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The gesture substratum of stone tool making: an experimental approach

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Abstract

In this paper, we present an experiment to evaluate the gestures that preceded stone knapping. The goal of the present research was to shed light into the emergence of stone tools. We compared the knapping performed by expert and novice knappers. From this comparison, we hypothesized about the role non-human primate-like technological behaviours, such as nut-cracking, play on the dawn of lithic technology. Our results point to some continuity between these activities and stone knapping. Consequently, they highlight the urgency of researches and experiments especially designed to evaluate the magnitude of this connexion.

Keywords: experimental archaeology, stone knapping, nut-cracking, cognition, human evolution.

Introduction

Stone tools have a pre-eminent place in Prehistory and Human Evolution research. This is due to their perennial nature and to the fascination they awake for being an exclusively human trait. No other animal species make tools. For this reason, the appearance of stone tools – 2.5 myr ago (Semaw *et al.*, 1997) – is seen as a first mental rupture. This is why since Darwin times many scholars have perceived a close relation between stone tools and the development of human cognition.

Despite the intense theoretical disagreement about this relation (see Stout, 2006 for a revision), there are several studies about it. The most remarkable are the study of stone tools (e.g. Wynn, 1989), the experiments and studies with non-human primates (e.g. Schick *et al.*, 1999; Toth *et al.*, 1993), primate archaeology (e.g. Haslam *et al.*, 2009; Joulian, 1996; Mercader *et al.*, 2002) and finally, the study of our own species *Homo sapiens*. Here, three different approaches can be highlighted: neuro-imaging (e.g. Stout *et al.*, 2008; Stout *et al.*, 2000), ethno-archaeology (e.g. Stout, 2002) and experimental psychology (e.g. Bril *et al.*, in press; Nonaka *et al.*, in press; Roux *et al.*, 1995). In ethno-archaeology and experimental psychology, there is a raising interest for the gesture involved in stone knapping. The aim is to find the atom of the action to discern the uniqueness of stone knapping (Roux & Bril, 2005b).

Following these researches, we present an experiment to evaluate the gestural substratum previous to the acquisition of lithic technology. We compared the performance of experts and complete novices while knapping a crude handaxe. Our aim was to gain insight to the previous moments to the appearance of stone knapping and make inferences about its emergence.

Experiment

Participants

18 volunteer participants were grouped in two categories: 9 experts (7 men and 2 women) and 9 novices (7 women and 2 men). Experts were knappers with different degrees of previous theoretical and practical notions of stone knapping. On the other hand, novices were persons with "no prior instruction, either practical or theoretical, in stone knapping or artifact typology" (Stout & Semaw, 2006: 39). Experts mean age was 41 ± 6 years, mean height was 174 ± 8 cm, and mean weight was 79 ± 12 kg. Novices mean age was 32 ± 15 years old, mean height was 169 ± 10 cm high, and mean weight was 64 ± 13 kg. All participants were right-handed, except for one expert, who, despite being left-handed, usually knaps with the right hand.

Materials

Bricks were used as the blank for the crude handaxe. Two reasons justified this choice: bricks have the same mechanical properties (conchoïdal fracture) as stones, and they provide a homogeneous raw material and a standardized core form for all subjects (Roux *et al.*, 1995). The bricks measured 271x131x27 mm and they weighed 1774g (Fig. 1). All the participants used the same hammer: a limestone pebble of 85x73x52 mm and 485g (Fig. 1).

