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Their lips are sealed: identifying hard stone, soft stone, and antler hammer direct percussion in Palaeolithic prismatic blade production

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ABSTRACT

The present experiment examined the differentiation between hard stone, soft stone, and antler hammer in Upper Palaeolithic direct percussion, prismatic blade production through the experimental knapping by two knappers who were asked to produce a series of medium-sized blades. The use of two knappers in the experiment tested knapper variability in the resultant experimental assemblage. While the majority of the attributes of blades and proximal fragments – including the presence of lipping, platform preparation, bulb presence and prominence, and curvature amongst others – did not vary significantly in regards to which hammer type either knapper used, a number of blade attributes differed, significantly yet weakly, and there was almost no direct correlation between the individual knappers blades and the hammer type they used. This suggests strongly that for a given goal of producing medium-sized blades, this can be accomplished equally well using antler, hard stone, or soft stone hammers, and the resultant blades will be difficult to tell apart. Therefore, based on the results of this series of knapping experiments, we would be hesitant in using the 21 variables tested here to differentiate between blades produced with antler, hard stone, and soft stone hammer types in the archaeological record.

1. Introduction

In discussing the 'big deal about blades' in human evolution, Bar-Yosef and Kuhn (1999) noted that a tenacious, yet erroneous, generalisation had been that the adoption of a blade technology was a hallmark of anatomically modern humans, and often included in a checklist of fully modern behaviour. Blade production, had, however, been in use before the Upper Palaeolithic, as evidenced in numerous European, African, and Eurasian sites, with continuing debate as to the merits of a blade technology (Eren et al., 2008), why it would be ignored by some groups (Pastoors, 2009), or the relative complexity of prismatic versus Levallois blade production (Coolidge and Wynn, 2004). Blade production has been viewed as having been attractive from a raw material conservation point of view, as well as allowing a greater control of size of blank which would have been useful for lithic traditions based on composite tools (see discussion in Bar-Yosef and Kuhn, 1999). For the former at least, experimental work based on North American Paleoindian (Jennings et al., 2010) and European Middle/Palaeolithic (Eren et al., 2008) technology has, however, suggested that blade production is not more efficient than flake production.

Beyond just the production of blades, researchers have gone further and differentiated between blades produced using hard and soft hammers, with Palaeolithic soft hammer blade production identified in Europe (Aubry et al., 2001; Pasty et al., 2002; Sirakov et al., 2007; Bordes and Teyssandier, 2011; Aubry et al., 2012; Wierer, 2013), Asia (Chauhan, 2009; Patnaik et al., 2009; Zwyns et al., 2012), Africa (Soriano et al., 2007; Villa et al., 2010), and the Near East (Meignen, 2002; Berillon et al., 2007; Lengyel, 2007; Kuhn et al., 2009). Researchers argue that differentiating between hard or soft hammer in blade production "often provides some indication of the relative position of a site within the Late Upper Palaeolithic cultural sequence" (Sano et al., 2011, 1472), while others have, in the context of the Middle Palaeolithic, used the evidence for the use of different hammer types to interpret Neanderthal site spatial complexity, and therefore buttress arguments for behavioural complexity (Henry et al., 2004).

The majority of experiments conducted on distinguishing between hard or soft hammer percussion have been on the debitage

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produced during biface manufacture or the production of flakes (e.g. Hayden and Hutchings, 1989; Pelcin, 1997; Redman, 1998; Bradbury and Carr, 1999), with the attributes usually noted as distinguishing the hammer type being lipping, bulb, thickness, weight, length, crushed platform, platform width, curvature, and platform angles. Using a mechanical knapper Pelcin (1997) examined the difference between flakes produced with steel and antler hammers on glass. The results showed that the glass flakes produced with an antler hammer were longer, thinner, but with no difference in width or platform width and all flakes produced had lipped platforms. Redman (1998) analysed the debitage produced by multiple knappers during the production of chert bifaces. Redman (1998, 90–91) argued that the results suggested that categories of hard hammer flake and soft hammer flake "are, in a sense, meaningless" as greater variability was seen between the three different knappers rather than hammer. The only variables immune to idiosyncratic knapper difference were bulb thickness, max thickness and mid-point thickness; while immune to knapper difference they were nevertheless only weak at distinguishing between hammer types.

Experimenting specifically with the effects of hammer types in direct percussion prismatic blade production has been less frequent. Pelegrin (1995, 2000) presented results of experiments, describing, but not quantifying, that soft organic hammer blades are characterised by small, plain, lipped platforms with diffuse bulbs compared to hard stone hammer blades, and soft stone hammer blades are similar to hard stone but more elongated and with less marked bulbs. While Pelegrin (2000) noted that the experiments he outlined were undertaken by a variety of knappers, the experiments did not analyse knapper variability specifically.

The vast majority of subsequent analyses of archaeological assemblages from around the world that have differentiated hard/soft stone/antler direct percussion in Palaeolithic prismatic blade production have cited Pelegrin's (2000) experiments (e.g. Meignen, 2002; Aubry et al., 2001; Pasty et al., 2002; Lengyel, 2007; Sirakov et al., 2007; Soriano et al., 2007; Chauhan, 2009; Bordes and Teyssandier, 2011; Villa et al., 2010; Zwyns et al., 2012; Wierer, 2013). The present experiment sought to examine the differentiation between hard stone, soft stone, and antler hammer in direct percussion, prismatic blade production through the experimental knapping by two knappers who were asked to produce a series of medium-sized blades, defined here as between 30 and 50 mm in length. The use of two knappers in the experiment tested knapper variability in the resultant experimental assemblage.

