg vessels respectively). At the end of phase 2,
 365 the maximal radii observed depended on both the Mass and the Shape, varying in a range of 4.7
 366 to 15.6 cm (for the 0.75 kg cylinders and 2.25 kg bowls respectively). These results demonstrate
 367 that the Shape parameter does not influence the centering and hollowing but only the thinning
 368 and final shaping stages.

369

Shape	Mass (kg)	H (%)	B (%)	A (%)	MD (%)	HMD (%)
Cylinder	0.75	6.4	5.1	4.8		
	2.25	5.8	5.8	4.4		
Bowl	0.75	5.4	4.6	2.8		
	2.25	4.5	4.5	2.5		
Sphere	0.75	4.0	5.1	6.1	4.0	6.6
	2.25	6.3	4.7	6.3	1.9	7.5
Vase	0.75	4.7	6.2	6.9	4.3	8.7
	2.25	4.7	6.4	7.8	3.1	7.9

370

371 **Table 2. Coefficients of variation of the vessels' absolute dimensions.** The values correspond
 372 to the average across the six participants. H: Height, B: Base, A: Aperture, MD: Maximal
 373 Diameter, HMD: Height at Maximal Diameter.

374

Maximal radius (cm)								
Shape	Cylinder		Bowl		Sphere		Vase	
Mass (kg)	0.75	2.25	0.75	2.25	0.75	2.25	0.75	2.25
Phase 1	4.1 (0.3)	5.7 (0.3)	4.2 (0.3)	5.9 (0.2)	4.1(0.2)	6,0 (0.2)	4.2 (0.2)	6,0 (0.3)

Phase 2	4.8 (0.1)	6.7 (0.2)	10.7 (0.6)	15.6 (0.5)	7.2 (0.4)	10.7 (0.4)	7.6 (0.4)	11.4 (0.4)
----------------	-----------	-----------	------------	------------	-----------	------------	-----------	------------

375

376 **Table 3. Maximal radius of the vessels at the end of the pre-forming and forming phases.**

377 Means and standard deviations (between parentheses) were calculated across the six
378 participants. Phase 1: pre-forming phase; Phase 2: forming phase.

379

380

381 **3.2. Regulation of the rotation velocity: global analysis**

382

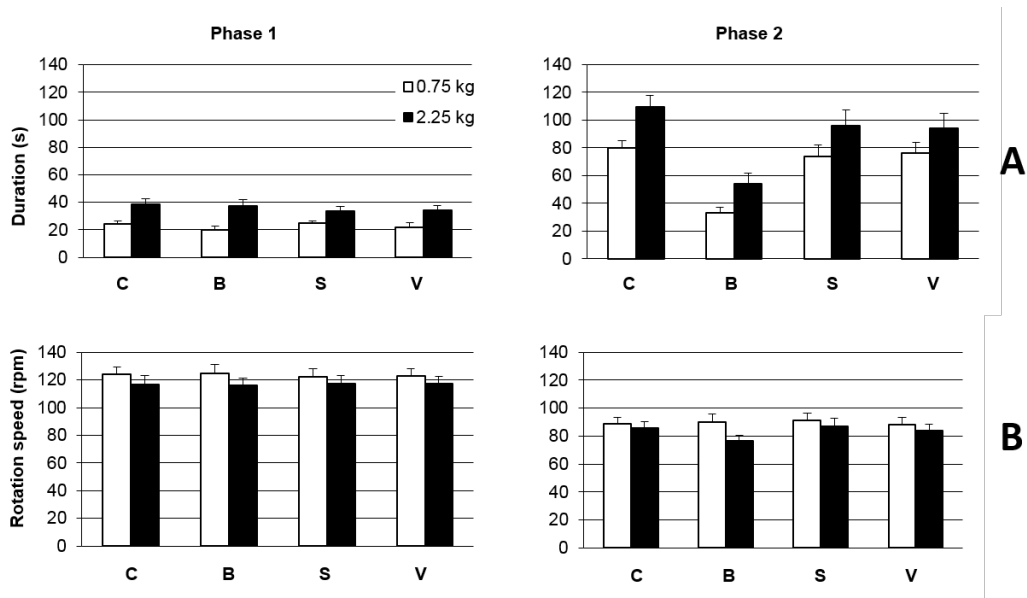
383 Figure 5 presents the average fashioning duration and the average rotation velocity as a
384 function of Phase, Mass, and Shape. As can be seen from Fig. 5-A, Phase 1 was systematically
385 shorter than Phase 2 (on average 29.3 and 77.1 s, respectively; $F(1, 5) = 67.47, p < .001$)
386 indicating that centering and hollowing require much less time than thinning and final shaping.
387 During both phases fashioning the 2.25 kg mass took longer than fashioning the 0.75 kg mass
388 (on average 62.1 and 44.2 s, respectively; $F(1, 5) = 41.08, p < .001$), which can be explained
389 by the larger quantity of clay to deform. Post-hoc (Newman-Keuls) analysis of the Shape x
390 Phase interaction ($F(3, 15) = 40.07, p < .001$) indicated that Shape did not affect the duration
391 of Phase 1. In Phase 2, the cylinder took longer to throw than the sphere and vase which in turn
392 took longer than the bowl (p 's $< .05$). Average durations were 94.5, 84.8, 85.2, and 43.8 s for
393 the cylinder, sphere, vase and bowl respectively. We interpret this result as reflecting the
394 different levels of familiarity participants had with the distinct shapes: the bowl is a common
395 shape for Indian potters whereas the cylinder is less familiar.

