Identifying handedness at knapping; an analysis of the scatter pattern of lithic remains.

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ABSTRACT

Determining hand laterality during human evolution is important in order to identify brain hemispheric lateralization for motor tasks and, indirectly, to gain information on the complex cognitive functions of the human brain. In this paper, we present a new method for inferring handedness from lithic evidence. The study is based on an analysis of the scatter patterns of lithic remains from stone knapping episodes. An experimental programme was carried out by fourteen knappers (eight right-handed and six left-handed), ranging from individuals that had never even struck two pebbles together to individuals who were quite familiar with prehistoric tools and had some degree of practice. The results of the experiment show that the material scatter patterns of right- and left-handed knappers at group level are different, but they do overlap at certain intervals. At the individual level, the probability of falsely ascribing left- and

right-handedness has been also estimated. In addition, we have adapted this method to be applied to the archaeological record. In this case, only well-preserved knapping events with no post-depositional alterations can be used to assign left- or right-handed knappers, the former being more reliably detected than the latter.

Keywords: experimental archaeology, stone knapping, handedness, scatter-patterns, density maps.

1. INTRODUCTION

The development of hand laterality in human evolution is one of the major issues in cognitive archaeology. Questions such as when, how and why a tendency toward right-handedness appeared are still under study. These issues have been addressed from a wide range of disciplines, including primate ecology (McGrew and Marchant 1997; Uomini 2009; Llorente et al. 2010; Mosquera et al., 2012), brain asymmetries (LeMay 1976; Holloway et al. 2004), bone lateral asymmetries (Plato et al. 1980; Corballis 1983), buccal striations (Bermúdez de Castro et al. 1988; Lozano et al. 2009) and various archaeological approaches (Toth 1985; Cornford 1986; Phillipson 1997; Rugg and Mullane 2001; Pickering and Hensley-Marschand 2008; Peresani and Miolo 2012; Uomini and Meyer 2013).

The study presented here belongs to the last category and represents the first step in identifying the handedness of prehistoric hunter-gatherers by analyzing the scatter patterns of the lithic remains from stone knapping. To this end, we first developed an experimental stone knapping programme and analyzed the scatters of lithic remains from the knapping performed by both right-handed and left-handed knappers. Secondly, we adapted this method to be applied to the archaeological record.

Scatter patterns from stone knapping have been studied by Leroi-Gourhan and Brézillon (1966), as well as Roberts and Parfitt (1999), who compared archaeological and ethnographic examples in observational research. There are some preceding publications on the experimental study of refits (Cziesla et al. 1990), and the experimental reproduction of spatial patterns (e.g., Newcomer and Sieveking 1980). The methods used by these latter authors were the precursors to studies using experimental programmes to answer archaeological questions. However, Newcomer and Sieveking (1980) focused on examining the position of the knapper during experimental stone-knapping episodes, comparing different scatter patterns produced by knappers seated in chairs, sitting on the ground with their legs stretched out straight, and sitting on the ground with their legs bent. The study conducted by Schick (1986) was similar but had a broader scope, since she documented the maximum spatial distribution of remains depending on whether the knapper was standing up, kneeling, crouching or sitting on the ground with their legs stretched out straight.

Along these lines, the work of Ahler (1989) introduced the notion of lithic remains spatial distribution, and Kvamme (1997) and Högberg (1999) focused on reconstructing the techniques and identifying the raw materials used. Kvamme (1997) studied the spatial features and the scatter patterns of lithic remains in relation to different raw materials and hammer types (soft and hard). He developed an exponential equation for modelling the scattering of remains around the knapper. Högberg (1999) approached experimental knapping with the aim of identifying the diagnostic features of the flakes obtained through bifacial and multifacial knapping. In the same work, Högberg also dealt with other subjects, such as the functional characteristics of the knapping area (looking for ethnographic parallels such as the use of blankets to collect the lithic macro-remains), the position of the knapper, and the features of the knapping areas when knapping tasks were performed by children. However, none of these studies focused on identifying the hand laterality of the knapper.

The study presented here is innovative, as the spatial distribution of lithic remains during knapping will enhance the interpretation of archaeological sites, particularly those in which domestic areas, well delimited in time and space, have been preserved (Vaquero et al. 2007; Vaquero 2008). Moreover, it will enable the identification of tools made by right- or left-handed hominins.

This study may also help to determine the approximate point at which hand laterality appeared in hominin evolution. Some work on the handedness of extant hominins points to a hand preference similar to ours in species such as *Homo heidelbergensis* from Atapuerca (Bermúdez de Castro et al., 1988; Ollé, 2003; Lozano et al. 2009). However, most of these studies focus on the dental use-wear generated when individuals used their front teeth as a third hand, probably for cutting meat or other subsistence and/or domestic activities. Unfortunately, all hominin species do not display this behaviour nor are human remains very abundant in the global archaeological record. In fact, the lithic industry makes up the greatest proportion of archaeological evidence from the Pleistocene. In addition, although well-preserved knapping events are not very abundant, they are undeniably more common than hominin remains.

This study starts from the hypothesis that handedness may, in some way, affect the scatter patterns of lithic remains during knapping, thereby making it possible to distinguish between the spatial patterns produced by right- and left-handers. To test this hypothesis we designed and performed an experimental knapping programme involving 28 knapping events.

2. EXPERIMENTAL PROGRAMME

As a first step, we conducted a pilot experiment in order to check the reliability of the method and establish the most suitable procedures. The pilot experiment was based on the same procedures and variables as the formal experiment presented here, but it was conducted using 18 knapping events, while the formal experiment, that includes the pilot experiment, comprised 28.

2.1. Participants

Fourteen volunteers (eight women and six men) took part in the experiments. Six were left-handed and eight were right-handed (Table 1). The volunteers had knapping skills ranging from novice (who had never struck two pebbles together) to a certain degree of practice in knapping. Six were from Universitat Rovira i Virgili (URV, Tarragona), seven from the Institut Català de Paleoecologia Humana i Evolució Social (IPHES, Tarragona), and one was from the Universidad de Burgos (UBU, Burgos). The mean age of the knappers was 30.5 years (SD 6.48 years), they had a mean height of 168 cm (SD 0.06 cm), and a mean weight of 70 kg (SD -9.81 kg).

Table 1

2.2. Materials

The raw material used for the experiments was chert, in the form of blanks from the Ulldemolins area, and limestone hammerstones from the river Francolí and its terraces, both in the province of Tarragona (Spain). This chert is fine-grained, thereby ensuring good conchoidal fracturing. The chert blanks had not been previously shaped. The hammerstones differed in weight, although a Kruskal-Wallis test (p=0.34) found no significant differences between them. Each participant freely selected one hammerstone to use. The mean weight of the hammerstones was 542 gr. (SD 290,39 gr.).

The current research is a continuation of a previous experimentation program, where the handedness of the knappers were investigated through the technical characteristics of the flakes detached (Bargalló and Mosquera, 2013). On its hand, this paper deals with the identification of the handedness of the knapper by means of the spatial analysis of the scatters of the flakes detached. Our study involves twenty-eight scatters of lithic remains, which were generated during the knapping activities of the fourteen volunteers. Of these, 12 scatters belong to left-handers and 16 to right-handers. We have considered the distribution of all the flakes extracted, with no size and morphology restrictions (see Figure S1 for examples of flakes obtained by novice knappers).

2.3. *Protocol*

All the knapping experiments were conducted outdoors, on a surface measuring approximately 4 m^2, covered with a cloth in order to prevent the flakes from breaking when they fell to the ground (see Bargalló and Mosquera 2013 for further details of the protocol). Each participant knapped alone, in the presence of two observers who recorded the experiment. There was no trial period, as all knappers were able to detach flakes right from the start. No time limit was set for the experiment. The goal was to obtain flakes, regardless of their size and knapping technique used (see Supplementary Information 1). Although most archaeologists assume that prehistoric stone working was conducted in squatting, kneeling, or sitting positions, a view that is supported by the limited ethnographic data available (White and Thomas, 1972; Binford et al., 1984; Kvamme, 1997; Hiscock, 2004), different combinations of technological strategies, hammerstones, blank types, body positions, and ground surfaces may drastically influence the characteristic spatial signatures. For this reason, we decided to control as many parameters as possible, seating the participants on a log and telling them to knap either without supporting themselves, or by supporting their arms on their legs.