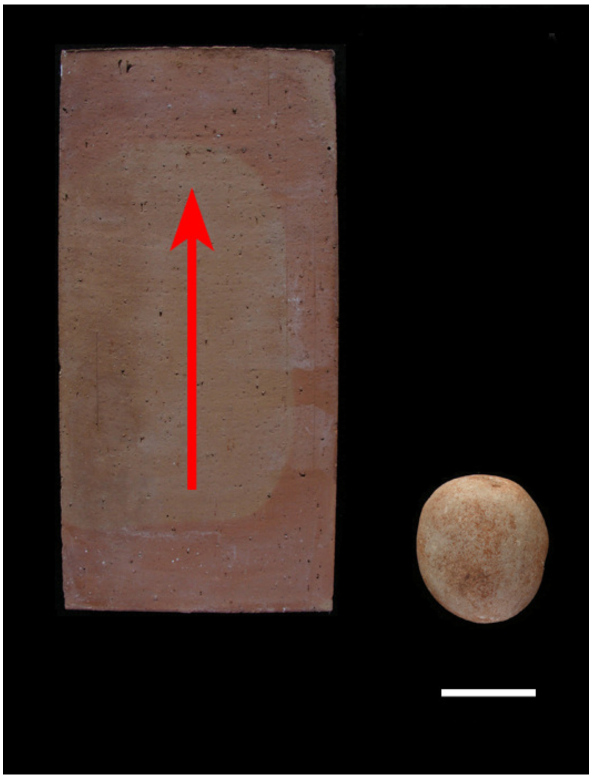

Fig.1. Experimental material: on the left, brick used as blank (271x131x27 mm and 1774 g); on the right, limestone pebble used as hammer (85x73x52 mm and 485 g). Scale represents 5 cm.

Protocol

Participants were asked to produce a crude handaxe. No verbal instructions were given: participants were presented with a handaxe knapped on the same type of brick used in the experiment (Fig. 2). The handaxe production was chosen because its reduction sequence was long and diverse enough to generate a rich knapping behaviour, and also easy enough for the novice knappers to achieve.

No postural restraint was imposed to the participants. They performed the task individually and made all the decisions concerning the knapping process, including when to finish and how to deal with knapping accidents. In case of fracture, the participants decided whether to restart the experiment or to go on knapping one of the fragments. Participants performed as many attempts as they wished to obtain what they judged as a satisfactory result.

The two frontal faces of the brick were marked with a red and black arrow, respectively, to facilitate the posterior analysis of the knapping process (Fig. 2). After the experiment all pieces were collected, including the knapped tool and the waste generated during the process.

The entire knapping process was recorded, using a Sony® HDR-HC1E, HDV 1080i video camera with a sampling rate of 50 frames per second. The camera was located in front of the knapper. Recording began when the knapper was ready to start the production sequence, having studied the model and both the brick and the hammer stone.

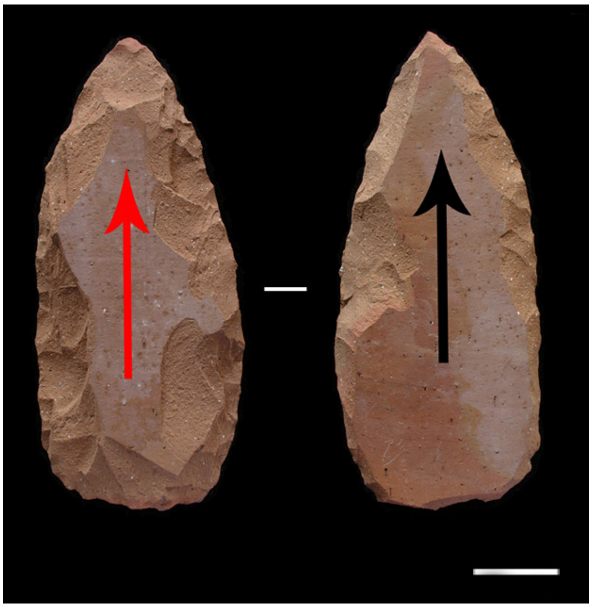

Fig.2. Hand axe model presented to the participants (left: superior view; right: inferior view). The two frontal surfaces of the brick were marked with a red and black arrow, respectively, to facilitate the posterior analysis of the knapping process. This model was knapped by one expert participant (e1). Scale represents 5 cm.

Data analysis

The knapping process was segmented into units, following the rules of the observational methods (see Anguera, 2003; Bakerman *et al.*, 2005; Martin & Bateson, 2007). These methods study behaviour or a part of it known as behavioural stream. This stream must be segmented into identifiable and quantifiable units: behavioural units. They are the smallest behavioural element observed. Before the analysis, a behavioural catalogue must be defined. This is the list of the behavioural units that occur in the behavioural stream we study. The behavioural catalogue used in the present research was constituted by two main behavioural units: percussion and turn. Both of them were characterized by a series of variables (Tab. 1).

All the occurrences of each behavioural unit were registered. A correspondence analysis was performed to assess the weight of each category in explaining the variability between experts and novices. All statistical analyses were performed using the software PAST (Hammer, Ø. *et al.*, 2008).