2. Methods

2.1. Material and experiment organisation

The chert used in the experiment was nodular chert from the Aquitanian Formation, collected from a near primary source in Aragón, Spain, close to the confluence of the Segre and Ebro rivers. The majority of the nodules have a thin to very thin cortex, with the form ranging from flat and lenticular, to more rounded nodules; both complete and split nodules were selected. Nodules of varying sizes and forms were collected and subsequently separated into groups in a manner that each pile contained roughly the same proportion of shapes and sizes. These were then assigned randomly to each knapper. The knappers were then free to choose which nodules to use, and if a given nodule was deemed unsuitable for blade production after beginning, it and all its debitage was collected and removed. During the knapping of each nodule, the majority of debitage was collected periodically and bagged, and after the knapping of each nodule, all the cores and remaining debitage (mainly fragments and <20 mm debitage) were bagged. In order to keep the techniques separate, if a nodule was knapped with more than one technique (i.e. during the antler knapping, using a soft stone for core preparation) all of the resultant debitage was bagged and the differing technique noted. Overall, the chert was of a medium to medium–high quality, with many of the nodules not particularly suitable for sustained blade production (due to a lack of homogeneity, imperfections/inclusions, thermal damage etc.) – for the final analysis, only nodules which produced a good series of blades were subsequently sampled. Granite cobbles collected from a river bed, were used for hard stone hammers, limestone cobbles collected from the sea shore for soft stone hammers, and deer antler for soft organic hammer. The granite and limestone cobbles used were sub-circular to oblong, and ranged from c. 150–400 g in weight with the larger hammerstones generally used in the core preparation and the smaller for blade extraction; the deer antler weighed 220 g.

The two participants used in the experiment are both accomplished knappers with around 10 years of knapping experience each. The knappers both used a similar method of prismatic blade production, using the three techniques of hard stone, soft stone, and organic hammer; however, the technical procedures used (see Inizan et al., 1999 for the differences between method, technique, and technical procedures) were open to the knappers, and varied according to their knapping style: the differing technical procedures included the differing style of core preparation such the abrasion of an overhang, the preparation of an edge prior to removal and so forth.

2.2. Attributes analysed and statistical procedures

The knappers were asked to produce blades of 30–50 mm in length, with 25–55 mm blades subsequently sampled for analysis. After all the knapping was completed, the debitage was divided into 25–55 mm complete blades and flakes, <25 mm and >55 mm complete debitage, proximal fragments, and non-proximal fragments. The 25–55 mm blades and the proximal fragments were then sampled randomly using SPSS 21.0 (IBM SPSS), which was also used for all of the statistical analyses. The sample consisted of 420 artefacts – 105 complete blades for each knapper using three different hammer types, and the same for the proximal fragments. In all, 19 attributes of the complete blades were analysed, with a further three attributes analysed for the proximal fragments (Table 1); when necessary log transformations were used during analysis with these noted in Table 1. The measurements for dimensions are in millimetres, grams for weight, and degrees for curvature, following a standard method for taking dimensions (e.g. Andrefsky, 1998).

Relative bulb thickness is bulb thickness minus mid-point thickness, with occurrences of false bulb thicknesses due to blade morphology not used in the analysis; blade curvature was calculated based on Andrefsky (1998). For bulbs, the definition of

Table 1
Attributes analysed.

Max length	Curvature
Max width	Impact point distance (ordinal)
Max thickness (LOG)	Platform type
Mid-point thickness	Lipping
Weight (LOG)	Bulb
Platform width (LOG)	Bulbar scar
Platform thickness	Impact point
Length/width ratio	Platform crushing
Length/thickness ratio (LOG)	Fragment type
Width/thickness ratio (LOG)	Break type
Relative bulb thickness (scale and ordinal)	Platform collapse

Table 2
UNIANOVA post hoc Bonferroni test for variables with statistically significant different means.

			p
Max length	Antler	Soft stone*	0.000
		Hard stone*	0.002
	Soft stone	Hard stone*	0.046
Max width	Antler	Soft stone*	0.000
		Hard stone	0.220
	Soft stone	Hard stone	0.053
Length/thickness ratio	Antler	Soft stone*	0.001
		Hard stone*	0.001
	Soft stone	Hard stone	1.000
Width/thickness ratio	Antler	Soft stone*	0.002
		Hard stone*	0.011
	Soft stone	Hard stone	1.000
Weight	Antler	Soft stone*	0.009
		Hard stone	0.293
	Soft stone	Hard stone	0.548
Curvature	Antler	Soft stone	1.000
		Hard stone*	0.013
	Soft stone	Hard stone	0.114

* Denotes significant difference.

diffuse or prominent are often descriptive only – in this analysis the bulbs were based on measurements and subsequently binned into ordinal scales: diffuse (<1.5 mm) and prominent (≥1.5 mm). Due to the difficulties in accurately measuring platform angle (see Andrefsky, 1998), this was not recorded. Impact point distance is the distance from the ventral edge, with the distance analysed in groups of <1 mm and ≥1 mm. The category of platform crushing defines cases where the impact point is greater than just a mark, but the crushing is not so extreme that the platform has collapsed – cases of platform collapse were categorised as blade fragments and therefore excluded from the analysis of complete blades.