In order to obtain a larger sample set, each participant knapped two consecutive times. Each scatter of lithic remains was recorded using a video camera located in front of the knapper. After each experiment concluded, photographs were taken of the spatial distribution area. All knapping events and final scatter areas were recorded with a Sony HDRHC1E, HDV 1080i video camera, always using the same recording angle and camera position.

3. METHOD

The area where the experiment took place measured approximately 4 m^2, a surface large enough to collect more than 90% of the lithic fragments detached during knapping. The knapper performed the task whilst sitting on a 30-cm-tall log. The position of the log and knapper were constant throughout the experiments (Figure 1). This meant the scatters from the different knapping events always had the same initial point, allowing a direct comparison to be made between them.

Figure 1

3.1. Data collection

Several steps were followed in order to achieve our goal:

1- Digitalizing the position of each lithic item within the scatter in which it was produced. The point of the lithic item that was digitalized was the central point of the piece (half of its length). We transformed the photographs into digital images using the Golden Software SURFER 8 program, in order to obtain a database of the Cartesian coordinates of each lithic item, and the digital scatter of all the lithic remains detached by each knapper (Figure 2).

2- The Golden Software SURFER 8 program was also used to obtain density maps. The first step in obtaining the density maps is adapting the data (degrees and distance) to a grid. In this study, the grids are divided into 10 cm^2 sections, in order to achieve a better resolution.

Figure 2

3- Searching for the maximum amplitude of the spatial distribution, which is determined by measuring the angle and distance of each fragment in relation to the point of origin. We first calculated the point of origin of the scatter using the digital data transformed into Cartesian coordinates. This point is the central axis of the log, and was calculated using the average of the X coordinates of the trunk and the average of the Y coordinates of the trunk (Figure 2).

4- After determining the point of origin of each item, we entered this into the Cartesian coordinate database. These data were then used to obtain the angle of each lithic fragment in relation to the point of origin. To do this, we first had to ascertain the distance of each lithic fragment using Pythagoras's theorem ($h=\sqrt{\alpha^2+\beta^2}$), calculating α and β for each (see Figure 2). This process was carried out for each lithic fragment in each scatter. Once α and β had been obtained, the distance of each was calculated (Figure 2).

5- The angle of each lithic fragment was calculated using the formula: cos^β=α/h (Figure 2).

3.2. Data analyses

The data were first analyzed with descriptive statistics using *Microsoft Excel* software, to understand the numeric pattern of the sample (Barceló, 2007). Secondly, the data were analyzed through inferential statistics using the Past software program (Hammer et al., 2001, 2008). We performed Man-Whitney and skewness tests to evaluate any differences between individuals and/or groups with regard to handedness. Rose diagrams were constructed using the Rozeta 2.0 software package.

Scatters from left-handed and right-handed knappers may be distinguished in three ways: 1) by examining the maximum amplitudes of their spatial distribution and asymmetry; 2) by analyzing the way in which the lithic remains are scattered within the spatial distribution; and 3) by evaluating where the greatest densities of lithic remains are concentrated.

4. RESULTS

The sample set comprises 28 scatters, 16 (57.1%) from right-handed knappers, and 12 (42.9%) from left-handed knappers. A total of 3,716 lithic fragments were digitalized. Of these, 1,485 belonged to the knapping series of the left-handers and 2,231 to the knapping series of the right-handers (Table 2).

Table 2

4.1. Group level

We analysed two sets of data: 1) the angle; and 2) the distance of the lithic remains within the scatters. As Figure 3 shows, to the naked eye, the superposition of digitalized scatters reveals certain differences in the group scatter patterns of the remains. The lithic remains of left-handed knappers tend to be concentrated to the left of the knapper, while lithic remains of right-handed knappers tend to be grouped to their right.

Figure 3

1) Amplitudes of the spatial distribution and asymmetry.

By using the angles and distances of the lithic remains calculated from the Cartesian coordinates, first we extracted a frequency table, where the number of items produced by each knapper is represented by intervals of angles. Secondly, we extracted the percent of each interval angle based in the number of items produced in each interval with respect to the maximum number of items for each group. We use the percent because is more clear to see the differences and to make the data comparable. (Table 3 and Figure 4; Supplementary information 2). While the left-handed group produced the largest number of lithic remains in the intervals from (-30º, -39º) to (10º, 19º), the right-handed group generated the highest concentrations of items between the intervals (-19º, -10º) and (4~~2~~0º, 4~~2~~9º). When comparing the highest concentrations produced, the distributions of the two groups have an overlap of around 40º. This area of uncertainty corresponds to the intervals between (-19º, -10º) and (10º, 19º), inclusive. To test for significant differences between the distributions we applied the Man-Whitney test. The data used in this test was the total number of lithics found in 10º intervals. The results below 0.05 ($p < 0.0001$) indicate significantly different distributions between the two groups.

Table 3

Based on these group data, we obtained the distribution of the lithic remains according to the handedness of the group (Figure 4). In both cases, we observed a wide amplitude of scatter, encompassing intervals (-89º, -80º) to (80º, 89º). Nevertheless, we needed to determine the degree of symmetry in each group. In order to answer this question, we calculated the skewness coefficient. The right-handed sample showed negative values (-

0.168), while the left-handed sample gave positive values (0.063), thus indicating a differential asymmetry between the spatial distributions of the two groups.

Figure 4

2) The way in which the lithic remains are scattered within the spatial distribution.

Figure 5 summarizes all the lithic remains in rose diagrams from the Rozeta software, differentiating right-handed (Figure 5 right) and left-handed knappers (Figure 5 left). These graphs allows us to identify the interval angles that have the most lithic remains. Both graphs show a unimodal distribution. There does seem to be a preferential orientation: we can see that the right-handed sample orientates towards the northeast and the left-handed sample is oriented towards the northwest. The right-handed sample has the highest lithic fragment concentration in the interval (20º, 29º) while for the left-handed group, this is in the interval (0º, 10º).

Figure 5

3) Density maps of the lithic remains.

Once all the results of the maximum spatial distribution and highest concentrations had been obtained, we needed to show the highest densities for the two groups. Figure 6 reveals substantial differences in the density maps:

1) The maximum contour of the scatter indicates the position of the spatial distribution axis. The right-handed group shows this axis oriented to the right, whereas the left-handed group shows the axis to the left.
2) The map also shows different densities. For the right-handed group, the highest density contour (black; shades number 8 and 9) is oriented to the right, just like the spatial distribution axis of the lower concentrations (grey; shades from 0 to 7). The spatial pattern of the left-handed group is not as clear, because the maximum density distribution (black) is more localized, while the axis of the lower concentrations (grey) is oriented towards the left.

Figure 6

4.2. Individual level

Up to this point we have been dealing with results at group level, but we must bear in mind the fact that archaeological evidence is the result of tasks performed by individuals. As archaeologists it is interesting to know whether we can identify the different individuals who knapped in the past as being right- or left-handed. Therefore, a major question is how individuals compare within the left- or right-handed groups. If we analyze the individuals within each group, we can see that the scatters are heterogeneous (Figure 7).

Figure 7

At the individual level, for 81.3% of the right-handed group the knapping events show a preferential direction of the maximum contour of the remains to the right (Figure 7). This result agrees with the results obtained for the entire group (Figure 6). The remaining, 18.7% of the scatter patterns of right-handed knappers reveal no preferential direction. Furthermore, the majority (75%) of the right-handed knappers show the same preferential spatial distribution orientation as seen at group level.