Results

Novices performed many more behavioural units than experts (see Table 2 for means and standard deviations). Therefore, novices used more behavioural units than experts to achieve the same goal. Novices performed an average of about twice as many percussions as experts, who in turn performed around 3.5 times more turns than novices. So, novices concentrated their efforts on percussion, barely using turns, whereas experts employed a better balance of percussions and turns.

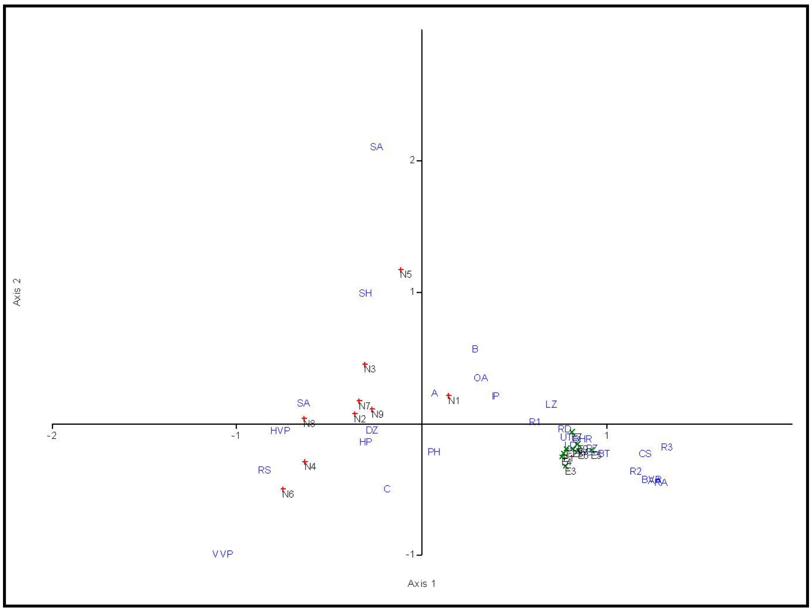

Fig.3. Correspondence analysis. Relation between behavioural units and experimental participants, according to axis 1 and 2, which represent the 68.84% of inertia (45.66% and 23.18% respectively). Behavioural units are labelled in blue (for a description of the abbreviations, see table 1). Experts (E_n) are represented by a green x and novices (N_n), by a red cross.

The correspondence analyses separated novices from experts, as well as the variables used by each group (Fig. 3). Some of the variables were shared by both skill level groups. For example, all the participants struck on the A, B and C surfaces in a more or less balanced way. The use of the obtuse angle was also frequent in both groups. However, the rest of variables opposed novices and experts (Fig. 3).

1) *Zone of percussion*: while novices mainly shaped the distal zone, experts paid attention to all zones.
2) *Percussion support*: novices used the reverberated support and the support on anvil, while experts did not use any support or they used the cushioned support.
3) *Position of the blank*: the inclined position was dominant among both experts and novices, but the latter also used the other three positions.
4) *Angle of percussion*: while novices used the secant angle, experts used acute and right angles.

5) *Struck hemisphere*: all the novices struck on the secondary hemisphere during their performance, while none of the experts did so.
6) *Turn*: finally, all the turn variables were located near experts, meaning that novices hardly used turns during their performance. On the contrary, experts used all possible types of turns.

Discussion

Our results showed clear differences between novices and experts. However, this is not surprising. Nowadays, experimental knapping is a widespread practice, showing that a period of learning is required (e.g. Whittaker, 1994). Ethno-archaeology and experimental psychology have also focused on the learning process involved in stone knapping. Stone knapping is controlled by the laws of conchoidal fracture (e.g. Pelegrin, 2005), so these parameters restrict the range of gesture possibilities. Therefore, some variables must remain unchanged; otherwise, knapping cannot occur.

These variables are identified in the behavioural units used by experts: the angle of percussion, the position of the blank and the percussion support. The angle of percussion is the key variable of knapping. It must be equal to or less than 90º. The position of the blank plays an important role in achieving an adequate percussion angle and some authors consider it a key element for obtaining a successful conchoidal fracture (Biryukova *et al.*, 2005; Pelegrin, 2005). Finally, the percussion support ensures the proper transmission of forces and prevents the blank from fracturing. The results of our experiment showed that novices did not control any of the essential parameters to achieve a conchoidal fracture. Not only did they use angles of more than 90º, but they did not adjust the other variables to seek the correct angle. This inability highlights the learning component in stone knapping.