For the statistical analysis, a 95% confidence level was used throughout. The principal statistics used for scale data were ANOVA (Analysis of Variance) and UNIANOVA using GLM (General Linear Model) which provide analysis of variance. As with ANOVA, UNIANOVA is an analysis of variance, with the procedure providing an analysis of variance for one dependent variable by one or more variables, in this case the variables of hammers and knappers. Using this GLM procedure, null hypotheses are tested about the effects of other variables on the means of various groupings of a single dependent variable, and interactions between factors as well as the effects of individual factors can also be investigated (IBM SPSS). For UNIANOVA, one category from each variable is used as the reference category for that variable with which to compare to the other categories. In analysis of variance, Bonferroni post hoc tests were used to assess which group means differed significantly from which others. For categorical data, Multinomial Logistic Regression and GZLM (Generalised Linear Model) were used for multi-categorical data and binary-categorical data respectively. The GZLM was used for similar predictions tested using logistic regression, but in cases where the categories are binary responses, such as absence/presence of an attribute.

3. Results and discussion

3.1. Complete blade dimensions, weight, and curvature

The GLM UNIANOVA procedure tested whether the differences between the means were significant, first examining the effect of the three hammer types, then of the two knappers, and then the interaction between hammer types and knappers. Appendix A provides the mean, median, and standard deviation for the 12 scale variables, with Appendix B presenting the GLM UNIANOVA results, and Table 2 the Bonferroni post hoc results for variables with statistically significant difference of means.

The first step of the test ignores the effect of the different knappers, and examines the blades based on the effect of the three hammer types. The antler hammer produced significantly longer blades (Appendix A), and the soft stone hammer produced the shortest blades, with the difference between the hard and soft stone hammers also significant (Fig. 1). The antler produced the widest blades, and were significantly wider than the soft stone but not the hard stone, and no significant difference between the hard and soft stone. For both length/thickness ratio and width/thickness ratios the antler hammer produced the relatively thinner blades with a significant difference compared to both stone hammers, but no significant difference between the stone hammers. For weight, the antler hammer produced the heaviest blades and significantly heavier than the soft stone, but not the hard stone, and with no

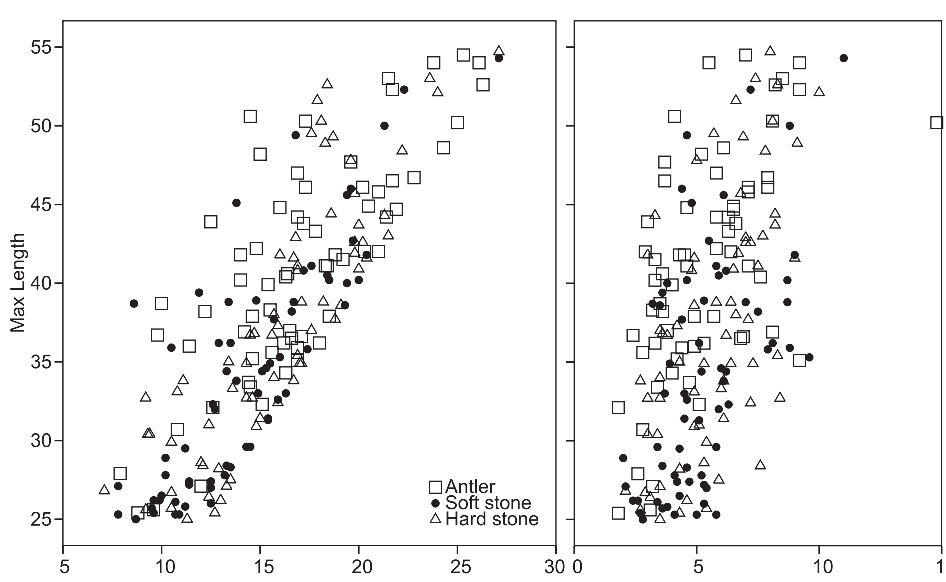

Fig. 1. Scatterplot. Length by width and thickness (mm).

significant difference between the stone types. For curvature, the antler hammer produced the more curved blades and the hard stone the least curved, with the differences between antler and hard stone significant, but no significant differences between antler and soft stone, nor between the stone types. For the remaining six variables (length/width ratio, relative bulb thickness, platform width and thickness, max. and mid-point thickness) the differences were not statistically significant. Overall, while significant differences were reported for six of the 12 scale variables, the $\eta\rho^2$ values (Appendix B) suggest that the effect of hammer type on the means is significant yet weak for all except blade length.

In summary, the blades produced with the antler hammer were significantly heavier, larger, wider, more curved and with a significantly greater length/thickness and width/thickness ratio – but these significant differences were not equally shared with both stone hammer types. And while the antler hammer blades' means were significantly different, the effect of hammer type was weak except for blade length. Between the blades produced with hard and soft stone hammers, while the soft stone hammer produced smaller, narrower, thinner, and more curved blades, the only statistically significant difference was length.

The second step of the test ignores the different hammer types, and examines the blades based on the effects of the different knappers. Of the 12 variables tested, only blade width was significantly different between the two knappers, with Knapper A producing narrower blades, but the $\eta\rho^2$ result suggesting that the effect is significant yet weak (Appendix B). Therefore, while Knapper B produced a series of blades that were on average (based on median) longer, wider, heavier, relatively thinner, slightly more curved, with smaller bulbs and narrower platforms, the two knappers' collections of blades are not significantly different from each other apart from a weak significant difference in width.

