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Handaxes as a Measure of the Mental Capabilities of Early Hominids

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Handaxes are often used to discuss the evolution of mental capabilities in early hominids. There are several reasons handaxes are used for this purpose, but principal among these is the notion that handaxe shape is an arbitrary imposition of form, on varied raw material, that reflects shared mental templates. If this is so, then changes in handaxe shape through time and space may speak directly to evolving mental capabilities. It is argued here, however, that far too little attention has been paid to much simpler levels of explanation that may say much less about mental capabilities. This point is illustrated by re-examining some data sets that have been used by others to show patterns in handaxe shape interpreted as reflecting differences in mental constructs or for elevated mental abilities. It will be argued here that some very basic factors, such as raw materials and reduction intensity, are better able to explain the observed patterns. As a result, the existence of mental templates for preferred handaxe shapes seems unlikely.

Keywords: ACHEULIAN, HANDAXES, MENTAL CAPABILITIES, INTELLIGENCE, SYMBOLISM, STYLE, TECHNOLOGY.

Introduction

Many scholars have drawn conclusions about the mental abilities of Lower and Middle Palaeolithic hominids from stone tools. In particular, handaxes have received considerable attention in this regard (Wynn, 1979, 1985, 1991, 1993, 1995; Gowlett, 1984, 1986; Isaac, 1986; Davidson & Noble, 1989, 1993; Dibble, 1989; Davidson, 1991; Mithen, 1994; Steele *et al*., 1995). The reasons are fairly obvious. First, handaxes were manufactured over a very long period of time and over a very large region of the Old World, making it relatively easy to track changes through time and space without many of the methodological pitfalls that are encountered when, as in the Middle to Upper Paleolithic transition, entirely different tool types come and go. Second, while there are multiple handaxe typologies that can sometimes make regional comparisons difficult, handaxe studies have generally relied on measurement systems which, while varied, share a common set of measures amenable to statistical analysis. It is, therefore, possible to build a very large data set from published handaxe assemblages throughout the Old World. Third, handaxes were manufactured by at least two hominid taxa: *Homo erectus* and similar forms and *Homo sapiens neanderthalensis* or *Archaic Homo sapiens*. Thus the implications of evolutionary changes in the biology of early hominids can be directly tested. Fourth, and most important, it is generally believed that handaxes are intentionally shaped tools resulting from the arbitrary imposition of form independent of the material's original form. If this is true, then a finding that handaxes in a given site are similar to one another and different from handaxes at another site may indicate that their makers shared some sort of mental image or template of what a handaxe should look like. By studying the shape of handaxes, we are, therefore, entering into the mind of their makers, which is where we need to be to answer questions about the mental abilities of early hominids. The potential relationship between biology and behaviour and the changes they exhibit through time are particularly important when discussing topics such as evolution of hominid intelligence and the origins of symbolism, which are undoubtedly linked at some level to changes in the size and organisation of the brain.

While the first three points listed above are accepted facts derived from the archaeological record, the fourth point is more debatable. Davidson & Noble (1993), for instance, have directly challenged the mental template position and argued instead that handaxe shape is a simple by-product of the application of a bifacial technology. In Britain, Ashton & McNabb (1994) have argued that some shapes are more a function of raw material size and shape than has been previously acknowledged. Similarly, Jones (1979, 1994) has demonstrated the effect of raw material type and blank form on morphological variability in handaxes from Olduvai Gorge.

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Elsewhere, I have suggested that handaxe shape is largely a product of the size of raw materials and the intensity of bifacial reduction (McPherron, 1994, 1995, n.d.). From this perspective, particular handaxe shapes are viewed as representing stages in a continuous reduction process. Interestingly, this reduction process seems to be remarkably similar from site to site. Handaxes begin large, elongated, pointed and relatively thick. As the bifacial edge is continually reworked, and as the edge expands to encompass more of the original nodule or flake blank, the handaxe becomes smaller and the shape gradually becomes broader, more rounded and relatively thinner. If this reduction model is correct, then sites with very different handaxe shapes may nevertheless share a single reduction strategy and differ only in the intensity of bifacial reduction.

All of these studies are part of a recent trend to re-examine and address some of the lower levels of explanation that may account for variability in handaxe shape. Isaac (1986) called this a step-wise approach, wherein one begins with the most basic levels of explanation and proceeds step by step in a process of accounting for and eliminating sources of variability within and between assemblages until one arrives finally at step 5 where "it is legitimate to consider the possibility that arbitrary, stylistic differences between particular material culture systems are being observed". What is clear, however, is that despite a century of research documenting variability in handaxe shape, we still know very little of why handaxes look the way they do or of why they might have varied from one site to the next and through time. In spite of this fact, there has been a general tendency to leap to Isaac's step 5 with all of its implications for mental abilities without a careful consideration of more fundamental explanations.