The technical behaviour of novices revealed some similarities in their actions. The behaviour of novices provided insight into the actions that could be performed without knowing the mechanical laws of rocks. Novices did not understand these laws, and therefore their responses were limited by the constraints of the task (Roux & Bril, 2005a). Novices' common behaviour may help tracing the origin of stone technology. Before its generalization among prehistoric groups, there was probably a period when nobody knew the benefits of the conchoidal fracture (Harlacker, 2006). This period corresponds with the emergence of stone tools. This is a highly debated subject: some researchers support the sudden emergence of stone tools (Semaw, 2000), whereas others support a gradual development (Panger *et al.*, 2002).

The proponents of a gradual development suggest that stone tools emerged from percussion actions linked to the obtaining and processing of food, such as the nut-cracking behaviour of chimpanzees (Boesch, 1993; Mercader *et al.*, 2002; Panger *et al.*, 2002; Sugiyama & Koman, 1979; Wynn & McGrew, 1989). These authors suggest that stone knapping may have emerged when hominids understood that cutting edges could be obtained through the percussion or fracturing of rocks, observing the features of the accidentally broken fragments.

Our results may support nut-cracking as the previous stage of stone knapping. Novices used actions that resemble nut-cracking, such as the reverberated support and the support on anvil. We may hypothesize that the initial task constraints of stone knapping may have been reminiscent to nut-cracking. Systematic comparisons between stone knapping and nut-cracking are needed to evaluate this relation (Bril *et al.*, 2009; Foucart *et al.*, 2005), as well as the necessary cognitive capabilities for the development of stone tools.

knapping has been stated long ago and it is defended by many scholars. Systematic comparisons are only now beginning and, therefore, future researches must emphasize on this topic. In this sense, our work showed the feasibility of using *Homo sapiens* to study the first steps of stone technology.

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Behaviour	Variables		Nomenclature / Definition	Code
PERCUSSION			*Percussion*: the subject strikes the blank with the hammer stone.	P
	ZONE OF PERCUSSION: area of the blank that concentrates the percussion. It is defined regarding the final morphology of the tool: a handaxe.		*Distal*: area of the brick that finally will be the pick tip.	DZ
			Proximal: bottom area. About 1/3 or ¼ of the piece.	PZ
			Lateral: any of the lateral areas of the brick out of the distal and the proximal zones.	LZ
	SUPPORT OF PERCUSSION: support where the blank leans during the knapping process		*Cushioned*: the knapper leans the brick on any part of the body.	CS
			On anvil: the knapper leans the brick on an anvil, like a piece of broken brick.	AS
			Reverberated: the knapper leans the brick on the ground.	RS
			Without support: the knapper performs the task directly holding the brick in his/her hands	WS
	POSITION OF THE BLANK: the way the blank is located to strike it.		*Horizontal*: the blank is in horizontal position.	HP
			Inclined: the blank is inclined, neither in vertical nor in horizontal position.	IP
			Vertical horizontal: the horizontal axis of the blank is in vertical position.	HVP
			Vertical vertical: the vertical axis of the blank is in vertical position.	VVP
	ANGLE OF PERCUSSION: the angle formed during the percussion between the upper face of the brick and the hammerstone.		*Acute*: $\alpha < 90°$	AA
			Obtuse: $\alpha > 90°$	OA
			Right: $\alpha \pm 90°$	RA
			Secant: $\alpha \pm 180°$	SA
	STRUCK SURFACE: surface where the core is struck		*Surface A:* first frontal face struck	A
			Surface B: second frontal face struck	B
			Surface C: any of the four side faces of the brick	C
	STRUCK HEMISPHERE: half of the surface of percussion where the core is struck		*Preferential hemisphere*: If the knapper holds the brick with the left hand and strikes with the right hand, the percussion concentrates in the right hemisphere of the brick. The opposite for left-handed knappers.	PH
			Secondary hemisphere: If a knapper holds the brick with the left hand and strikes with the right hand, but the percussion is done on the left hemisphere. The opposite for left-handed knappers.	SH
TURN			*Turn*: a change of the position of the blank at preparing the percussion.	G
	BIFACIAL (BT): the knapper change the faces to strike during the process	ROTIATIONAL AXIS: axis along which the turn is performed	*Horizontal*: the brick turns around its horizontal axe.	BHR
			Vertical: the brick turns around its vertical axe.	BVR
	UNIFACIAL (UT): the knapper always modifies the same face of the blank.	ROTATIONAL ANGLE: intensity of the turn	1st degree (90º): the knapper turns the brick 90º from his/her perspective.	R1
			2nd degree (180º): the knapper turns the brick 180º from his/her perspective.	R2
			3rd degree (270º): the knapper turns the brick 270º from his/her perspective.	R3
		DIRECTION OF ROTATION: direction towards which the turn is performed	Right: the knapper turns the brick towards his/her right, in a clockwise movement.	RD
			Left: the knapper turns the brick towards his/her left.	LD