The third step of the test examines the assemblage based on the interaction of the hammer types and knappers on the blades' means. Here, the different knappers and hammer types produced significant differences in terms of blade length, width, thickness, mid-point thickness, platform width and thickness, length/thickness ratio, and weight, and not for the remaining four variables. Based on the $\eta\rho^2$ results, however, the significant differences for these eight variables are all weak (Appendix B), and UNIANOVA was used again to test the different knappers' effects separately for these eight.

Table 3 presents the UNIANOVA Bonferroni post hoc tests for the two knappers separately, highlighting that the significant differences between the same variables are disparate – for Knapper A length was significantly different between antler and soft stone, and hard stone and soft stone, but not between antler and hard stone; for Knapper B length was significantly different between antler and hard and soft stone, but not between soft and hard stone. For Knapper A width was only significantly different between the stone hammers, while for Knapper B's blade, there was no significant difference between stone hammers but there was between antler and both stone hammers. For Knapper B's blade thickness, there was no significant difference between hammer types, and for Knapper A there was only a significant difference between antler and hard stone. Platform width was the only variable where both knappers matched: both showed a significant difference between antler and hard stone, but not between antler and soft stone nor between stone types. For length/thickness ratio, Knapper B's hammer types blades were not significantly different, while Knapper A's were between antler and both stone types but not between stone types. Finally, for weight, Knapper A's blades showed no significant difference for hammer type, while Knapper B's antler were significantly different than both stone types, but no difference between stone types.

Table 3
UNIANOVA post hoc Bonferroni tests for each knapper for variables identified with statistically significant different means.

Variable	Knapper A		*p*	Knapper B		*p*
Max length	Antler	Soft stone*	0.000	Antler	Soft stone*	0.000
		Hard stone	1.000		Hard stone*	0.000
	Soft stone	Hard stone*	0.000	Soft stone	Hard stone	1.000
Max width	Antler	Soft stone	0.065	Antler	Soft stone*	0.002
		Hard stone	0.644		Hard stone*	0.002
	Soft stone	Hard stone*	0.002	Soft stone	Hard stone	1.000
Max thickness (LOG)	Antler	Soft stone	0.392	Antler	Soft stone	0.354
		Hard stone*	0.020		Hard stone	0.789
	Soft stone	Hard stone	0.648	Soft stone	Hard stone	1.000
Midpoint thickness	Antler	Soft stone	0.705	Antler	Soft stone	0.050
		Hard stone	0.098		Hard stone	0.573
	Soft stone	Hard stone	0.999	Soft stone	Hard stone	0.802
Platform width (LOG)	Antler	Soft stone	0.183	Antler	Soft stone	0.251
		Hard stone*	0.017		Hard stone*	0.024
	Soft stone	Hard stone	1.000	Soft stone	Hard stone	1.000
Platform thickness	Antler	Soft stone	0.063	Antler	Soft stone	0.145
		Hard stone	0.115		Hard stone	0.208
	Soft stone	Hard stone	1.000	Soft stone	Hard stone	1.000
Length/thickness ratio (LOG)	Antler	Soft stone*	0.000	Antler	Soft stone	1.000
		Hard stone*	0.002		Hard stone	0.377
	Soft stone	Hard stone	0.485	Soft stone	Hard stone	1.000
Weight (LOG)	Antler	Soft stone	1.000	Antler	Soft stone*	0.002
		Hard stone	0.360		Hard stone*	0.002
	Soft stone	Hard stone	0.052	Soft stone	Hard stone	1.000

* Denotes significant difference.

Therefore, for blade dimensions, weight, and curvature, the two knappers produced quite disparate sets of blades, confounding a clear cut division of blade attributes based on differences of hard stone, soft stone, antler hammers. On the one hand, when the dimensions, curvature, and weight of the blades are analysed based on a division between the two knappers only – ignoring the fact that each knapper used three different hammer types – their resultant blade assemblages are not statistically different, apart from blade width, suggesting that the knappers are producing relatively homogeneous sets of blades. On the other hand, when the different knappers's blades are analysed separately, there is a disparity in the results as evidenced in the separate UNIANOVA testing for each knapper's blades (Table 3). While blade length was noted above as having the strongest significant difference between hammer types, the post hoc tests of the separate UNIANOVAs show that the differences vary by knapper with the only commonality being the difference between antler and soft stone, and the only variable that the knappers match on was platform width, but this variable was shown above not to be significantly different when tested by knapper or hammer alone. Therefore, for dimensions, weight, and curvature, no clear significant differences were noted except that blades produced with antler hammers are significantly longer than those produced with a soft stone hammer.

3.2. Complete blade platform attributes

The first variables to be analysed all involved the presence or absence of a variable and were tested using the GZLM binary logistic procedure. As with the GLM procedure, GZLM first tests for the effects of hammer type only, then knapper only, and finally the interaction of the hammer types and knappers. Table 4 and Fig. 2 present the count and percent for the presence of lipping, bulb, bulbar scar, impact point, platform crushing, and platform preparation, while Table 5 presents the GZLM results. The blades produced with antler hammer more frequently had lipping, and less bulbs, bulbar scars, impact points, platform crushing, and less platform preparation compared to both stone types. And compared to the hard stone, the soft stone produced blades had more lipping,

Table 4
Complete blades. Percent and count for presence of lipping, bulb, impact point, and crushed platform.