In contrast, 33.33% of the spatial distribution orientations of left-handed knappers show a preferential orientation opposite to that which is expected and observed at group level; i.e., to the right. In fact, although when considered as a group the left-handers show a preferential orientation of their spatial distribution to the left (Figure 6), they behave rather variably at the individual level. Figure 7 shows that 58,33% of the scatter from left-handed knappers preferentially orients to the left, 33.33% goes to the right and 8.33% has no preferential orientation at all.

In summary, the analyses of the preferential direction of individual knapping scatters does allow us to identify the handedness of the knapper, but certain conditions must be taken into account: 1) the right-handed group is more homogeneous than the left-handed group, and they never show a preferential pattern of spatial distribution to the left; 2) left-handed knappers tend to be more variable, and 33.33% of their spatial distribution show preferential orientations to the right. This factor must be considered for an archaeological approach, because a left preferential orientation of the maximum contour of the scatters always indicates a left-handed knapper, whereas a right orientation of this spatial distribution simply indicates a higher probability that the knapper was right-handed.

4.3. Archaeological adaptation

As the position assumed by the knapper in archaeological events is unknown, we need to ensure that this position does not affect the identification of knappers hand laterality. There are two options to face this problem: 1) Standardizing the position of each lithic fragment within all the knapping scatters; and 2) Simulating slightly "wrong" locations of knapping from the experiments and evaluating the influence of such "wrong" location of *loci* upon the assessment of handedness. In our view, the first option is more reliable. Therefore, in order to standardize the position of each lithic fragment within all the knapping scatters, we firstly extracted the angles and distances of each lithic piece; secondly, for each event, we standardized the degree of each spatial distribution from the arithmetic mean of the angles for each lithic fragment. Finally, we used the transformed angles of all the pieces to statistically compare the fragment scatter of each knapper. This comparison allowed us to identify possible differences between the lithic spatial distribution of right-handed and left-handed knappers.

Based on these standardized data, we generated Figure 8, which shows the distribution of the lithic remains according to the handedness of the group. In the case of the right-handed group, a wide amplitude of scatter is noticeable, which includes the angle intervals from (-129º, -120º) to (100º, 109º). In contrast, the left-handed group shows a reduced spread, from (-99º, -90º) to (100º, 109º). Both groups have positive skewness coefficient values: 0.653 for right-handed knappers and 0.502 for left-handed knappers, reflecting a greater asymmetry towards high values in the right-handed group. However, the Man-Whitney test shows no significant differences (p=0,3) between both groups.

Figure 8

However, an important aspect involves the individual spread or limits in the knapping spatial distributions, since this is what we find in the archaeological record. In this sense, the density maps allow us to apply our method to the archaeological record (Supplementary information 3). Unlike the group results, the individual results after standardization are quite similar to those obtained previously (Point 4.2.): around half of the left-handed group (58.33%) shows the maximum contour on the left; another 33.33% shows the maximum contour on the right, and 8.33% of the entire group shows no preferential direction. For the right-handed group, the results are similar to those obtained prior to data standardization: 81.3% show the maximum contour to the right, and 18.7% shows no preferential orientation (Point 4.2.).

5. DISCUSSION AND CONCLUSIONS

This work has been designed to enable the assignation of handedness from lithic evidence in the archaeological record, specifically from an analysis of the scatter patterns of lithic remains resulting from stone knapping. The experimental programme and method applied to achieve this goal allowed us to distinguish between the scatters produced by left-handers and those generated by right-handers.

The method is based on determining the maximum amplitude of the spread, the way in which the lithic remains are scattered within the spatial distributions, and the density of distributions resulting from the knapping activities of the two groups of handedness. To achieve this, we obtained the angle of each fragment in relation to the position of the knapper, which was the centre of a log on which the knappers were seated. The angles of all the pieces were then used to statistically compare the spatial distributions of the lithic remains of all the knappers, and to identify possible differences between the lithic scatters of right-handed and left-handed knappers.

In this experimental program we did not fix a time limit and the knapping technique was free. We only restricted the participants to knap either without support, or by supporting their arms on their legs. In our view, the time limit does not induce different spatial distributions of flakes during knapping, but the knapping techniques perhaps produce different spatial scatters. For this reason, participants were warned that knapping must be hand holding.

The differences between the two groups can be seen in the digital images (graphs and density maps). Our results verify that the lithic remains produced by right-handed knappers tend to be clustered in an arc to the right of where the knapper was sitting, while the lithic remains of left-handed knappers tend to be concentrated towards the knapper’s left. These patterns can be seen at figure 7.

To our knowledge, this is the first method established for identifying the handedness of a knapper through analysing the scatter pattern of their lithic production.

The experimental procedures make use of variables and constants, the latter enabling a comparison to be made between the different experiments, and the former allowing variability within the group to be identified. The position of the knappers was constant, so the scatters of lithic remains always had the same point of origin. This makes it possible to compare all the scatters and all the knappers' individual events. However, we must be aware of this data can only provide information about the hand used at knapping. In general, this entails identifying right and left-handers, but not ambidextrous individuals, who may use indistinctly both hands at specialized tasks.

Nerveless at the individual level, we have also obtained very interesting results on the spatial distributions (Figure 7), where it is possible to identify a right-handed knapper with 75% confidence, and a left-handed knapper with 50% confidence with regard to their own groups. These results change when focusing on their scatter patterns. In this sense, a lithic distribution with left orientation is likely to correspond to a left-handed knapper, as we have not identified any right-handed knappers with this spatial pattern. However, if the lithic remains are right-oriented there is 81.3% possibility that they correspond to a right-handed knapper, and a 16.6% possibility that they belong to a left-handed knapper. Finally, if the lithic spatial distribution shows no preferential orientation there is a 50% possibility that this spatial distribution corresponds to either a right- or left-handed knapper.

These results become less clear when we standardize the data with the aim of approaching archaeological data sets. In order for this method for identifying the handedness of fossil hominins to be applied in archaeological contexts, two conditions must be met, making its usefulness rather limited: (1) the site must not have suffered severe natural, post-depositional alteration; and (2) the exact place where the individual did the knapping must be identified. This second limitation may be overcome by isolating different knapping episodes that took place in the same area by means of lithic refits.

Once an archaeological lithic scatter spatial distribution has been isolated, and where there is no indication at all about individuals or groups, by applying the method developed in this study we will be able to identify the preferential axis of the spatial distribution: if it is left oriented we can say with 100% certainty that the knapper was left-handed, since none of the right-handed knappers showed left orientations of their spatial distributions (Figure 7). However, if the preferential axis is right-oriented, there is only 85.71% confidence level of the fact that the knapper was right-handed, since some left-handed knappers (14.28%) show a similar scatter pattern to right-handers.

In conclusion, the method presented here involving twenty-eight experiments allows the variability between the left and right-handed knappers to be identified and quantified through an analysis of the scatter patterns of both groups, and provides a probability range for its potential use in archaeology. This application may contribute to the knowledge of the process of brain lateralization in prehistoric hunter-gatherer communities, adding to our understanding of the evolution of higher cognitive functions in the early stages of human evolution.

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Figure legend

Figure 1. On the left, location of the log and knapper in the knapping area. Top right: one of the participants sitting on the log. Bottom right: an example of a lithic knapping spatial distribution.

Figure 2. Example of digital scatter, where the maximum amplitude of spatial distribution of each lithic fragment is represented, and its angle is determined: α is the

result of subtracting the point of origin on the x axis from the final position of the lithic item. β is the result of subtracting the point of origin on the y axis from the final position of the lithic remain. h is the hypotenuse (referred to as "distance" hereafter). ^β is the angle between the hypotenuse and the major cathetus of the lithic fragment.

Figure 3. Superposition of all digital scatters of left-handed knappers (left) and right-handed knappers (right).

Figure 4. ~~Frequency graph~~Histogram of the number of lithic remains documented within the 10º intervals for the right-handed and left-handed populations.

Figure 5. Rose diagrams representing the number of lithic remains by their final position in degrees. The left graph corresponds to the left-handed sample set and the right graph corresponds to the right-handed samples. The centre of the rose diagram (0º, 90º) was the position of knapper.