396

397 Rotation velocity (see Fig. 5-B) was considerably lower during Phase 2 (on average
398 86.4 rpm) than during Phase 1 (on average 120.2 rpm) ($F(1, 5) = 271.16, p < .001$). This striking
399 difference confirmed our hypothesis that the larger vessel diameters present in the forming
400 phase induce a lower rotation velocity than the smaller vessel diameters present in the pre-
401 forming phase, in line with the control of linear velocity. Mass systematically affected the
402 rotation velocity ($F(1, 5) = 73.34, p < .001$) during both phases, with the larger masses being
403 thrown at slightly lower rotation velocities (on average 100.1 and 106.5 rpm for 2.25 and 0.75
404 kg vessels respectively). This difference, although small, could also be explained by the control
405 of the linear velocity: with larger masses inducing larger vessel diameters (in both the pre-
406 forming and forming phases, see Table 3), a reduced rotation velocity is required for the larger

407 masses to maintain the linear velocity within a comfortable range. Another reason explaining
 408 the lower rotation velocity for the larger masses could be that for a given amount of energy
 409 injected by one kick, an object with a greater moment of inertia would gain a smaller increase
 410 in rotation velocity. This would suggest that potters may be limited in the intensity of the kick
 411 they can perform comfortably. Finally, post-hoc analysis of the Shape x Mass x Phase
 412 interaction ($F(3, 15) = 3.36, p < .05$) indicated that Shape affected rotation velocity only during
 413 the second phase, with the 2.25 kg bowl having a smaller rotation velocity than the other 2.25
 414 kg shapes (Fig. 5-B). This was once again coherent with the control of linear velocity which
 415 should be limited by a decrease in the rotation velocity for the largest diameter shapes.

416



417

418 **Fig 5. Average fashioning duration and average rotation velocity as a function of Phase,**
 419 **Mass, and Shape.** Duration in seconds (A); Average rotation velocity in rotations per minute
 420 (B). The error bars represent the between-participants standard error. Phase 1: pre-forming phase;
 421 Phase 2: forming phase.

422

423

424 3.3. Regulation of the rotation velocity: local analysis

425

426 Figure 4 shows the evolution of the rotation velocity during the throwing of a cylindrical
 427 pot. Based on equivalent time series for all pots, Figure 6-A presents the average number of

428 acceleration and deceleration bouts as a function of Phase, Mass, and Shape. Significant main
429 effects on the number of acceleration and deceleration bouts were found for Mass ($F(1, 5) =$
430 $16.31, p < .01$), Phase ($F(1, 5) = 23.45, p < .01$), and Shape ($F(3, 15) = 19.98, p < .01$). These
431 main effects were accompanied by significant interactions between Shape x Phase ($F(1, 5) =$
432 $26.02, p < .001$) and Type x Mass x Phase ($F(1, 5) = 8.99, p < .05$). Post-hoc analysis of the
433 Shape x Phase interaction revealed that Shape did not affect the number of bouts during Phase
434 1. During Phase 2, however, an effect of Shape came to the fore, with a larger number of both
435 acceleration and deceleration bouts for the cylinder than for the sphere and vase (p 's $< .05$).
436 Fashioning a bowl required the smallest number of bouts (p 's $< .05$). These results mirrored
437 those observed for duration (Fig. 5-A) and revealed the same effects: centering and hollowing
438 were performed in less time than thinning and final shaping, fashioning was longer for larger
439 clay masses, and fashioning familiar shapes was faster than fashioning less familiar shapes.

440

441 As can be seen from Figure 6-B, the amplitude of the change in rotation velocity was
442 systematically smaller for the acceleration bouts than for the deceleration bouts (on average
443 22.3 vs. 27.0 rpm, respectively; main effect for Type $F(1, 5) = 63.86, p < .001$), a finding
444 consistent with the observed global decrease in rotation velocity over the course of fashioning.
445 Significant main effects on the amplitude of change in rotation velocity were found for Phase
446 ($F(1, 5) = 103.90, p < .001$), and Shape ($F(3, 15) = 3.57, p < .05$), accompanied by significant
447 interactions between Type x Mass ($F(1, 5) = 8.99, p < .05$), Type x Shape ($F(3, 15) = 16.41, p$
448 $< .001$), Shape x Phase ($F(1, 5) = 6.60, p < .01$) and Mass x Phase ($F(1, 5) = 35.17, p < .01$).
449 Post-hoc analyses of this pattern of results revealed that Shape did not affect the amplitude of
450 change in rotation velocity during Phase 1. During Phase 2, fashioning a bowl was characterized
451 by acceleration and deceleration bouts of larger amplitudes than fashioning the other shapes
452 (p 's $< .05$), showing that the potter allowed himself a larger range of rotation velocity for this
453 bowl shape. Fashioning the larger masses gave rise to acceleration and deceleration bouts of
454 larger amplitude during Phase 1, while such an effect of mass was no longer observed during
455 Phase 2. This indicates that more clay deformation was effected for larger clay masses during
456 centering and hollowing (Phase 1), but not during thinning and final shaping (Phase 2).