Variable	Antler	Soft stone	Hard stone	Total	Antler	Soft stone	Hard stone	Total	Knapper A	Knapper B	Knapper A	Knapper B
Presence of	%	%	%	%	Count	Count	Count	Count	%	%	Count	Count
Lipping	28.6	24.3	14.3	22.4	20	17	10	47	28.6	16.2	30	17
Bulb	65.7	77.1	75.7	72.9	46	54	53	153	71.4	74.3	75	78
Bulbar scar	52.9	52.9	60.0	55.2	37	37	42	116	48.6	61.9	51	65
Impact point	67.1	74.3	82.9	74.8	47	52	58	157	80.0	69.5	84	73
Platform crushing	28.6	38.6	34.3	33.8	20	27	24	71	48.6	19.0	51	20
Platform preparation	47.1	54.3	60.0	53.8	33	38	42	113	74.3	33.3	78	35

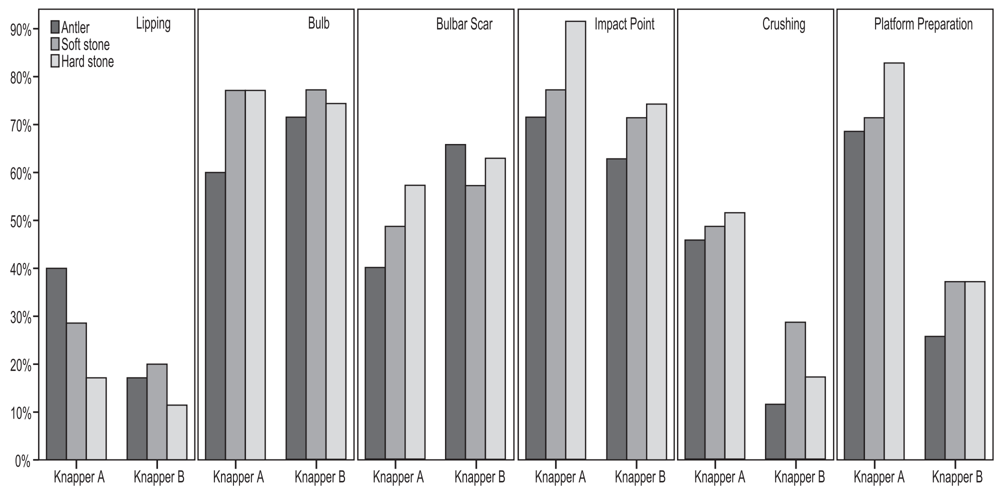

Fig. 2. Frequencies of lipping, bulb, bulbar scar, impact point, platform crushing, and platform preparation. Bars equal percentage of presence for hammer type and knapper.

Table 5
GZLM. Dependent Variables: Lipping; Bulb; Bulbar Scar; Impact Point; Platform Crushing, Platform Preparation. Model: (Intercept), Impactor, Knapper, Impactor * Knapper. Reference categories: Knapper A and Antler.

	Lipping			Bulb			Bulbar scar			Impact point			Platform crushing			Platform preparation		
	χ^2	df	p	χ^2	df	p	χ^2	df	p	χ^2	df	p	χ^2	df	p	χ^2	df	p
Impactor	3.573	2	0.168	2.585	2	0.275	0.927	2	0.629	5.078	2	0.079	2.390	2	0.303	2.928	2	0.231
Knapper	3.976	1	0.046	0.141	1	0.707	3.754	1	0.053	3.696	1	0.055	19.721	1	0.000	33.407	1	0.000
Impactor * Knapper	0.954	2	0.620	0.871	2	0.647	1.629	2	0.443	1.416	2	0.493	1.888	2	0.389	0.767	2	0.682

bulbs, and crushing, but less bulbar scars, impact points and platform preparation. Nevertheless, the differences in frequencies for these six variables between hammer types were not significant. The impact point distance from ventral edge was divided into less than 1 mm and ≥1 mm. As the soft stone hammer only produced one impact distance of ≥1 mm, that hammer type was excluded from GZLM testing, which used the ordinal logistic procedure. While the antler blades more frequently had the impact point on or close to the edge (i.e. <1 mm) (Table 6), there were no significant differences for frequencies for hammer type ($p = 0.608$).

One of the difficulties with the category of bulb is at what point can one objectively state that the bulb is diffuse or prominent.

Table 6
Impact point distance (mm).

	Antler	Soft stone	Hard stone	Total
<1	43	51	53	147
	91.5%	98.1%	88.3%	92.5%
≥1	4	1	7	12
	8.5%	1.9%	11.7%	7.5%
Total	47	52	60	159

Earlier in the analysis this was avoided by using the scale variable of relative bulb thickness. In order to compare the same data but in the categories of diffuse and prominent, the data was converted into ordinal data, with the relative bulb thickness used (based on a cut point of one standard deviation) to define the bulb as diffuse or prominent, with diffuse bulbs being those with a relative bulb thickness of ≤1.37 and prominent as those above this. Based on this, while the antler hammer produced the prominent bulbs most frequently (17%) and soft stone the least frequently (14%), there was no significant differences in frequencies of bulb type between the hammer types ($p = 0.920$). A further distinction was made during the analysis where, using median percent and standard deviation, bulbs of ≤0 were considered diffuse, and >1.37 prominent and the middle dimensions excluded as being neither diffuse nor prominent – again, no significant difference was noted.

In testing the effect of the different knappers on the frequencies, Knapper A's produced blades with greater frequencies of lipping, impact points, platform crushing, and platform preparation, but less bulbs and bulbar scars, with the differences in frequencies statistically significant for the presence of lipping, platform crushing, and platform preparation (Table 5). Over twice as many of Knapper A's blades had platform crushing, and nearly twice as

Table 7
Break type and platform collapse. 'a' = no break; first entry is longitudinal break, second is transversal; diagonal breaks treated as longitudinal.