Figure 6. Density map of the lithic remains produced by left-handed (left) and right-handed knappers (right). The position of the knapper corresponds to 0 at the horizontal axis.

Figure 7. Density maps of each individual knapping event. The position of the knapper corresponds to 0 at the horizontal axis. The knapper was looking to the South and the lithic remains distribution is in front of him/her. The line on each scatter inform us about the direction of the maximum spatial distribution.

Figure 8. Histogram~~Frequency graph~~ of the number of lithic remains documented per 10º intervals for the right-handed and left-handed population, once the data had been standardized.

Table legend

Table 1. Participant information and characteristics. The level of expertise is grouped into three categories: "Technical" participants who know about lithic *chaînes opératoires* and have knapped occasionally, but not regularly (about once a year); "Visual" participants who have seen others knapping at some time, but have never knapped themselves and have no theoretical knowledge of lithic *chaînes opératoires*; and "None": participants with no previous knowledge of knapping or lithic technology.

Table 2. Number of scatters produced by left- and right-handed knappers (each participant knapped twice), total number of pieces in each scatter, and total number of each handedness sample.

Table 3. Distribution of percentage of the lithic remains using 10º intervals, distinguishing the left-handed and the right-handed populations. Shaded cells mark the angle intervals with the most abundant remains for each population.

Supplementary information 1

Figure S1. Some of the flakes obtained by novices knappers. 1a) Right-handed and 1b) Left-handed.

Supplementary information 2

Table S2. Distribution of lithic remains using 10º intervals, distinguishing individual knapping events and knapper's handedness.

Supplementary information 3

Figure S2. Individual density maps of each knapper events after data were standardized. Left-handed knappers in the top and right-handed knappers at the bottom. The position of the knapper corresponds to 0 at the horizontal axis. The knapper was looking towards South and the lithic remains distribution is in front of him. The line on each scatter inform us about the direction of the maximum spatial distribution.

Dear Editor,

We really thank you and the reviewer the suggestions to improve our manuscript, which we have followed to change and explain our data. To make easier this process, we are answering in red after the reviewer comments.

Reviewer #2: The paper has been largely improved and the authors considered each of the reviewers' comments. However, I think few details still need to be clarified and/or improved.

Figures: you added an arrow for the orientation of the knapper but you do not mention it in the figure captions. I do know what this arrow is because I made the previous comment but future readers of the paper might be confused without any explanation in the figure captions. Make clear that this arrow shows where the knapper is looking at, the important is to know where are the back and the face of the knapper to understand flakes distribution. If I understand well the knapper was looking towards South? I am still not sure, we really need to know clearly where the knapper is looking to understand if the flakes distribution is rather on his back or in front of him and if you talk about the left/right of the graphs or the left/right of the knapper.

Right. We included an explanation in the figure captions (Figure 7 and Supplementary information Figure S2). In all cases, the knappers looked towards the South, independently that some flakes may have fallen towards his/her sides. Therefore, with the exception of Figures 1 and 2, the rest of the figures show the position of the knapper as if he/she was the reader; that is, the left/right of the knapper in the graphs is the left of the reader.

Table 3: the way of selecting highest number of artifacts is still unclear.
You explained that "We selected those zones of highest number of artefacts that also were showing continuous increment. Therefore, we dismissed the zones that show significant decrease. One example is in left-handed between the zone (-39º, -30º) and the zone (-49º, -40º), that decrease 28 lithic items, but this significant decrease may be seen in the other zone in Table 3."
So following this we could consider that your cut-off is 28. This is also working for the intervals (10,19) and (20,29) with 136 and 108 artifacts respectively. However, if the cut-off is 28, why don't you cut between (-19,-10) and (-9,0) with 115 artifacts and 145 artifacts respectively so 30 artifacts decrease. If your reason is that there is an apparent continuity between (-29,-20) and (-9,-0) then why don't you consider that there is an apparent continuity between (10,19) and (30,39) as the decrease is not as important as in between (-29,-20) and (-9,-0)? It is the same for right-handed. The figure 4 show it well actually. You can also "normalize" your table 3 using percent (of the maximum number of artifacts for example) in order to make the data more comparable with each other. This would help you to define a clear and more objective cut-off. You can also make a table showing the decrease between intervals, it is very fast to do (I did it for myself with your data within few minutes). You can have a look to the table 3 in percent I provide. Based on that you could for example decide that your cut-off is a 25% decrease from the maximum number of artifacts. This means that intervals with a number of artifacts corresponding to more than 75% of the maximum encountered number of artifacts will be considered to be containing a high number of artifacts. This would correspond to almost the same results as you presented for left-handed but the intervals [30-39] contains also a high number of artifacts. For right-handed, it would be a continuous spread of high number of artifacts between [-29,49].

Right. We changed table 3 and we used the percentage.

Also you have "0" and "-0" in your intervals. Please modify to show in which interval the 0 is taken into account.

Right. We corrected "-0" for "-0.1" in Figure 4, 8, Table 3 and Supplementary information 2 Table S2.

Figure 7: Arrows help a lot reading the graphs. The interpretation of ABEX2 is very questioning as there are numerous artifacts on the left as shown by the darker grey area but the arrow point to the right just because there is the furthest artifact on the right. This artifact is quite isolated based on the graph. So I think this line shows the "maximum distance between the knapper and the furthest artifact" rather than the "maximum spatial distribution".
You said that "the directionality of the scatter is marked by the piece located furthest from the knapper, the origin point." Don't you think that this can be very misleading as it gives high importance to outliers? This is, I think, what happen with ABEX2 for example.

The reviewer is questioning the interpretation of ABEX2. In this case, it is true that the maximum spatial distribution is not continuous: we can see numerous artefacts on the left and a little artefacts group (no isolated artefacts) on the right. The difference between these two artefacts groups is that the group on the right is farthest than the group on the left. For this reason, we interpret that the arrow points to the right.

Minor points:
Notation of intervals haven't been corrected in figures and tables.

Line 125-126: When talking about ages please provide the unit, mean and SD also have the same unit. We can guess that it is "years" but this should mentioned.

Right. We corrected it

Line 137: "290.39 g" instead of "290,39"

Right. We corrected it

Line 174: "more than 90% of"

Right. We corrected it

Figure 2: "lithic item" instead of "lthic item" in the legend

Right. We corrected it in the legend of Figure 2

Line 206: the problem of square root remained the same, this might be due to pdf conversion, pay attention that this is well done in the final version of the paper otherwise the given formula is erroneous.