This point can be illustrated by taking a fresh look at data published by Wynn & Tierson (1990). They studied the shape of over 1100 handaxes from 17 sites located in Africa, the Near East, India and Europe and found differences that sorted by region. In their conclusion, they suggested three possible explanations: raw material variability, chronological variability, and cultural variability. They acknowledged that raw materials play a part in determining handaxe shape, but given the wide range of raw material variability within each region, particularly in Israel, they argued that it cannot account for such consistent regional differences. They admitted that, given the lack of good dates for the sites in their study, they were unable to reject the possibility that chronological change might explain the regional differences they see. Nonetheless, they (Wynn & Tierson, 1990: 81) state:

> [The] presence of geographically distinct styles is characteristic of modern culture and its absence has occasionally been used to argue for the primitiveness of Acheulean culture. The existence of regional traditions at the end of the Acheulean, however subtle these differences seem, is therefore of relevance to any discussion of cultural evolution.

They went on to say that, regardless of the source of this variability, the pattern itself showed that the Acheulian was less homogenous than others had suggested.

More recently, Crompton & Gowlett (1993; Gowlett & Crompton, 1994) have analysed handaxes from the African sites of Kariandusi and Kilombe and found that, in addition to presumed functional and stylistic variability that must exist in handaxes, some variability in shape can also be tied to differences in size. They noted that Wynn and Tierson were able to distinguish with their method Kariandusi handaxes made of obsidian from those made of basalt. The former, however, tend to be much smaller than the latter. Thus the differences in shape may be more related to differences in size than in raw materials. Crompton & Gowlett (1993: 196) went on to state that "it now becomes important to establish whether allometric factors offer at least a partial explanation for these differences, or whether the differences are more a matter of cultural and other functional variation". Building on their suggestion, what follows is a re-examination of Wynn and Tierson's original study with a special focus on the relationship between handaxe size and shape.

Wynn and Tierson's study

The method used by Wynn & Tierson (1990) was based on an analysis of digitised outlines of over 1100 handaxes (excluding cleavers) from Africa, the Near East, India and Europe. The digitised data were recorded using a series of 22 radial measurements taken at specified intervals from the centre of the handaxe (Figure 1(a)). Radial measurements have been applied to lithic studies for years (Montet-White, 1973) and can describe shape quite effectively, though there are some issues that affect such an approach (Dibble & Chase, 1981). In their study, the centre of the handaxe was taken as the mid-point of the long axis of the piece, with the long axis defined as the line running from the tip to the furthest point on the base. In cases where the tip was relatively flat and unpointed, the mid-point of the tip was used. Because the long axis seldom divides a handaxe into two identical halves, the narrow side was always placed to the right (Wynn & Tierson, 1990: 74). The radial measurements were not taken at equal intervals. Instead, a higher concentration of the measurements were taken near the tip and the base because previous work with the same technique indicated that more measurements near the tip were needed to distinguish cleavers and handaxes.

The first step in their analysis of these measurements was a principal components analysis with an orthogonal rotation (Varimax) of the 22 variables in the complete sample. The results consisted of a series of