457

458 Figure 6-C presents the duration of acceleration and deceleration bouts as a function of
459 Phase, Mass, and Shape. A main effect for Type ($F(1, 5) = 14.86, p < .01$) was accompanied by
460 significant interactions between Type x Phase ($F(1, 5) = 96.47, p < .001$) and Type x Shape x

461 Phase ($F(3, 15) = 2.75, p < .05$). Post-hoc analysis of the overarching Type x Shape x Phase
462 interaction revealed that deceleration bouts increased in duration from Phase 1 to Phase 2, while
463 acceleration bouts decreased from Phase 1 to Phase 2.

464

465 The absolute values of rotation velocity acceleration and deceleration (denoted A/D),
466 occurring during acceleration and deceleration bouts, are presented in Figure 6-D. They directly
467 represent the forces at the origin of the changes in rotation velocity, that is, the pressure forces
468 for the decelerations and the kicking forces for the accelerations. A significant main effect on
469 A/D was found for Phase ($F(1, 5) = 50.29, p < .001$), while significant interactions were found
470 for Type x Mass ($F(1, 5) = 25.36, p < .01$), Type x Phase ($F(1, 5) = 92.59, p < .001$), and Mass
471 x Phase ($F(1, 5) = 43.90, p < .01$). Post-hoc analyses of this pattern of results revealed larger
472 A/Ds during both acceleration and deceleration bouts for the larger masses in Phase 1
473 (comparable to the effect observed for the amplitudes), while similar levels of A/D were
474 observed for the two masses in Phase 2. This reveals that the mass parameter mainly affects the
475 pressure and kicking forces during Phase 1. Although no effect of Shape reached statistical
476 significance, we note that for the bowl the A/D during the deceleration bouts was somewhat
477 higher than that of the three other shapes, indicating the application of larger pressure forces.

478

479 Taken together these results show that the transition between the (pre-forming) Phase 1
480 and the (forming) Phase 2, where potters move from centering and hollowing to thinning and
481 final shaping, is reflected in the variations in wheel rotation velocity. Interestingly, although
482 the amplitude of rotation velocity change decreased over the fashioning process (Fig. 6-B)
483 during both the deceleration and acceleration bouts, these decreases resulted from different
484 origins. In Phase 2, when the rotation velocity is being reduced (Fig. 5-B), the acceleration and
485 duration profiles (Figs. 6-D, 6-C) indicate that, during deceleration bouts, the potter exerted
486 smaller pressure forces than in Phase 1 (Fig. 6-D), but over noticeably longer durations (Fig. 6-
487 C). In contrast, for the acceleration bouts, the duration of the bouts noticeably decreased in
488 Phase 2 (Fig. 6-C) and this was accompanied by a smaller reduction in acceleration than that of
489 deceleration bouts (Fig.6-D). This increased sensitivity with which the potter exerted the
490 pressure forces in Phase 2 is no doubt an adaptation to the increasing fragility of the thinning
491 walls. During the forming phase the slightest sudden gesture could destroy the pot, especially
492 during the final shaping step.