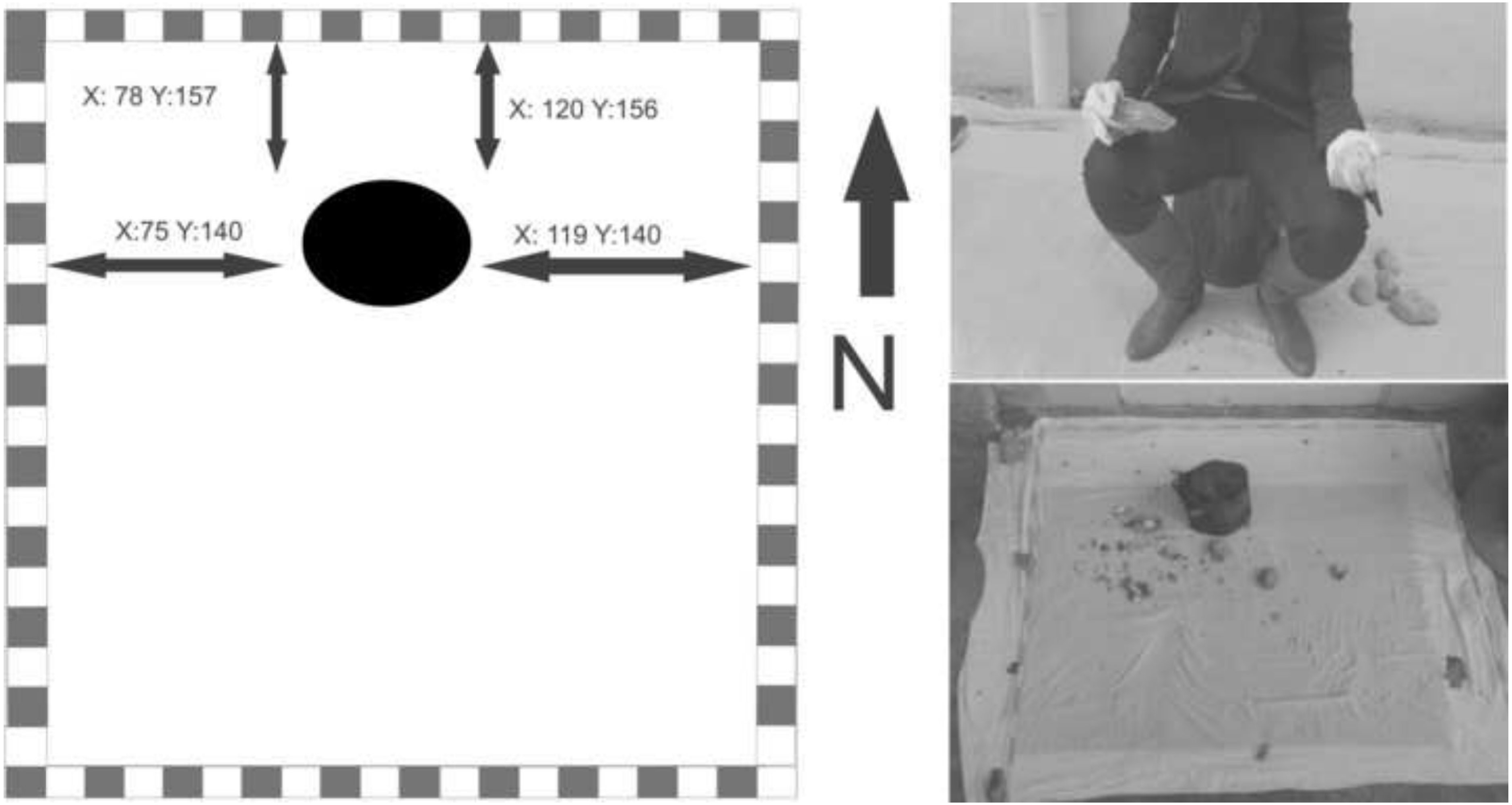
OK. We will pay attention of this matter in the final version of the paper, because in our Word versions I see it correctly.

Figure 4: Broken lines (and line graphs) are showing the evolution of a phenomenon over time which is not the case here. Moreover, you deal with intervals so histogram is the appropriate type of graph.

Right. We changed the line graphs by histogram.

Line 254-255: "The data used in this test was the total number of lithics found in 10º." Do you mean "10° intervals"?

Right. Text changed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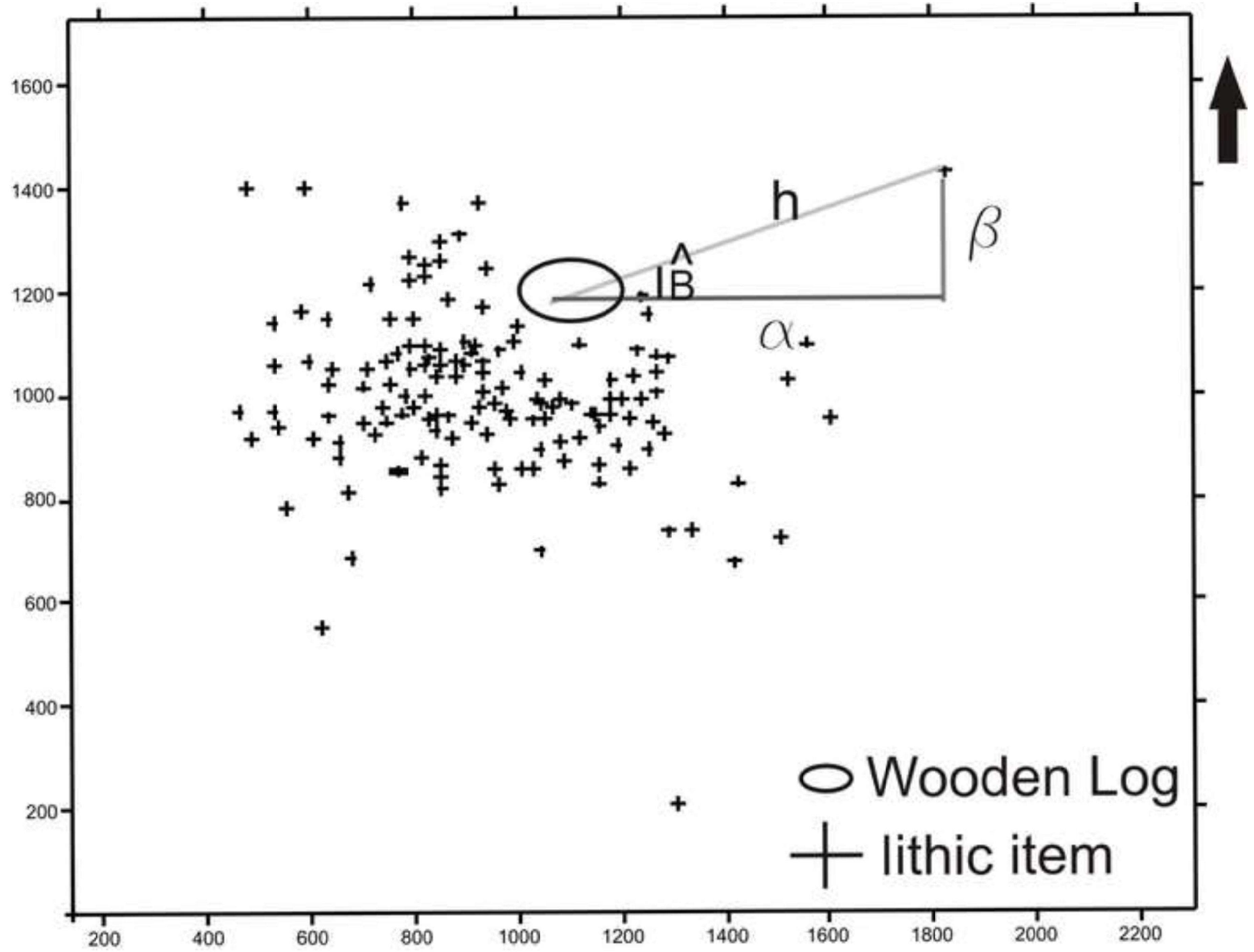
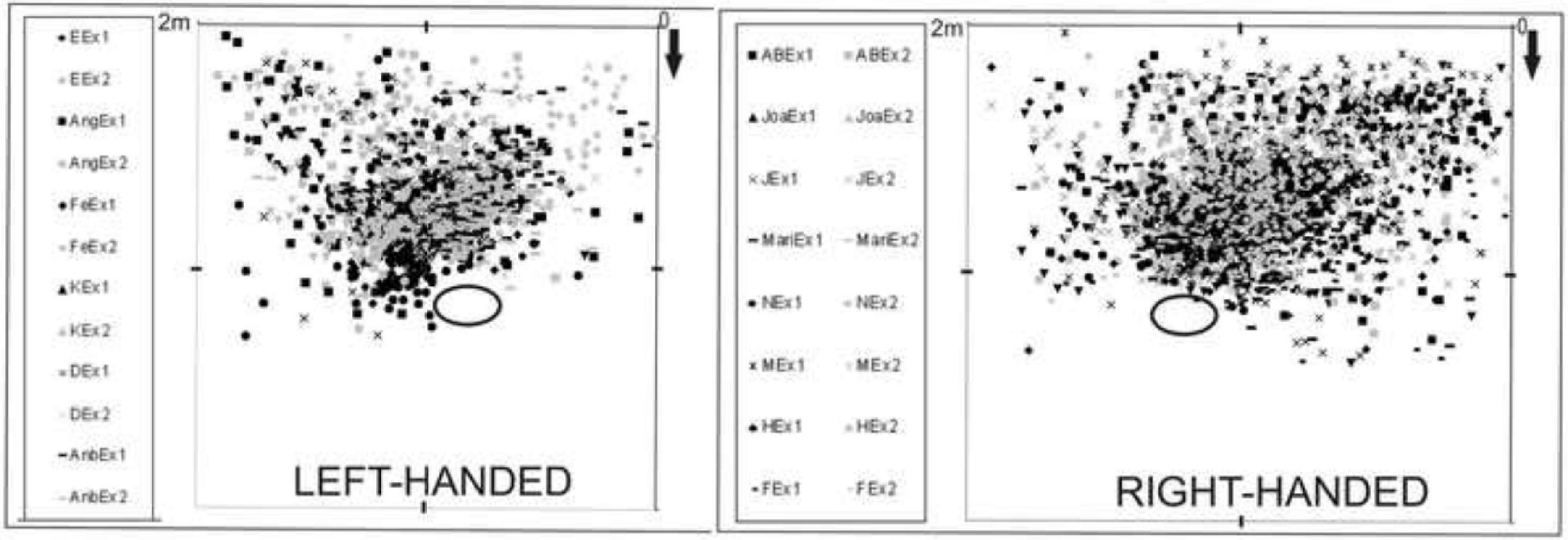
X: 120 Y:156
X:75 Y:140
X: 119 Y:140
N