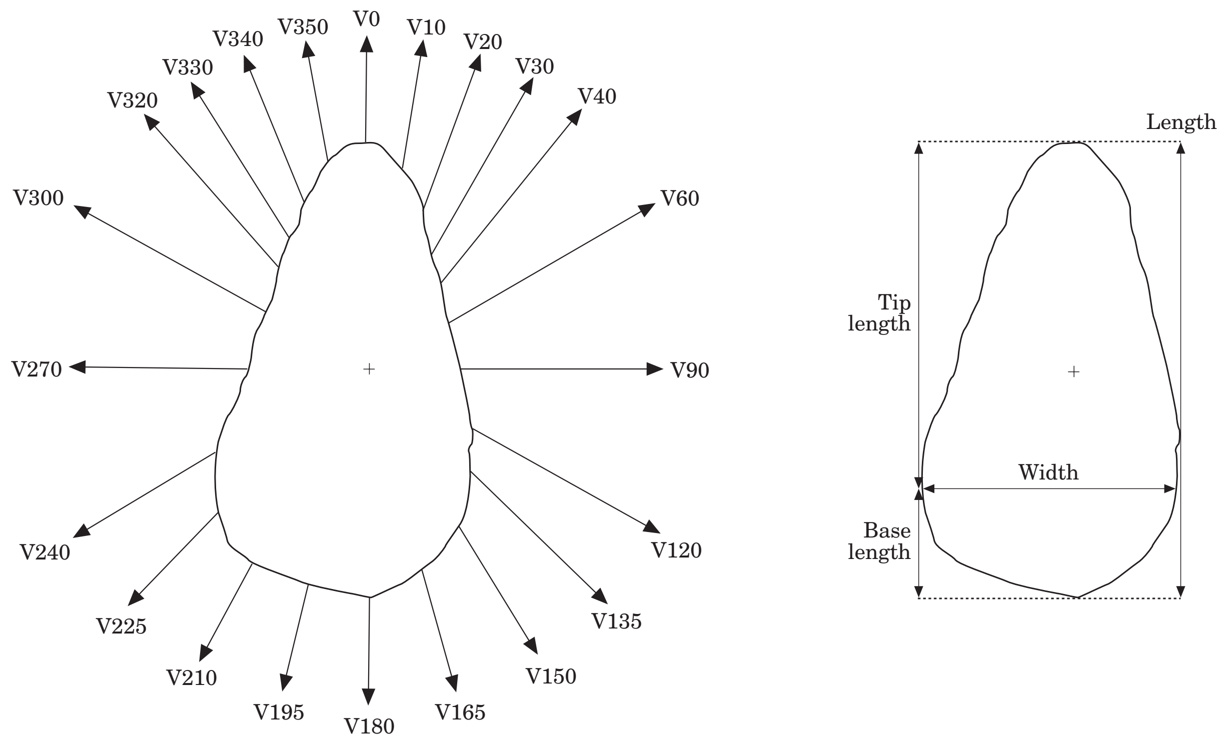

Figure 1. (a) Wynn & Tierson's (1990) system of radial measurements, and (b) standard measurements of handaxe shape.

components that are combinations of the input variables. The first component accounted for 83·1% of the variability in the data set, and the first two components together accounted for 89·6%. As interpreted by them, "the contribution of size to the first component was clearly seen", and, in fact, "both components were related to size, since the component loadings over all variables were similar (for example, the lowest loading was still greater than 0·3)" (Wynn & Tierson, 1990: 75–76). This result is quite typical for this type of analysis (Crompton & Gowlett, 1993: 187), but the approaches for dealing with it vary considerably.

To remove the contribution of size from their study, Wynn and Tierson divided each radial measurement by the length of the handaxe (Figure 1(b)). In other words, they scaled their handaxes to a standard length. As a result, two of the 22 measurements (V0 and V180) were lost because they were coincident with the handaxe length. All other measurements were then made to be relative to length as described above. In doing this, however, the width measurements (V90 and V270) are, in essence, transformed into elongation ratios since elongation is equal to width divided by length. This is unfortunate since elongation is one of the basic components of traditional handaxe typology (Bordes, 1961; Roe, 1964, 1968, 1981) that Wynn and Tierson appeared at first to try to avoid relying on with their method of radial measurements. Another approach to eliminating size from the analysis would have been to focus on the remaining components of their first PCA (Whallon, 1982). If the first two components accounted for variability in size in the data set, then the remaining components, encompassing the remaining 10% of the variability, may have accounted for non-size related variability. This is, of course, the purpose of doing a principal components analysis in the first place. Likewise, Crompton & Gowlett (1993; Gowlett & Crompton, 1994) recognised size as one important aspect of handaxe variability and explicitly included it in their analysis using allometric statistics that are more typically applied to biological data sets. Similarly, I have argued that size-related variables can measure bifacial reduction intensity and can explain most of the variability identified in the standard handaxe typologies (McPherron, 1994, 1995).

The second step in Wynn & Tierson's (1990) analysis repeated the principal components analysis with orthogonal rotation (Varimax) on the size-adjusted measurements. In this case, the first four components, reproduced in Table 1, accounted for 84·3% of the total variability. The first component, which accounted for 54·3% of the variability, was interpreted by Wynn and Tierson as representing shape differences on the left-hand side of handaxes. Now the highest loading variable was V270, which, as stated above, represents elongation. The variables with the next highest loadings alternated above and below V270 and can be easily interpreted as the next best predictors of elongation.

The second component, which accounted for only 15·6% of the variability, related to differences in handaxe tips. It is more difficult to know exactly what

Table 1. Loadings for first four rotated components of PCA on 1178 handaxes. Reproduced from Wynn & Tierson (1990: 77). Note that only loadings greater than 0·5 are shown

Radial measurement	Component number			
	1	2	3	4
V10		0·8338		
V20		0·8128		
V30		0·7507		
V40		0·6712	0·5591	
V60		0·5506	0·6481	
V90			0·7331	
V120			0·8081	
V135			0·8149	
V150			0·7386	0·5459
V165			0·5474	0·5610
V195				0·8387
V210				0·8191
V225	0·7033			0·5697
V240	0·8542			
V270	0·8714			
V300	0·8161			
V320	0·7495	0·5618		
V330	0·6888	0·6131		
V340	0·5766	0·6898		
V350		0·7477		

tip measures divided by length really are. It is tempting to attribute these measures to tip length (Fig. 1(b)), but since they were measured from the centre of the handaxe and not from the point of maximum width or thickness, this is not completely accurate. All we really know from this analysis is that tip measures tend to covary. The third component, which accounted for only 9·0% of the variability, reflected differences in the lower right-hand side of the handaxes, and the last component, accounting for 5·0% of the variability, reflected differences in the base of each handaxe.