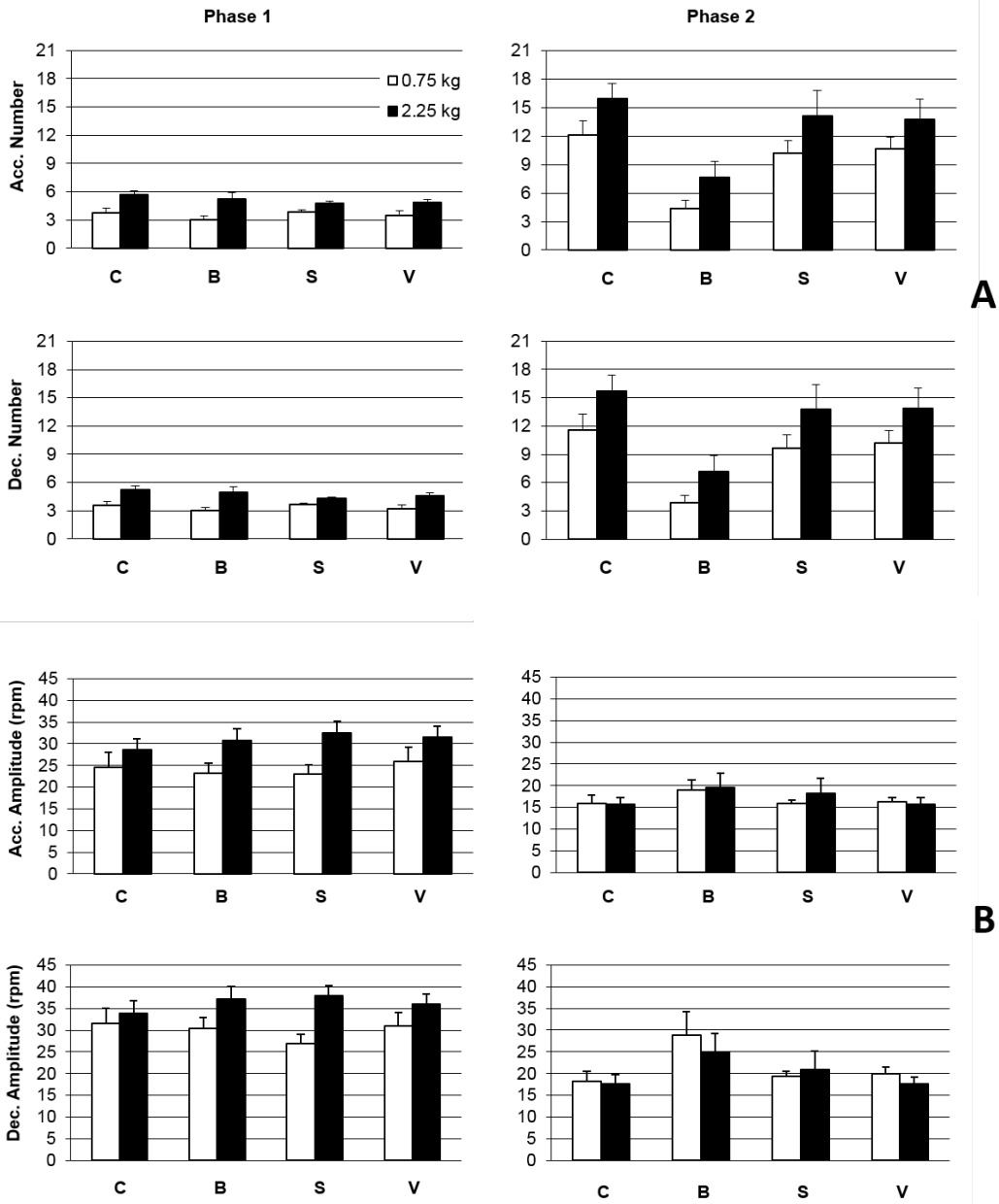
493

494

3.4. Effects of mass and shape on rotation velocity

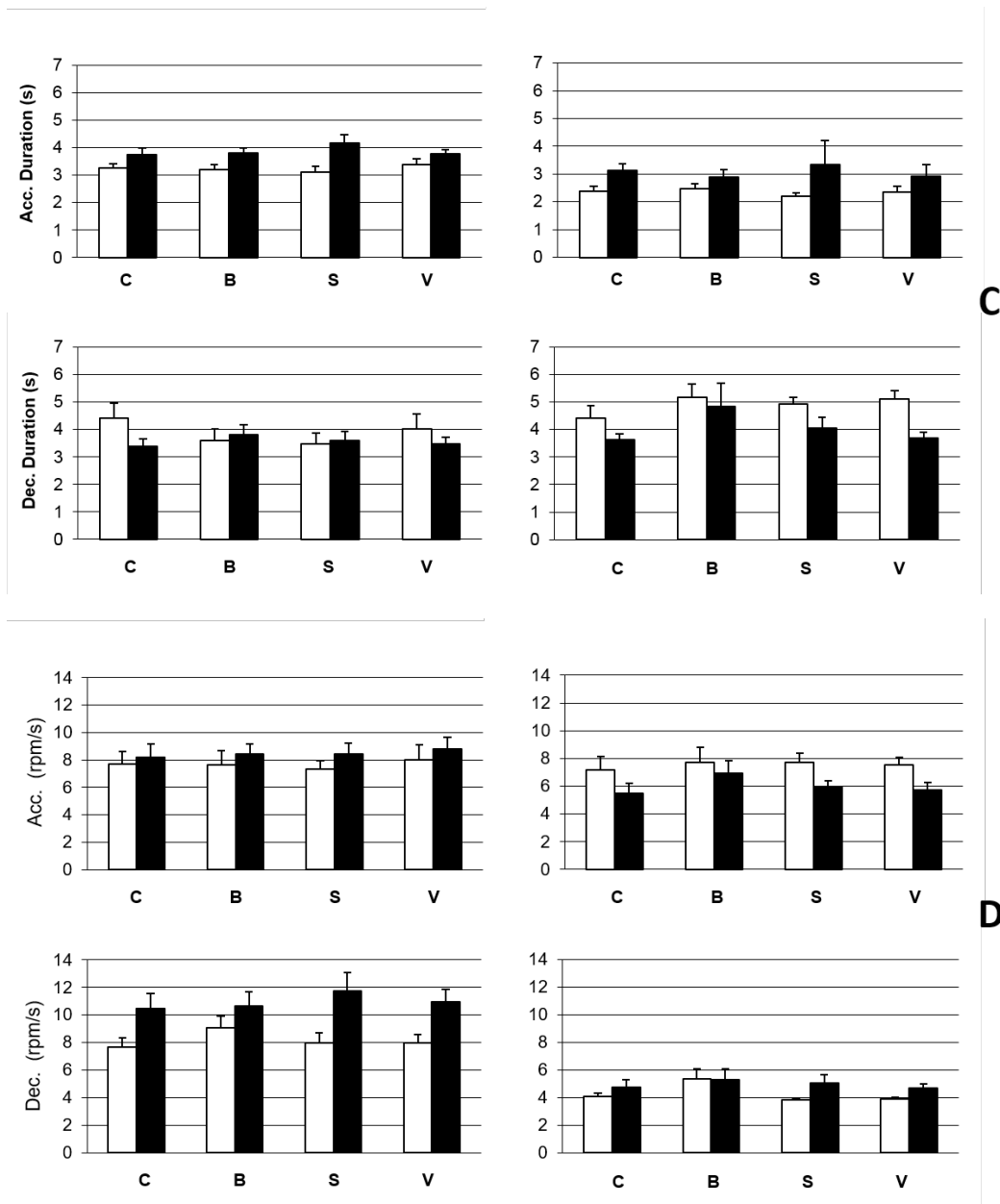
495

496 During the pre-forming phase, fashioning of larger clay masses was achieved with
497 rotation velocity changes of larger amplitude and acceleration compared to fashioning of
498 smaller clay masses (Figs. 6-B and 6-D). This confirms that higher manual pressure forces are
499 required to deform the larger clay masses during the centering and hollowing steps compared
500 to the thinning and final shaping steps where both small and larger clay masses required
501 undifferentiated manual pressure forces. Interestingly, these larger changes in rotation velocity
502 for the larger masses occurred when rotation velocity itself was lower (Fig. 5-B). As stated
503 earlier, larger masses represent a larger moment of inertia of the wheel-throwing system and to
504 set the rotation velocity at the same level for both masses would have required to supply more
505 energy in the kicking for the large masses. Potters did increase the forces applied with each kick
506 for larger masses as observable in the acceleration increase (Fig. 6-D) but still, they did not
507 supply sufficient energy to rotate larger masses at the same rotation velocity as smaller masses,
508 suggesting a limitation in the kick strength. In the forming phase while the mass has no effect
509 on the amplitude of rotation velocity change of the acceleration bouts (Fig. 6-B), we see that
510 larger masses undergo lower acceleration (Fig. 6-D) yet over a longer duration (Fig. 6-C). This
511 increase of sensitivity in the kicking applied during the forming phase for larger vessels