Figure

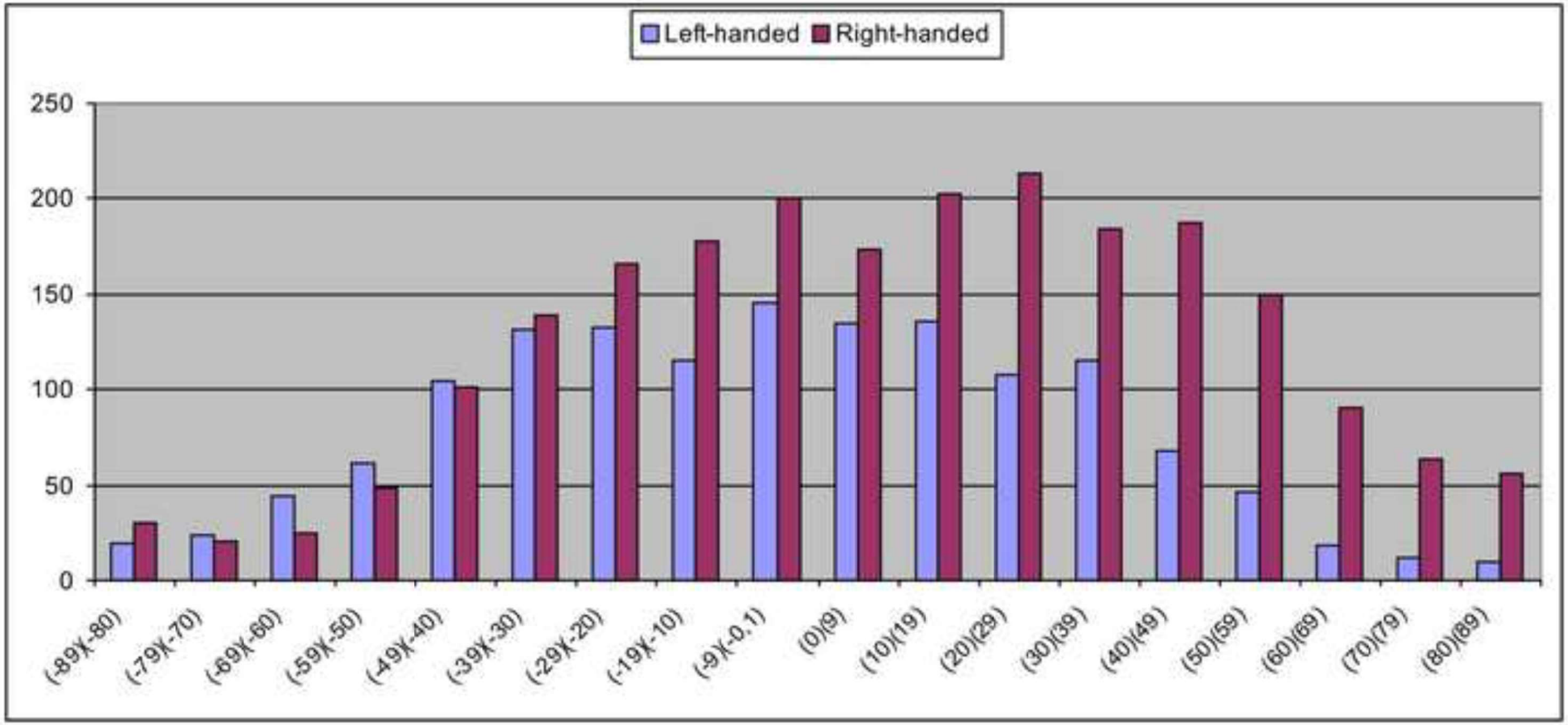

1600
1400
1200
1000
800
600
400
200
200
400
600
800
1000
1200
1400
1600
1800
2000
2200
h
β
α
IB̂
Wooden Log
lithic item

Figure



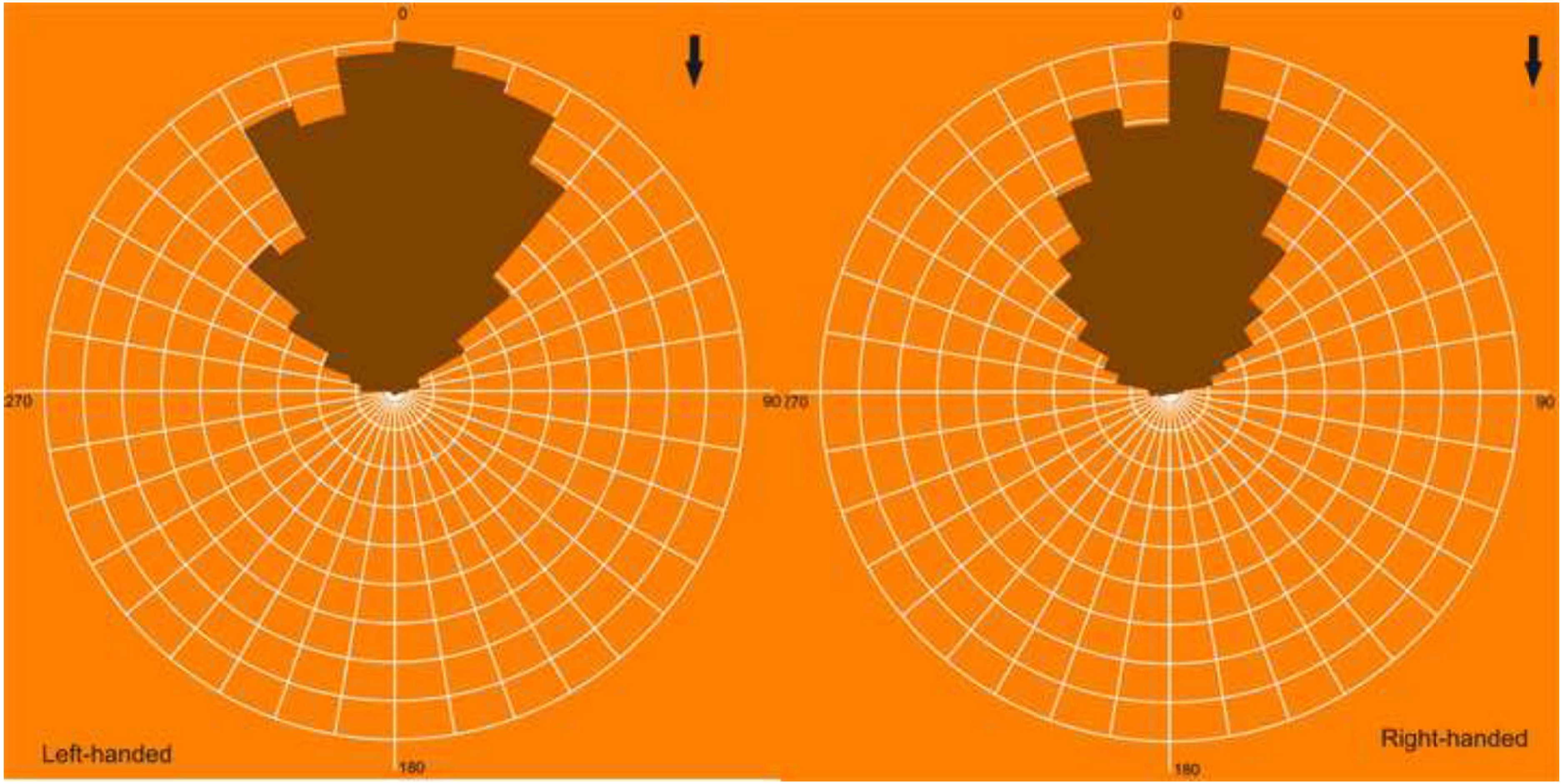
EEx1
EEx2
AngEx1
AngEx2
FeEx1
FeEx2
KEx1
KEx2
DEx1
DEx2
AnbEx1
AnbEx2
2m
0
LEFT-HANDED
ABEx1
ABEx2
JoaEx1
JoaEx2
JEx1
JEx2
MarEx1
MarEx2
NEx1
NEx2
MEx1
MEx2
HEx1
HEx2
FEx1
FEx2
2m
0
RIGHT-HANDED