The next step in their analysis involved a step-wise discriminant function analysis of the size-adjusted handaxe measurements with the region of origin as the known grouping variable. What they tried to do here was to test the degree to which the radial measurements can be used to predict the region of the Old World from which the handaxes come. Results of this type of analysis are evaluated by comparing the number of handaxes which actually do belong to a particular region with the number of handaxes which the statistical test placed in that region based solely on the radial measurements of edge shape. In their study, only 42·4% of the handaxes were correctly placed in their region (Table 2).* However, when the results of different regions are compared against one another, it is clear that the method had better success discriminating between some regions than others. The inter-region

*Because Wynn and Tierson use the same handaxes to create the discriminant functions and to evaluate the results, the success rates are probably too optimistic (Baxter, 1994: 201). A better approach would be to split the sample into two groups, one for developing the discriminant functions and the other for testing their success at correctly classifying the handaxes by region.

Table 2. Wynn & Tierson's (1990) discriminant analysis results. Overall prediction success rate is 42·4%

	Africa	India	Israel	England
Africa	159	38	45	32
(N=274)	(58·0%)	(13·9%)	(16·4%)	(11·7%)
India	34	20	42	9
(N=105)	(32·4%)	(19·0%)	(40·0%)	(8·6%)
Israel	48	51	270	26
(N=395)	(12·2%)	(12·9%)	(68·4%)	(6·6%)
England	198	53	102	51
(N=404)	(49·0%)	(13·1%)	(25·2%)	(12·6%)

success of the technique is a measure of the similarity or differences in the handaxes of those regions. The greatest success was with distinguishing between African and Near Eastern handaxes, and the worst rate of success was with the African and Indian handaxes. In all instances, the regions were found to be significantly different from one another.

Finally, Wynn & Tierson (1990) repeated the step-wise discriminant analysis on handaxes with completely trimmed edges. Their assumption was that these handaxes would yield a better result because the final edge shape reflects purposeful shaping rather than the vagaries of the original nodule of raw material or flake blank. In fact, the overall success rate of this analysis only increased by 4% to 46·3%, and all of the inter-regional patterns remain unchanged.

Reinterpreting Wynn & Tierson's (1990) study

Despite the complexity of the statistical tests used in this analysis, the results are quite interesting. The validity of the differences between regions is not in question here. Wynn & Tierson's (1990) interpretation of the differences is another matter. They considered raw material, time and cultural traditions. They rejected the first of these but were torn between the remaining two. However, a fourth explanation, namely a combination of raw material size and reduction intensity, was not considered and, in fact, their own results support such an explanation.

When the loadings of each measurement are examined for the four size-adjusted principal components, it is possible to give alternative interpretations to the significance of each. It is important to emphasise here that when particular variables load high (in absolute values) on a component it simply means that they covary. In other words, as the value for any one of these variables changes, the values of the others change as well. As previously mentioned, the variable that loaded highest on the first component, which Wynn and Tierson called left-side shape, is size-adjusted width (V270) or left-side elongation. The next two highest variables were the measurements immediately above and below this one, and the next two were the ones immediately above them. The last two variables that loaded highly were both above size-adjusted width (V330 and V340) and closer to the tip. In other words, as the left-side width at the midpoint increases, so do the other measures of left-side width. This is not a startling conclusion; it simply means that left-side edge shape is typically smooth or continuous.

Thus, in the absence of length (i.e. once the other measures are standardised for length), the greatest source of variability in the data set is left-side elongation. It might be expected that rather than alternating above and below left-side width, the measures should instead alternate from left to right (V90). However, Wynn and Tierson always placed the narrower side of the handaxe on the right. This means that the measurements above and below the left side width (V270) are more likely to covary with each other than with the measurements on the right side.