512 suggests that potters avoid sudden variations in linear velocity for the larger vessels: they
513 applied longer kicks with less forces which would help to maintain a more constant linear
514 velocity over the complete circumference of the vessel. Finally, the Shape parameter influenced
515 the pressure and kicking forces during the forming phase: the most familiar shape (the bowl)
516 was fashioned with fewer fashioning gestures than the other shapes (Fig. 6-A) but involved
517 gestures with higher pressure forces (Fig. 6-D), explaining why bowl vessels were produced in
518 less time (Fig. 5-A).



519

520



521

522

523 **Fig 6. Local characteristics of the rotation velocity as a function of Phase, Mass, and Shape**
 524 **in Phase 1 (pre-forming) and Phase 2 (forming) during acceleration and deceleration**
 525 **bouts.** Number of bouts (A), Amplitude of rotation velocity change expressed in rotations per
 526 minute (B), Bout duration in seconds (C), and Acceleration/Deceleration in rotations per minute
 527 (rpm) per second (D), for the acceleration (Acc.) and deceleration (Dec.) bouts. The error bars
 528 represent the between-participants standard error.

529

530

531 **4. Conclusion**

532

533 In line with earlier claims, we believe that the study of technique is essential to the
534 interpretation of ancient artefacts and tools (Lemonnier, 1986; Bleed, 2008; Dietler & Herbich,
535 1998; Hegmon, 1998). Here, we addressed the issue of rotation velocity regulation in wheel-
536 throwing. Long assumed to be a key parameter in the control of the centrifugal force, we
537 interpreted its role rather as a means to control the linear velocity at the point of hand-clay
538 contact.