Figure

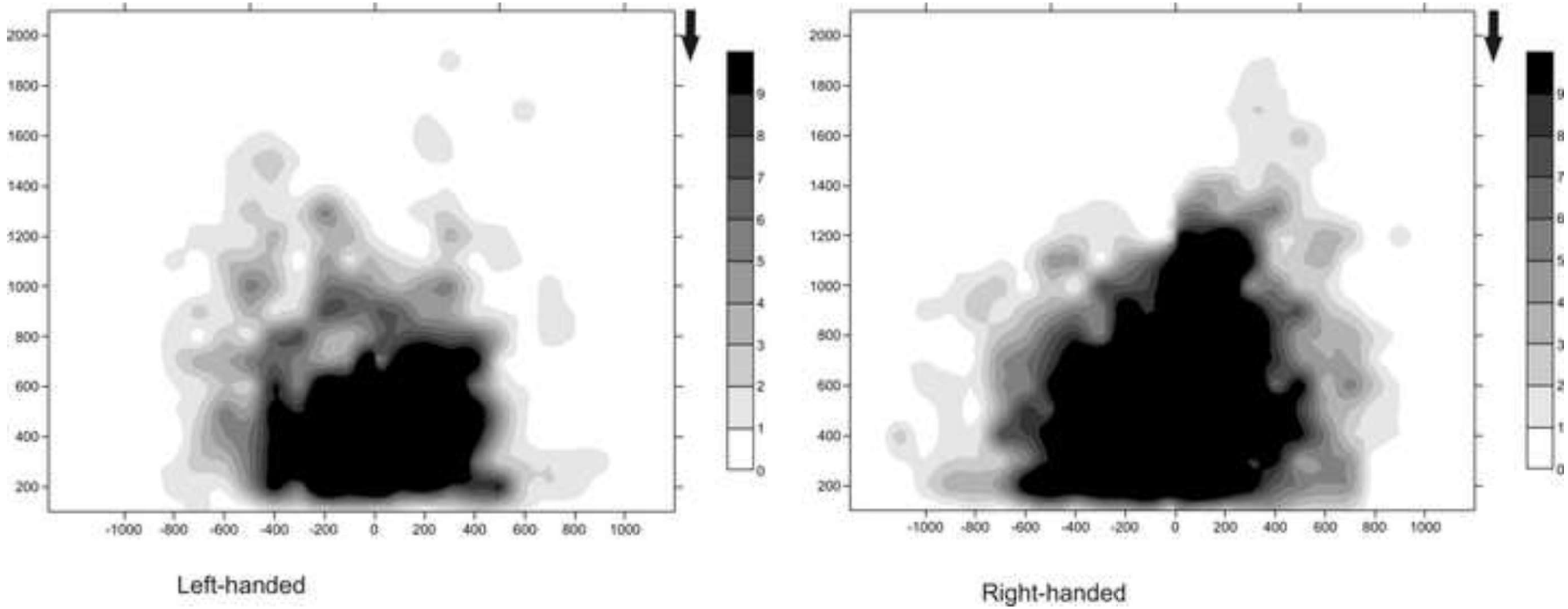


Left-handed
Right-handed
250
200
150
100
50
0
(-89)(-80)
(-79)(-70)
(-69)(-60)
(-59)(-50)
(-49)(-40)
(-39)(-30)
(-29)(-20)
(-19)(-10)
(-9)(-0,1)
(0)(9)
(10)(19)
(20)(29)
(30)(39)
(40)(49)
(50)(59)
(60)(69)
(70)(79)
(80)(89)