The second component, which Wynn and Tierson interpreted as variation in the tip, accounted for 15% of the variability in the data set. The variable that loaded highest on this component (V10) was the one immediately adjacent to one that approximated tip length (V0), but given that this size-adjusted measure was expressed as a percentage of length (V10/(V0+V180)), such a result is to be expected. The variables that follow were all closely associated with the tip, though they did not alternate from the left to the right side of the tip as nicely as the width measurements alternated above and below the width. This too may be the result of the intentional left–right bias in their data. Also, the fact that the tip measures expressed as a percentage of length all covaried on a single component simply means that changes in the tip shape are continuous or smooth, but says nothing about the actual shape of the tip—whether it is pointed or rounded. Furthermore, since principal components are independent of one another, we can say nothing about the relationship between elongation and tip shape.

The remaining two components were essentially mirror images of the first two and accounted for very little variability. Here, too, the most that can be said is that they show that edge shape is continuous. Obviously, the more intriguing result is that, despite criticism of the method just outlined, Wynn and Tierson were able to show differences between regions. Yet, the criticisms outlined here suggest that their results could be obtained much more simply.

As shown above, Wynn and Tierson's first component, which accounted for over half of the variability in the data, is simply elongation or the ratio of the length to width. In this case, it should be possible to replicate their ability to separate handaxes into regions using just the two measures of length and width. To try this, average length and width measurements from 148 assemblages representing Africa, the Near East, Europe and India were input and, on the basis of only these two variables, a discriminant analysis was conducted. This is the same statistical test used by Wynn and Tierson to detect regional variability in their data set, but, in this case, only two variables are used, and the data set consists of assemblage averages rather than measurements on individual handaxes. As shown in Table 3, the results exceed those of Wynn & Tierson (1990). Where they were able to correctly classify 42·4% of their handaxes, this study correctly classifies 56·1% of the assemblages. Within each region the results are also very similar to theirs. For instance, African and Near Eastern assemblages are the easiest to correctly classify, while the Indian assemblages are more difficult to classify. The European assemblages, however, fair much better in the analysis presented here. Wynn and Tierson were only able to correctly classify 12% of their English handaxes, whereas nearly 55% of the French and English handaxe assemblages are correctly classified here.

Table 3. Discriminant analysis on Acheulian assemblages using average assemblage length and width. The percentages read across. Overall success rate is 56·1% (N=148)

	Africa	Europe	India	Near East
Africa (*N*=50)	31 (62·00%)	10 (20·00%)	6 (12·00%)	3 (6·00%)
Europe (*N*=77)	13 (16·88%)	42 (54·55%)	12 (15·58%)	10 (12·99%)
India (*N*=11)	2 (18·18%)	2 (18·18%)	4 (36·36%)	3 (27·27%)
Near East (*N*=10)	0 (0·00%)	1 (10·00%)	3 (30·00%)	6 (60·00%)

When the length and width data are plotted and coded by region, it is clear why these variables are so adept at predicting the region (Figure 2). The Near Eastern and African assemblages represent two extremes in size with the European and Indian assemblages falling between the two. As a result, it is easiest to separate Near Eastern assemblages from African ones, and the European and Indian assemblages are more likely to be mistaken for either African or Near Eastern assemblages. This graph supports the notion of Crompton & Gowlett (1993) that allometric or size-related factors are mostly responsible for the patterns documented by Wynn and Tierson.

Discussion

Whereas Wynn & Tierson (1990) emphasise differences between regions in their data and whereas Crompton & Gowlett (1993) emphasise differences between sites in theirs, this study highlights the similarities. In fact, the length and width plot shown in Figure 2 is remarkable for the degree of similarity displayed among these handaxe assemblages. Assemblages from across the Old World and through much of the Pleistocene all tightly cluster on a single line. What this suggests is that there is an underlying factor that affects handaxe