539

540 We demonstrated that during fashioning potters reduced the rotation velocity from the
541 pre-forming phase to the forming phase, but also for the large clay masses compared to the
542 small clay masses, and during the forming phase for the shapes characterized by the largest
543 diameter. This decrease in rotation velocity thus matched the increase of the mean vessel
544 diameter, thereby corroborating the hypothesis that the potters were applying a limit on the
545 linear velocity with which the clay passes the pressure-exterting hands. The fact that the
546 standardization of the experimental productions was close to 5% revealed a high level of
547 performance. Participants moreover always succeeded in performing the experimental task (not
548 a single vessel collapsed), indicating that they consistently kept the linear velocity below an
549 upper limit beyond which the fashioning process would have become uncontrollable. Overall,
550 these preliminary results provide empirical evidence supporting the role of linear velocity as a
551 key functional parameter in wheel-throwing. Future work using synchronized measurements of
552 both rotation velocity and instantaneous vessel diameter at the point of hand-clay contact would
553 allow precise modeling of the control of the linear velocity in wheel-throwing.

554

555

556 There is no reason to expect that the regulation of the linear velocity would leave any
557 observable trace on the vessel thrown and the purpose of our study was not to help identify the
558 wheel-throwing technique used in fashioning ancient vessels by such traces. Ceramic
559 fashioning techniques – including wheel-throwing – can be identified in other ways, such as
560 analysis of the surface features and microfabrics (Courty & Roux, 1995; Roux & Courty, 1998;

561 Ther & Toms, 2016). Focusing on the potter's experience, the main contribution of our results
562 to archaeology consists in furnishing a fuller understanding of the wheel-throwing practice in
563 which the control of linear velocity surely plays a central role. Our findings also shed some
564 light on the complex relation between the properties of the rotation devices (size, inertia,
565 maximal rotation velocity), the characteristics of the vessels produced (size, shape and weight),
566 and the fashioning techniques used by the potter (wheel-finishing, wheel-shaping, and wheel-
567 throwing).

568

569 Although the regulation of rotation velocity in wheel-throwing has been implicitly
570 acknowledged, our work firstly brings original results concretely demonstrating how potters
571 adapt the rotation velocity to the wheel-throwing constraints. This empirical evidence
572 strengthens the technical distinction between wheel-throwing – where potters put the rotational
573 motion to use throughout the fashioning process – and the other fashioning techniques (wheel-
574 finishing and wheel-shaping) where the rotational motion is used only in certain phases..

575 Secondly, our experiment provides a reference value for the rotation velocity used in fashioning
576 with the (fast-)wheel, a value supposedly not reached with the turntable and the slow-wheel.
577 The striking contrast between the rotation velocities in the pre-forming and forming phases
578 confirms that centering and hollowing require considerably more clay-deforming manual
579 pressure forces than the thinning and final shaping operations. This leads to the conclusion that
580 the rotation device should rotate sufficiently fast enough during the pre-forming phase for
581 wheel-throwing to be possible, with fast enough meaning approximately 120 rpm according to
582 our measurements (average of 123.5 and 116.8 rpm, for the 0.75 and 2.25 kg clay masses). This
583 value of 120 rpm can thus be used as a reference to distinguish the (fast-)wheel from the other
584 devices (turntable and slow-wheel). If an ancient rotation device has a maximal rotation velocity
585 of 100 rpm, it has more likely been used for wheel-finishing or wheel-shaping than for wheel-
586 throwing. Corollarily, if ancient vessels are identified as having been thrown, they have quite
587 certainly been manufactured with a (fast-)wheel allowing a rotation velocity of 120 rpm to be
588 reached. Importantly, archaeologists should bear in mind that the rotation velocity used in
589 wheel-throwing could vary with the clay hardness and mass. Experiments to test the effects of
590 these parameters remain to be done. Nevertheless, in the meanwhile the value of 120 rpm can
591 serve as a useful reference.

592 Thirdly, the fact that the large-diameter vessels were fashioned with a lower rotation velocity
593 than small-diameter vessels corroborates recent observations we made in the Hebron (Palestine)

594 pottery-making community where potters use electrical low-velocity wheels for the larger
595 vessels (above 20-30 cm high) and electrical high-velocity wheels for small and middle-sized
596 vessels. As demonstrated by our study, large vessels require a reduced rotation velocity to limit
597 the linear velocity at hand-clay contact. Moreover, the acceleration bouts results suggested that,
598 during the forming phase, potters avoided sudden variations in linear velocity for the larger
599 vessels by applying longer kicks. Therefore, we postulate that (fast-)wheels with low-velocity
600 and high-inertia may be more appropriate for throwing large vessels. A low velocity will
601 facilitate the limitation of the linear velocity, and a high inertia will allow the deceleration to
602 be reduced, providing regularity in the application of the pressure forces over the complete
603 circumference of the vessel, which is particularly important during the forming phase. We may
604 thus suggest that ancient large thrown vessels were produced with low-velocity and high-inertia
605 (fast-)wheels, a hypothesis to be further corroborated by studies including different variants of
606 potter's wheels. For small-diameter vessels, a reduced rotation velocity is not necessary to limit
607 the linear velocity. As demonstrated by the present results and also observed in the Hebron
608 pottery community, small and middle-sized vessels are thrown with a higher rotation velocity
609 than that used for large vessels. A high rotation velocity can be obtained in an equivalent manner
610 with both high- and low-inertia (fast-)wheels (see legend of Fig. 2), indicating that ancient small
611 and middle-sized thrown vessels could have been produced with both types of human effort-
612 driven wheels.