Break	Antler	Soft stone	Hard stone	Total	Antler	Soft stone	Hard stone	Total	Knapper A	Knapper B	Knapper A	Knapper B
	%	%	%	%	Count	Count	Count	Count	%	%	Count	Count
a-Uneven	4.3	7.1	5.7	5.7	3	5	4	12	8.6	2.9	9	3
a-Languette	27.1	21.4	14.3	21.0	19	15	10	44	14.3	27.6	15	29
Uneven-a	27.1	34.3	41.4	34.3	19	24	29	72	42.9	25.7	45	27
Languette-a	20.0	12.9	12.9	15.2	14	9	9	32	11.4	19.0	12	20
Languette-Languette	0.0	0.0	1.4	0.5	0	0	1	1	0.0	1.0	0	1
Uneven-Uneven	2.9	0.0	1.4	1.4	2	0	1	3	1.9	1.0	2	1
Uneven-Languette	5.7	5.7	1.4	4.3	4	4	1	9	4.8	3.8	5	4
Siret-a	11.4	15.7	17.1	14.8	8	11	12	31	14.3	15.2	15	16
Siret-Languette	1.4	2.9	1.4	1.9	1	2	1	4	1.0	1.0	1	1
Siret-Uneven	0.0	0.0	2.9	1.0	0	0	2	2	1.0	1.0	1	1
Platform collapse	34.3	31.4	18.6	28.1	24	22	13	59	33.3	22.9	35	24

many were lipped platform; the most dramatic difference recorded, however, was the presence of platform preparation, with 75% of Knapper A's blades showing evidence of being prepared against just 33% of Knapper B's (Fig. 2). There were no significant differences in frequencies of diffuse or prominent bulbs between knappers ($p = 0.946$), and no significant difference for impact point distance ($p = 0.979$). For the interaction between hammer type and knapper, there were no significant differences noted for the eight variables tested (Table 5; bulb type: $p = 0.946$; impact point distance: $p = 0.812$).

While for dimensions, weight, and curvature the results are not so clear cut, they are for platform preparation and the presence of lipping. The category of platform preparation included blades that showed evidence for abrading/scrubbing of the platform as well as the removal of overhang and the setting up of the platform for correct angle etc. The difference between the two knappers for this category is the most dramatic, with Knapper A's blades showing evidence in 75% of the cases, while Knapper B's blades showed evidence for preparation in just a third of the cases. This suggests a quite idiosyncratic difference in how the two knappers approached the same material and the same goal of producing the medium-sized blades. Moreover, as noted, the outcomes of the two different knappers were not significantly different – while Knapper B's blades, which showed less evidence for platform preparation, were on average longer, wider, heavier, relatively thinner, slightly more curved, with smaller bulbs and narrower platforms, the differences with Knapper A's blades were not significantly different apart from a weak statistical difference in blade width. Therefore, platform preparation, alongside the presence of lipping, appears in this series of experiments to be related more directly to the different knapping styles of the knappers rather than the choice of hammer type. And while the approach of the two knappers to the blade production in terms of their use of technical procedures differed slightly, the resultant blades did not differ significantly in terms of their metrical characteristics.

3.3. *Proximal fragment attributes*

The proximal fragments were tested for the proportion of collapsed platforms and the type of breaks. The breaks were recorded along the longitudinal and transverse axis, with diagonal breaks treated as longitudinal. The breaks were divided into uneven, languette, and siret for each axis. Table 7 presents the breaks by hammer type for the combined axes, showing that the antler hammer produced less siret breaks and more longitudinal languette breaks, and transverse only breaks. While for the knappers, both produced roughly the same proportion of siret breaks, with Knapper B producing less transverse only breaks and less languette breaks. For the statistical analysis, the breaks were first analysed by combining the two axes into break types (i.e. uneven, languette, siret, and combined types); using the Multinominal Regression procedure there was no significant difference for hammer type, knapper, or their interaction ($\chi^2 = 23.691$, df = 15, $p = 0.071$). Secondly, the breaks were grouped into transverse, longitudinal or combined, with again no significant difference ($\chi^2 = 6.784$, df = 10, $p = 0.746$). Thirdly, the breaks were grouped into siret and non-siret with again no significant difference identified ($\chi^2 = 2.882$, df = 5, $p = 0.718$). The final analysis examined the occurrence of platform collapse, with Table 7 showing that hard stone hammer resulted in less platform collapse than antler or soft stone, and Knapper A had platform collapse more frequently. However, there was no significant difference identified for hammer type, knapper, or their interaction ($\chi^2 = 8.590$, df = 5, $p = 0.127$).

4. Conclusion

This knapping experiment tested the effects of hammer types and knapper variability in Palaeolithic prismatic blade production, with two knappers producing a series of medium-sized blades, defined here as between 30 and 50 mm. The results have demonstrated that when examining the resultant blade assemblage based on knapper variability, the knappers' blades did not differ significantly in terms of dimensions, weight, or curvature except for blade width, and with no significant differences in the proximal fragments, but a clear distinction between the knappers was noted in occurrence of lipping and platform preparation and crushing. This suggests that these three attributes are idiosyncratic to the individual knappers. But this also implies that these three attributes do not change significantly the metrical characteristics of the blades produced. When examining the blades of the two knappers together to test for differences between the hammer types, out of the 21 variables tested, the only strong significant difference was length – for the 210 blades analysed, the mean length was 37.7 mm, with the mean of antler being 41.5 mm, and 37.3 mm for hard stone, and 34.4 mm for soft stone. This suggests strongly that for a given goal of producing medium-sized blades, this can be accomplished equally well using antler, hard stone, or soft stone hammers, and the resultant blades will be difficult to tell apart.