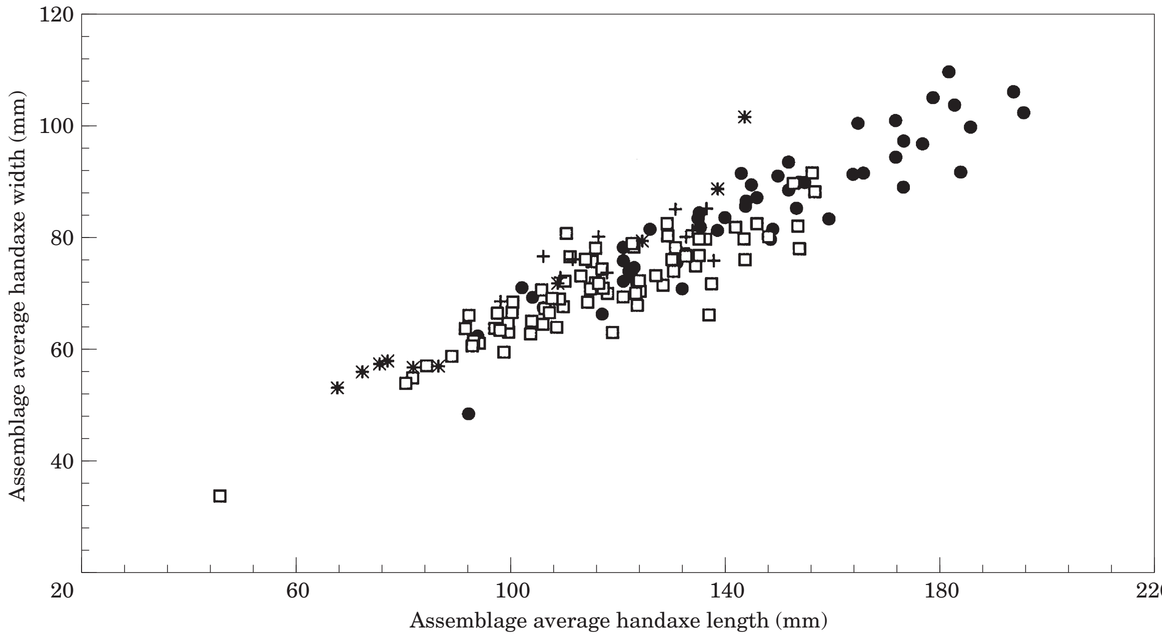

Figure 2. Average handaxe assemblage length to width (R=0·924, P=0·000, N=148). ●, African assemblages; □, European assemblages; +, Indian assemblages; ✱, Near Eastern assemblages.

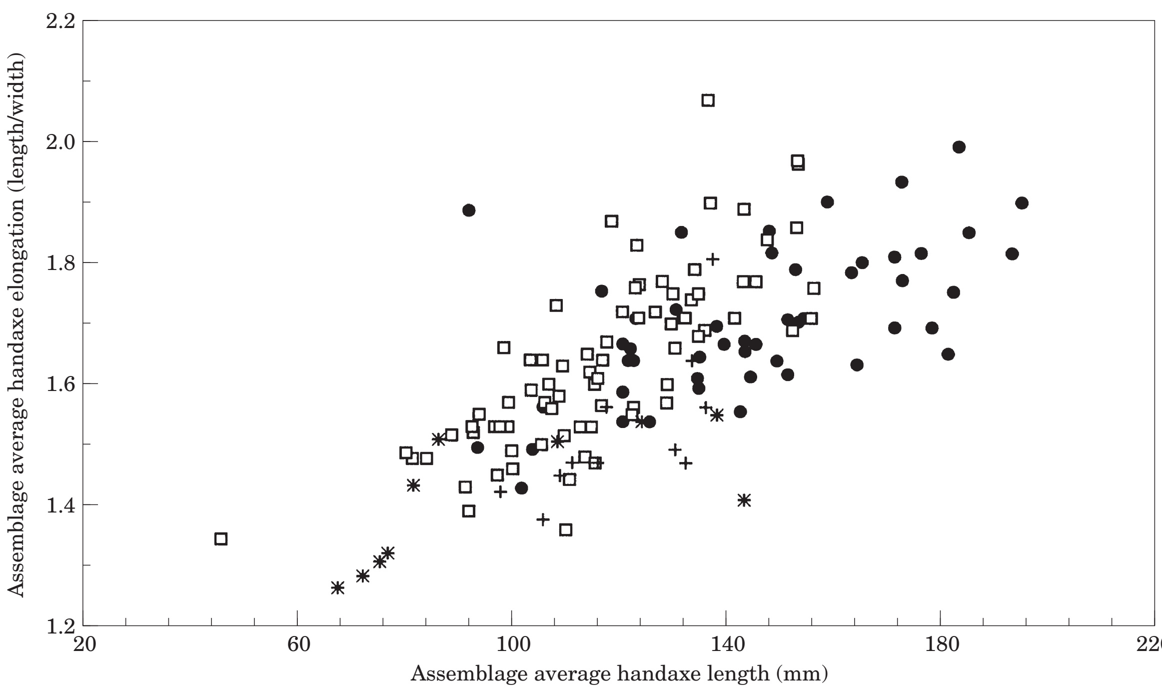

Figure 3. Average handaxe assemblage length versus elongation (R=0·712, P=0·000, N=148. ●, African assemblages; □, European assemblages; +, Indian assemblages; ✱, Near Eastern assemblages.

shape in some fundamental way. But the strong association between length and width does not in itself mean that all of these handaxes have the same shape. Elongation, or the ratio of length to width, which is a true shape-related variable, is clearly not the same in all of these assemblages. Rather, elongation is greater in assemblages with longer handaxes and smaller in assemblages with shorter handaxes (Figure 3). This pattern, noted by Isaac (1977) in some African assemblages over 20 years ago and more recently by Crompton & Gowlett (1993) and McPherron (1994), is more significant than it might seem at first glance.