Tab.1. Complete behavioural catalogue. List of the different behavioural units used in the observation of the knapping experiment, with their own names, definitions and codes.

VARIABLES	Experts				Novices			
	M	**Min.**	**Max.**	**SD**	**M**	**Min.**	**Max.**	**SD**
BEHAVIOURAL UNITS								
percussion	597,33	232	1445	393,05	1226,11	198	2798	742,17
turn	90,56	35	290	79,11	26,44	5	57	15,13
TOTAL	687,89	267	1735	467,04	1252,56	212	2819	747,30
PERCUSSION VARIABLES								
Zone of percussion								
distal	276,56	60	737	223,67	1074,67	129	2678	724,38
lateral	157,67	41	340	102,45	91,56	0	391	136,93
proximal	163,11	55	368	99,05	59,89	0	231	87,84
Support of percussion								
cushioned	424,89	50	1437	445,55	55,00	0	349	120,36
on anvil	0,00	0	0	0,00	195,22	0	1231	422,04
reverberated	1,11	0	10	3,33	875,78	0	2798	897,38
without support	171,33	0	499	161,76	100,11	0	790	261,30
Position of the blank								
horizontal	42,56	0	181	57,58	144,00	0	404	167,54
inclined	553,11	232	1264	345,64	665,56	56	1286	467,21
vertical horizontal	0,78	0	7	2,33	118,67	0	472	165,64
vertical vertical	0,89	0	8	2,67	297,89	0	2195	719,78
Angle of percussion								
acute	525,44	232	1218	325,93	21,00	0	189	63,00
obtuse	14,89	0	75	24,25	30,11	0	141	54,83
right	57,00	0	205	61,56	1,33	0	12	4,00
secant	0,00	0	0	0,00	1173,67	198	2798	733,06
Struck surface								
A	180,89	45	645	204,25	393,11	120	993	259,52
B	148,89	31	397	135,34	244,44	21	814	248,98
C	267,56	104	622	164,89	588,56	0	2401	773,50
Struck hemisphere								
preferential	595,89	232	1445	394,25	958,11	141	2692	747,26
secondary	1,44	0	13	4,33	268,00	14	644	253,90
TURN VARIABLES								
Type of turn								
unifacial	22,78	4	56	16,55	10,00	0	20	7,04
bifacial	67,78	25	234	65,04	16,44	4	37	10,53
Unifacial rotation angle								
1st degree	13,44	3	42	12,12	9,00	0	19	6,46
2nd degree	9,11	1	18	5,40	1,00	0	5	1,58
3rd degree	0,22	0	2	0,67	0,00	0	0	0,00
Direction of unifacial rotation								
right	11,78	4	25	6,74	5,22	0	15	4,66
left	11,00	0	42	13,20	4,78	0	10	3,31
Bifacial rotational axis								
horizontal	38,89	4	134	38,24	14,67	4	36	10,01
vertical	28,89	6	100	28,61	1,78	0	6	2,17

Tab.2. Means, minimum and maximum values and standard deviations of the different variables.

Conclusion

Our results showed some similarities between chimpanzee nut-cracking and novices' trials at stone knapping. The belief that there is a close link between nut-cracking and stone knapping has been stated long ago and it is defended by many scholars. Systematic comparisons are only now beginning and, therefore, future researches must emphasize on this topic. In this sense, our work showed the feasibility of using *Homo sapiens* to study the first steps of stone technology.

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