An added level of complication, however, arises when the blades are analysed based on the interaction between the different hammer types and knappers. In this case, while the majority of the attributes of blades and proximal fragments – including the presence of lipping, platform preparation, bulb presence and prominence, and curvature amongst others – did not vary significantly in regards to which hammer type either knapper used, a number of blade attributes differed, significantly yet weakly, and there was almost no direct correlation between the individual knappers' blades and the hammer type they used. Therefore, based on the results of this series of knapping experiments, we would be hesitant in using the 21 variables tested here to differentiate between blades produced with antler, hard stone, and soft stone hammer types in the archaeological record. These results are in line with previous experiments on chert with multiple knappers, such as Redman's (1998) on the analysis of flakes produced during biface production where Redman argued that the categories of 'hard hammer flake' and 'soft hammer flake' "are, in a sense, meaningless", and greater variability was seen between the three different knappers rather than the impactors. Similarly, on other materials such as quartz, experiments have shown that it is also difficult to differentiate between hard and soft hammer impactors in flake production (Driscoll, 2011).

While we would be hesitant to use 21 variables tested here to differentiate impactor types in blade production, we would not, of course, suggest that this experiment is the last word on the matter. Rather, the results presented should be seen as preliminary findings with which further experiments can designed and undertaken to confirm or refute the results. A limitation of the present experiment is that only two knappers were used, and future experiments could expand on this by adding more knappers, as well as possibly using knappers with varying knapping skills; a second limitation was that just one source of medium to medium–high quality chert was used, and future experiments could usefully test whether different qualities of chert, as well as different sources of chert, alter the attributes produced when using the variety of impactor types in the production of both blades and flakes, as well as the waste flakes produced during biface production. In conclusion, therefore, we would suggest that caution should used when attempting to identify which hammer type was used in prismatic blade production during prehistory. We would also suggest that a large scale experimental project, which utilises multiple knappers of varying skill and multiple sources of chert and other materials such as obsidian, should be devised to further our understandings of prehistoric prismatic blade production and other production methods, and to demonstrate how we may be able to differentiate prehistoric techniques such as hard or soft hammer production in the archaeological record.

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Appendix A. Complete blades. Mean, median, and standard deviation for 11 scale variables.

Impactor			Max length	Max width	Max thickness	Mid-point thickness	Platform width	Platform thickness	Relative bulb thickness	Length/Width ratio	Length/Thickness ratio	Width/Thickness ratio	Weight	Curvature
Antler	Knapper A ($n = 35$)	Mean	39.19	15.47	4.69	3.96	7.79	2.79	−0.14	2.61	9.14	3.59	2.78	175.18
		Median	39.90	15.60	4.20	3.50	7.50	2.60	0.00	2.48	8.38	3.26	2.45	174.74
		Std. deviation	6.24	3.48	1.66	1.40	3.55	1.44	1.40	0.48	2.77	1.20	1.77	2.30
	Knapper B ($n = 35$)	Mean	43.85	18.75	6.15	4.85	11.01	3.91	0.02	2.41	8.18	3.40	5.10	174.97
		Median	44.80	18.40	6.10	5.10	9.40	3.20	0.00	2.23	7.73	3.21	4.17	174.64
		Std. deviation	7.14	4.26	2.55	1.96	5.27	2.59	1.44	0.44	3.07	1.14	3.41	2.12
	Total ($n = 70$)	Mean	41.52	17.11	5.42	4.40	9.40	3.35	−0.04	2.51	8.66	3.50	3.94	175.08
		Median	41.80	16.90	5.15	4.40	8.55	2.90	0.00	2.38	7.99	3.23	3.19	174.69
		Std. deviation	7.06	4.20	2.26	1.75	4.75	2.16	1.41	0.47	2.94	1.17	2.94	2.20
Soft stone	Knapper A ($n = 35$)	Mean	32.30	13.44	5.77	4.41	8.99	3.73	0.23	2.47	6.50	2.68	2.52	175.61
		Median	31.40	13.20	5.20	4.10	8.60	3.80	0.10	2.35	6.33	2.64	1.52	175.63
		Std. deviation	6.03	3.26	3.11	1.75	3.04	1.80	1.10	0.48	2.18	0.75	1.99	2.65
	Knapper B ($n = 35$)	Mean	36.39	15.33	5.15	3.88	9.00	2.93	0.09	2.43	7.61	3.15	2.86	175.20
		Median	35.80	15.50	4.80	3.60	8.00	3.00	0.00	2.34	7.09	3.04	2.34	174.84
		Std. deviation	8.13	4.11	1.69	1.40	4.29	1.69	1.21	0.41	2.45	0.94	2.53	2.74
	Total ($n = 70$)	Mean	34.35	14.39	5.46	4.14	9.00	3.33	0.16	2.45	7.05	2.92	2.69	175.40
		Median	33.40	13.80	5.05	4.00	8.30	3.25	0.00	2.34	6.78	2.78	2.08	175.13
		Std. deviation	7.40	3.80	2.50	1.60	3.69	1.78	1.15	0.44	2.37	0.87	2.26	2.68
Hard stone	Knapper A ($n = 35$)	Mean	39.33	16.56	6.03	4.77	9.84	3.63	0.45	2.44	7.07	2.88	3.71	176.64
		Median	38.00	16.90	6.20	4.80	9.60	3.20	0.60	2.38	6.29	2.81	3.86	176.28
		Std. deviation	7.66	4.14	1.94	1.51	3.23	1.76	1.25	0.43	2.14	0.63	2.13	2.11
	Knapper B ($n = 35$)	Mean	35.34	15.32	5.42	4.32	8.04	3.01	−0.52	2.34	7.15	3.08	2.79	175.87
		Median	34.80	15.70	5.40	4.10	7.30	2.90	−0.45	2.25	6.72	2.83	2.24	176.37
		Std. deviation	7.93	3.74	1.86	1.58	3.35	1.70	1.84	0.33	2.49	1.08	1.95	2.46
	Total ($n = 70$)	Mean	37.34	15.94	5.72	4.55	8.94	3.32	−0.01	2.39	7.11	2.98	3.25	176.25
		Median	36.70	16.05	5.85	4.50	8.85	2.95	0.15	2.30	6.30	2.82	2.88	176.33
		Std. deviation	8.00	3.97	1.91	1.55	3.39	1.75	1.62	0.38	2.30	0.88	2.08	2.31
Total	Knapper A ($n = 105$)	Mean	36.94	15.16	5.50	4.381	8.88	3.38	0.23	2.51	7.57	3.05	3.00	175.81
		Median	36.20	14.90	5.30	4.20	8.70	3.10	0.40	2.39	6.84	2.85	2.45	175.73
		Std. deviation	7.39	3.84	2.37	1.58	3.36	1.71	1.24	0.46	2.62	0.97	2.02	2.42
	Knapper B ($n = 105$)	Mean	38.53	16.47	5.57	4.35	9.35	3.28	−0.13	2.39	7.65	3.21	3.58	175.35
		Median	38.30	16.30	5.30	4.20	8.30	3.00	−0.10	2.27	7.09	2.96	2.59	175.01
		Std. deviation	8.56	4.32	2.09	1.69	4.51	2.07	1.52	0.40	2.69	1.06	2.88	2.46
	Total ($n = 210$)	Mean	37.74	15.81	5.54	4.36	9.11	3.33	0.04	2.45	7.61	3.13	3.29	175.58
		Median	37.00	15.80	5.30	4.20	8.50	3.05	0.05	2.34	6.87	2.95	2.56	175.31
		Std. deviation	8.02	4.13	2.05	1.63	3.97	1.89	1.40	0.43	2.65	1.01	2.50	2.45