Figure

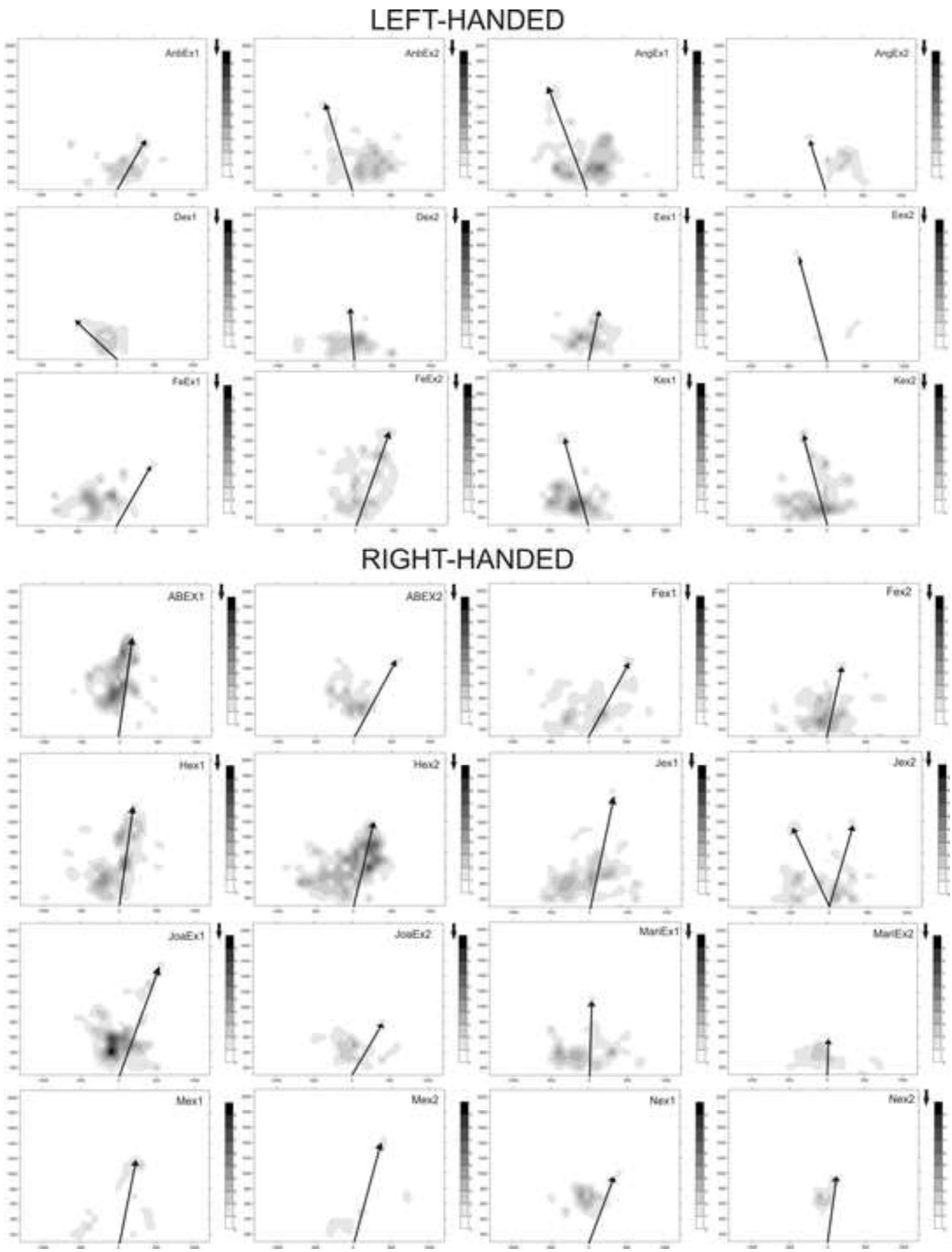


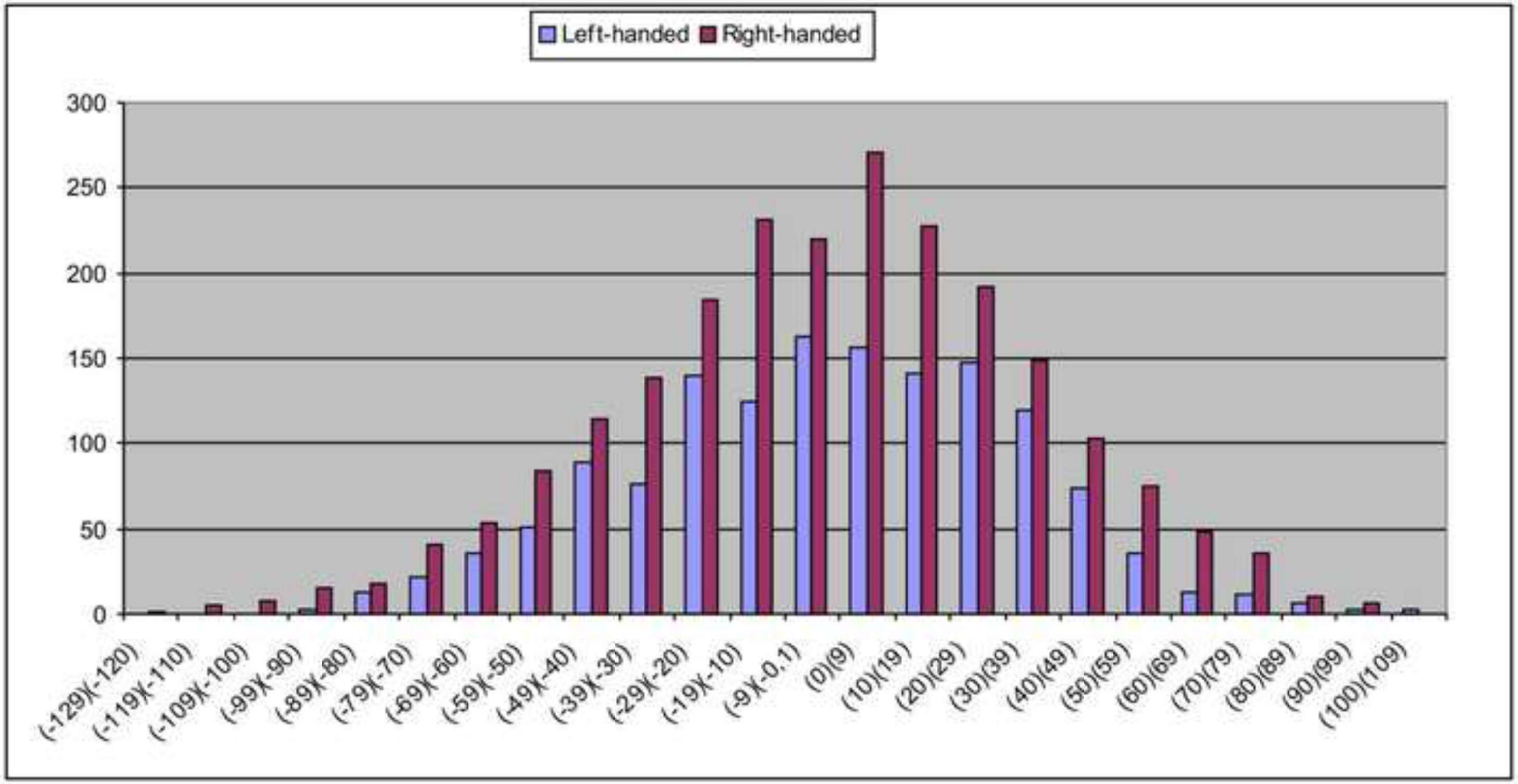
Figure


2000
1800
1600
1400
1200
1000
800
600
400
200
-1000 -800 -600 -400 -200 0 200 400 600 800 1000
0 1 2 3 4 5 6 7 8 9
Left-handed
Right-handed

Figure

Click here to download Figure Figure 7_r.jpg





Left-handed
Right-handed
300
250
200
150
100
50
0
(-129)(-120)
(-119)(-110)
(-109)(-100)
(-99)(-90)
(-89)(-80)
(-79)(-70)
(-69)(-60)
(-59)(-50)
(-49)(-40)
(-39)(-30)
(-29)(-20)
(-19)(-10)
(-9)(-0,1)
(0)(9)
(10)(19)
(20)(29)
(30)(39)
(40)(49)
(50)(59)
(60)(69)
(70)(79)
(80)(89)
(90)(99)
(100)(109)

KNAPPER	Handedness	Knowledge	Sex	Age
E	Left-handed	Visuals	W	39
Ang	Left-handed	Visuals	M	30
Fe	Left-handed	None	M	45
K	Left-handed	None	W	32
D	Left-handed	Technical	M	31
Anb	Left-handed	None	W	28
AB	Right-handed	None	W	27
Joa	Right-handed	Visuals	W	28
J	Right-handed	Visuals	M	29
Mari	Right-handed	Technical	W	45
N	Right-handed	Visuals	W	26
M	Right-handed	None	W	25
H	Right-handed	Visuals	M	34
F	Right-handed	None	M	33

Handedness	Partcipants	total pieces	total handedness
Left-handedness	EEx1	111	1485
	EEx2	96	
	AngEx1	187	
	AngEx2	68	
	FeEx1	131	
	FeEx2	164	
	KEx1	146	
	KEx2	162	
	DEx1	69	
	DEx2	115	
	AnbEx1	94	
	AnbEx2	142	
Right-handedness	ABEx1	216	2231
	ABEx2	103	
	JoaEx1	225	
	JoaEx2	85	
	JEx1	183	
	JEx2	130	
	MariEx1	132	
	MariEx2	69	
	NEx1	89	
	NEx2	51	
	MEx1	76	
	MEx2	60	
	HEx1	205	
	HEx2	286	
	FEx1	145	
	FEx2	176	
TOTAL	28 scatters	3716	3716

Degree intervals	Left-handed	Right-handed
(-89)(-80)	13,1	14,1
(-79)(-70)	16,6	9,9
(-69)(-60)	30,3	11,7
(-59)(-50)	42,1	23,0
(-49)(-40)	71,7	47,4
(-39)(-30)	91,0	65,3
(-29)(-20)	91,7	77,9
(-19)(-10)	79,3	83,6
(-9)(-0,1)	100,0	93,9
(0)(9)	93,1	81,7
(10)(19)	93,8	95,3
(20)(29)	74,5	100,0
(30)(39)	54,7	86,4
(40)(49)	46,9	88,3
(50)(59)	31,7	70,4
(60)(69)	12,4	42,3
(70)(79)	8,3	30,0
(80)(89)	6,9	26,3

Supplementary Material

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Supplementary Material
Supplementary information 2 Table S2_rr.jpg