613 Finally, the assessment of the deceleration bouts revealed that participants finely tuned
614 their manual pressure forces to the precision requirement of the task, with thinner walls (during
615 the forming phase) being fashioned more sensitively than thicker walls (during the pre-forming
616 phase). This adaptation to the operative task constraints is a characteristic of motor skill
617 expertise (Bernstein, 1967; Bril et al., 2010) and explains why experts can not only produce
618 high-quality artifacts, but can also reliably reproduce the same artifact, that is, produce
619 standardized assemblages (Table 2). Novice potters certainly need extensive training before
620 mastering this fine sensitivity of the manual pressure forces exerted during the forming phase.
621 Our results also indicated that shape familiarity influenced the fashioning behavior of the
622 participants who exerted larger forces over longer intervals for the bowl. This suggests that,
623 even when potters are experts, their ability to adjust the pressure forces to the task constraints
624 becomes more assured for the vessel shapes produced more frequently.

625
626

627 We believe that this type of research plays a crucial role in the production of empirical
628 data on the motor skill of craftsmen and provides results that offer insights into archaeological
629 problems. For future research, it would be interesting to compare different types of wheels that
630 afford distinct levels of precision in terms of rotation velocity regulation. In our study, it would
631 have been interesting to experiment with the two types of wheels used in the Indian cultural
632 area, the stick-wheel and the kick-wheel corresponding respectively to high- and low-inertia
633 (Fig. 2). Unfortunately, the high-inertia stick-wheel constantly changes its horizontal
634 orientation (like a spinning top), precluding a reliable recording of the rotation velocity using
635 our experimental protocol. This could be overcome by methodological developments. The high-
636 inertia stick-wheel, contrary to the kick-wheel, retains a fast rotation velocity for a long period
637 of time once it has been activated by the potter. With this kind of wheel, potters therefore cannot
638 easily control the rotation velocity as they do with the low-inertia kick-wheel (Roux & Jeffra,
639 2015). Potters would thus be forced to compensate the lesser degree of velocity regulation by a
640 still finer tuning of their manual pressures, which would increase the difficulty in the fashioning.
641 One might then expect a longer apprenticeship and perhaps a limitation both in the complexity
642 of the shapes produced and in the thinness of the walls achieved. These possibilities represent
643 new avenues of research in the endeavor to understand wheel-throwing fashioning technique.

644

645

646 **6. Acknowledgments**

647

648 We are grateful to the potters who participated in the experiments. We also wish to thank
649 John Endler, James Steele, and the two reviewers for helpful comments.

650

651 The authors have no competing interests to declare.

652

653

654 **7. Funding sources**

655

656 This work was supported by the European Union's Horizon 2020 research and innovation
657 programme [Marie Skłodowska-Curie grant agreement No 793451]. The funding source had
658 no involvement in the research.

659

660

661

662

663 **8. References**

664

665

666 Bernstein, N.A., 1967. The coordination and regulation of movements, Pergamon Press,
667 London.

668

669 Bleed, P., 2008. Skill matters. *Journal of Archaeological Method and Theory*. 15(1), 154–166.

670

671 Bril, B., Rein, R., Nonaka, T., Wenban-Smith, F., Dietrich, G., 2010. The role of expertise in
672 tool use: Skill differences in functional action adaptations to task constraints. *Journal of*
673 *Experimental Psychology: Human Perception and Performance*. 36(4), 825–839.
674 <http://dx.doi.org/10.1037/a0018171>

675

676 Dietler, M., Herbich, I., 1998. Habitus, techniques, style: An integrated approach to the social
677 understanding of material culture and boundaries, in: Stark, M. (Ed.), *The archaeology*
678 *of social boundaries*. Smithsonian Institution Press, Washington, pp. 232–263.

679

680 Foster, G.M., 1959. The potter's wheel: An analysis of idea and artefact in invention.
681 *Southwestern journal of anthropology*. 15, 99–118.

682

683 Gandon, E., Casanova, R., Sainton, P., Coyle, T., Roux, V., Bril, B., Bootsma, R.J., 2011a. A
684 proxy of potters' throwing skill: Ceramic vessels considered in terms of mechanical
685 stress., *Journal of Archaeological Science*. 38, 1080–1089.

686

687 Gandon, E., Pous, F., Coyle, T., Buloup, F., Bootsma, R.J., 2011b. Regulating rotation velocity
688 in wheel throwing: Effects of mass and shape, in: Charles, E.P., Smart, L.J.
689 (Eds.), *Studies in Perception and Action IX*. Psychology Press, New York, pp. 196–201.