Appendix B. GLM UNIANOVA.

Variable	Source	df	F	p	$\eta\rho^2$
Max length	Intercept	1	5716.017	0.000	0.966
	Impactor	2	17.378	0.000*	0.146
	Knapper	1	2.517	0.114	0.012
	Impactor * Knapper	2	7.841	0.001*	0.071
Max width	Intercept	1	3544.797	0.000	0.946
	Impactor	2	8.852	0.000*	0.080
	Knapper	1	6.085	0.014*	0.029
	Impactor * Knapper	2	6.332	0.002*	0.058
Max thickness (LOG)	Intercept	1	3869.329	0.000	0.950
	Impactor	2	0.938	0.393	0.009
	Knapper	1	0.439	0.508	0.002
	Impactor * Knapper	2	4.243	0.016*	0.040
Mid-point thickness	Intercept	1	1540.113	0.00	0.883
	Impactor	2	1.124	0.327	0.011
	Knapper	1	0.020	0.888	0.000
	Impactor * Knapper	2	4.2330	0.016*	0.040
Platform width (LOG)	Intercept	1	5268.437	0.000	0.963
	Impactor	2	0.007	0.993	0.000
	Knapper	1	0.203	0.653	0.001
	Impactor * Knapper	2	7.859	0.001*	0.072
Platform thickness	Intercept	1	670.304	0.000	0.767
	Impactor	2	0.004	0.996	0.000
	Knapper	1	0.157	0.693	0.001
	Impactor * Knapper	2	5.616	0.004*	0.052
Relative bulb thickness	Intercept	1	0.002	0.969	0.000
	Impactor	2	0.502	0.606	0.007
	Knapper	1	1.487	0.225	0.010
	Impactor * Knapper	2	2.728	0.069	0.036
Length/Width ratio	Intercept	1	6783.804	0.000	0.971
	Impactor	2	1.203	0.302	0.012
	Knapper	1	3.592	0.059	0.017
	Impactor * Knapper	2	0.661	0.518	0.006
Length/Thickness ratio (LOG)	Intercept	1	1890.328	0.000	0.903
	Impactor	2	8.859	0.000*	0.080
	Knapper	1	0.043	0.836	0.000
	Impactor * Knapper	2	3.939	0.021*	0.037
Width/Thickness ratio (LOG)	Intercept	1	2888.842	0.000	0.934
	Impactor	2	7.053	0.001*	0.065
	Knapper	1	1.246	0.266	0.006
	Impactor * Knapper	2	2.315	0.101	0.022
Weight (LOG)	Intercept	1	329.099	0.000	0.617
	Impactor	2	4.675	0.010*	0.044
	Knapper	1	2.243	0.136	0.011
	Impactor * Knapper	2	6.262	0.002*	0.058
Curvature	Intercept	1	1114750.591	0.000	1.000
	Impactor	2	4.450	0.013*	0.042
	Knapper	1	1.922	0.167	0.009
	Impactor * Knapper	2	0.241	0.786	0.002

* Denotes significant difference.

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