Superficially, it may seem that length and elongation are the same thing, in which case it would not be surprising that longer handaxes are more elongated. It is important to bear in mind, however, that it is entirely possible to make a handaxe assemblage in which the short handaxes are proportionately more narrow, meaning more elongated, than the longer handaxes. This only entails removing material from the width of the handaxe faster than from the length. Likewise, elongation could remain constant despite changes in size. In fact, this is what one might expect if their makers purposefully modified the handaxes to have a desired shape. So, the fact that this is not the case implies that some other factors were apparently more important than shape.

Crompton & Gowlett (1993) offered a functional explanation for the size-related changes in shape. They (1993: 195) argued that unless adjustments are made to the proportions or shape of handaxes, as size increases, weight will increase not geometrically but as a cube of the dimensions. Thus, when manufacturing large handaxes, sacrifices must be made in some other dimensions (resulting in a change in the artefact's shape) to prevent the weight of the handaxe from becoming unmanageable.

Similarly, Jones (1994) considered the relationship between edge length, surface area, volume or weight, and shape. He demonstrated that elongated shapes provide a better ratio of cutting edge to weight than do broader, more rounded shapes. Thus, large handaxes with long edges are more likely to be elongated than broad. There are, however, technological constraints that limit the extent to which the relationship between edge length, shape and weight can be maximised. Jones (1994: 270) argued that there are certain minimum length to width and width to thickness ratios that must be maintained for the artefact to remain flakable and strong. In addition, Jones cited (1994: 270) end-shock as an issue with long, narrow handaxes. Elongated handaxes are more like to flex or vibrate and snap in two when struck (Whittaker, 1994: 213).

An additional approach is to look at the implications of the relationship between size and elongation as size decreases. Lithic technology is, after all, reductive: regardless of the size of the original flake blank or nodule, shaping a handaxe requires removing material. Over 20 years of research on Old and New World assemblages demonstrates that stone tools were often reworked and that this lithic reduction process has important implications for morphologically based stone tool typologies (see Dibble, 1995). My own work (McPherron, 1994, 1995) has shown that most aspects of handaxe shape that are integral to the standard typologies can be largely accounted for by the combination of raw material and reduction intensity factors, specifically resharpening. The pattern seen in the handaxe data sets, including the ones discussed here, strongly suggests that proportionally more material was removed from the length than from the width. Stated another way, it means the width is conserved. This can be explained if one considers the possibility that a handaxe once made would have been reworked and rejuvenated rather than discarded after it had served its original purpose. If, as seems likely, this was the case, then by decreasing some dimensions more slowly than others (removing less width than length in each resharpening episode), the useful life of a handaxe could be extended further than if each rejuvenation episode removed material equally from each dimension. Given the technological limitations noted by Jones, in particular the problem of end-shock, it makes good sense that width and length change in the direction of decreasing elongation. Changing width less than length changes the shape of the handaxe with each resharpening episode, and thus the handaxes we find in the archaeological record represent various phases in a reduction sequence and not finished tool forms.

Jones (1994) illustrated this point with Bed IV Olduvai materials. He found that some of the differences between Developed Oldowan and Acheulian handaxes could be explained by resharpening reduction. Experiments on typical Acheulian handaxes showed that after three or four resharpening episodes the artefact could be classified as a typical Developed Oldowan handaxe. Thus the Acheulian and Developed Oldowan handaxes represent two stages in the use-life of a single tool.

This approach, while often supported by their own data, nonetheless conflicts with the most fundamental interpretation of most researchers, namely that the final form of handaxes represents or reflects intentional designs. Such an assumption is what Davidson & Noble (1993: 365; Davidson, 1991) have named the "finished artefact fallacy" for "the belief that the final form of flaked stone artefacts as found by archaeologists was the intended shape of a 'tool' ". For example, as already noted, Wynn & Tierson (1990) distinguished completely trimmed handaxes from partially trimmed handaxes, presumably because the former are a more complete representation of the desired end product. In this regard, it is interesting to emphasise that they found that fully trimmed handaxes could be classified only slightly better than the others (46.3% versus 42.4%), and this rate is still below what was accomplished in this study using only length and width. Davidson & Noble (1993) also directed their "finished artefact fallacy" at Gowlett (1984: 185), who suggested that a consistently high correlation between handaxe length, width and thickness at the Kilombe sites "shows a high degree of standardisation, and must imply a well-defined mental image of the desired end-product". Moreover, the fact that the regression lines for the relationship of length to width converge on zero led Gowlett to conclude that "*Homo erectus* of 700,000 years ago had a geometrically accurate sense of proportion, and could impose this on stone in the external world . . . mathematical transformations were being performed" (Gowlett, 1984: 185).