690

691 Gandon, E., Coyle, T., Bootsma, R.J., 2014a. When handicraft experts face novelty: Effects of
692 shape and wheel familiarity on individual and community standardization of ceramic
693 vessels. *Journal of Anthropological Archaeology*. 35, 289–296.
694 <https://doi.org/10.1016/j.jaa.2014.06.008>

695 Gandon, E., Roux, V., Coyle, T., 2014b. Copying errors of potters from three cultures:
696 Predictable directions for a so-called random phenomenon. *Journal of Anthropological*
697 *Archaeology*. 33, 99–107. <https://doi.org/10.1080/10407413.2018.1438200>

698

699 Gandon, E., Casanova, R., Bootsma, R.J., 2019. Wheel throwing and centrifugal force, in:
700 Roux, V. (Ed.), *Ceramics and Society: A Technological Approach to Archaeological*
701 *Assemblages*. Springer, pp. 76–83.

702

703 Hegmon, M., 1998. Technology, style, and social practices: Archaeological approaches, in:
704 Stark, M. (Ed.), *The archaeology of social boundaries*. Smithsonian Institution Press,
705 Washington, pp. 264–279.

706

707 Hulthen, B., 1974. On documentation of pottery, *Acta Archaeologica Lundensia* (Lund).

708

709 Jeffra, C., 2011. *The Archaeological Study of Innovation: An Experimental Approach to the*
710 *Pottery Wheel in Bronze Age Crete and Cyprus*, Diss. University of Exeter.

711

712 Kramer, C., 1997. *Pottery in Rajasthan. Ethnoarchaeology of two Indian cities*, Smithsonian
713 Institution Press, Washington.

714

715 Leroi-Gourhan, A., 1943. *L'homme et la matière*, Albin Michel, Paris.

716

- 717 Lemonnier, P., 1986. The study of material culture today : Toward an anthropology of technical
718 systems. *Journal of anthropological archaeology*. 5(2), 147–186.
719
- 720 Méry, S., Dupont-Delaleuf, A., Van der Leeuw, S., 2010. Analyse technologique et
721 expérimentations. Les techniques de façonnage céramique mettant en jeu la rotation à
722 Hili (Émirats arabes unis) à la fin du iiiie millénaire (âge du Bronze ancien). *Les*
723 *nouvelles de l'archéologie*. 119, 52–58. <https://doi.org/10.4000/nda.973>
724
- 725 Orton, C., Tyers, P., Vince, A., 1993. *Pottery in archaeology*, Cambridge University Press,
726 Cambridge.
727
- 728 Pierret, A., 2001. *Analyse technologique des céramiques archéologiques : Développements*
729 *méthodologiques pour l'identification des techniques de façonnage. Un exemple*
730 *d'application: Le matériel du village des Arènes à Levroux (Indre)*, Presses
731 *Universitaires du Septentrion*.
732
- 733 Rice, P.M., 1987. *Pottery analysis : A sourcebook*, University of Chicago press, Chicago.
734
- 735 Roux, V., 2003. Ceramic Standardization and Intensity of Production: Quantifying Degrees of
736 Specialization. *American Antiquity*. 68(4), 768–782. <https://doi.org/10.2307/3557072>
737
- 738 Roux V., 2012. Spreading of innovative technical traits and cumulative technical evolution:
739 Continuity or discontinuity? *Journal of Archaeological Method and Theory*. 20, 312–
740 330. doi:10.1007/s10816-012-9153-4
741
- 742 Roux V., 2019. *Ceramics and Society: A Technological Approach to Archaeological*
743 *Assemblages*. Cham: Springer International Publishing. doi:10.1007/978-3-030-03973-
744 8
745
- 746 Roux, V., Corbetta, D., 1989. *Wheel-throwing technique and craft specialization. The Potter's*
747 *Wheel: Craft specialization and technical competence*, Oxford and IBH Publishing,
748 New Delhi.
749

- 750 Roux, V., Courty, M.A., 1998. Identification of Wheel-fashioning Methods: Technological
751 Analysis of 4th–3th Millennium BC Oriental Ceramics. *Journal of archaeological*
752 *Science*. 25, 747–763.
753
- 754 Roux, V., Jeffra, C., 2015. The Spreading of the Potter’s Wheel in the Ancient Mediterranean:
755 A context Dependent Phenomenon, in: Gauss, W., Klebinder-Gauss, G., von Rüden, C.
756 (Eds), *The Transmission of Technical Knowledge in the Production of Ancient*
757 *Mediterranean Pottery*. Österreichisches Archäologisches Institut, pp. 165-182.
758
759
- 760 Saraswati, B., Behura, N.K., 1966. Pottery Techniques in Peasant India. *Anthropological*
761 *Survey of India*. 13.
762
- 763 Van der Leeuw, S., 1993. Giving the potter a choice: Conceptual aspects of pottery techniques,
764 in: Lemonnier, P. (Ed.), *Technological choices: Transformation in material cultures*
765 *since the neolithic*. Routledge, pp. 238–288.
766