Table 4. Standardisation in biface shape based on Gowlett's (1984: 185) data plus sites measured by the author

	Elongation	Refinement	Regression width to length	Regression thickness to width	Length
Kilombe EH (N=105)	1·61	2·13	0·83	0·46	152
Kilombe AH (N=27)	1·61	2·22	0·93	0·54	144
Kilombe AC/AD (N=115)	1·66	2·08	0·80	0·48	152
Kilombe EL/EHS (N=61)	1·64	2·22	0·86	0·51	140
Kilombe Z (N=16)	1·64	1·82	0·85	0·58	165
Gouzeaucourt Level H (N=180)	1·494	2·566	0·758	0·556	79·99
Longavesnes (N=84)	1·477	2·490	0·807	0·692	84·169
La Cotte Level A (N=23)	1·345	2·131	0·747	0·273	45·870
Cagny-la-Garenne (N=120)	1·759	1·906	0·668	0·571	122·090

Davidson & Noble's (1993: 371) response was to present data from assemblages in other parts of the world. Since Gowlett's conclusions were based in large part on the relationship between handaxe length and width, it is worth re-examining them here as well using an approach similar to Davidson and Noble's. Table 4 reproduces Gowlett's data for Kilombe along with the same data for several assemblages from northern Europe studied by the author: Gouzeaucourt Level H (Tuffreau & Bouchet, 1985), Longavesnes (Ameloot-Van der Heijden, 1991), La Cotte de St Brelade (Callow & Cornford, 1986), and Cagny-la-Garenne (Tuffreau, 1987). While elongation differs from site to site, the strength of the relationship between length and width, as measured by regression analysis, at the northern Europe sites is equal to or only slightly lower than at the Kilombe sites. Following Gowlett's logic, the strength of these relationships indicates the presence of a handaxe mental template at these sites as well. However, as Davidson & Noble (1993) and Dibble (1989) point out with slightly different data, it is the same mental template from Africa to Europe. Moreover, given the patterns presented in this paper, it is clear that even the differences in the actual elongation value fit a shared pattern. The assemblages with lower elongations tend to have shorter handaxes. In other words, there appears to be a single mental template as concerns elongation. With regard to the regression lines passing through zero, the lines for Gouzeaucourt Level H, Longavesnes, Cagny-la-Garenne and La Cotte Level A also converge on zero (Table 5). If Gowlett's interpretation of the significance of this fact were accurate, then it would be no surprise that later hominids in other parts of the Old World had retained the mathematical abilities of their African predecessors.

Table 5. Y-intercept (length) for regression of width to length

	Y-intercept
Gouzeaucourt Level H	8·173
Longavesnes	12·031
La Cotte Level A	− 6·171
Cagny-la-Garenne	27·685

It still must be questioned, however, whether these data actually indicate "mathematical transformations" or "mental templates" as Gowlett suggested. Is it really surprising, for instance, that length and width converge on zero? The fact is that in a reduction technology such as lithics, it can hardly do otherwise. If the process of removing flakes from the edges of a handaxe results in the removal of material from the length and from the width at a constant rate, then, regardless of the actual rate at which material is removed from either, the length and width will eventually reach zero. The only way it could be otherwise would be if the length or width removal rate changed at some point in the reduction sequence. If this were the case, then length and width would not be highly correlated, and Gowlett would not be able to argue for a high level of standardisation.

Much has been made of handaxe shape as it relates to the mind of Pleistocene hominids, and yet the sources of variability in handaxe shape are still very poorly understood and often misinterpreted. The tendency has been to interpret handaxe shape at the highest levels of explanation. Thus Gowlett writes of mental templates and Wynn and Tierson suggest regional, stylistic variants, but clearly much more work is needed at the lower level explanations of raw material variability, reduction intensity and technological constraints. Until the role of these factors in handaxe shape is better understood and explicitly addressed, spatial and temporal comparisons of handaxe shape between sites (Roe, 1968, 1981), let alone between regions (Wynn & Tierson, 1990), are suspect.

Moreover, the very distinct possibility that handaxes were reworked and that shape changed as a result, challenges the basic underlying assumption of most studies of handaxe shape: namely, that a particular shape is the desired end-product of the bifacial reduction sequence. This problem exists regardless of whether handaxes were cores or tools or both. Either way, handaxe shapes represent stages in a continuous reduction process. Given the data presented and reviewed here, it can be concluded that this reduction process was remarkably similar in various parts of the Old World and at various times in the Middle and Late Pleistocene, suggesting that if there were a mental template, it was the same mental template. So in contradiction to Wynn and Tierson, their own data show that the Acheulian is just as homogenous as others have suggested.

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