Rose diagrams and statistical tests for archaeological orientation data: a case applied to the Southfleet Road Elephant site, Ebbsfleet, UK

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Abstract

Archaeologists and other fieldworkers frequently record the orientation of artefacts or faunal remains in order to understand depositional and post-depositional processes. However, analysis of this kind of data is complex and not always well-understood by investigators. For example, *rose diagrams* are commonly used to display orientation data. While rose diagrams are a useful and intuitive way of visualizing the data, they are not on their own sufficient except in cases where preferential orientation is very evident. Class frequency, rather than the square root of class frequency, is commonly used to interpret the results. This can give a misleading impression of preferential orientation, when in fact observed patterns do not deviate significantly from random. Conversely, data may deviate significantly from random but this may not be clear from the diagram. At the same time, classic tests like the chi-square test are not appropriate for the display of circular data and alternative approaches are needed. This paper discusses the history of the use of rose diagrams to display orientation data, briefly reviews the archaeological literature in this regard, and discusses key problems and limitations. We then make some recommendations for best practice, which we demonstrate using R software for the Lower Palaeolithic “elephant butchery site” at Southfleet Road, Ebbsfleet, UK, excavated in 2004. The methods employed are clearly explained and all data are provided to ensure that the procedure is easily repeatable without specialist knowledge or programming experience.

Keywords: circular data; orientation patterns; rose diagrams; Rayleigh test, Kuiper test, R software

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Introduction

Fieldworkers in archaeology and related geographical or spatial sciences frequently record the orientation of artefacts, sediments or features as means of learning about their deposition or subsequent modification by natural or anthropogenic processes. For example, bones of mammals naturally collected by the action of water flowing along a stream bed would be preferentially aligned in the direction of water flow, resulting in preferred orientation of bone long-axes markedly different to an undisturbed scatter of bones from animal butchery by a hominid group (see, e.g. Voorhies 1969, Shipman and Rose 1983). Orientation is also relevant to more recent archaeological periods, since human cultures and societies have frequently tended to bury their dead aligned towards features or monuments such as mountains, astral bodies, or places of religious or cultural significance (Pearson 1999). Earth scientists also are frequently interested in orientation; sediment particles or drifting snow may be aligned in the direction of the prevailing wind, the orientation of stones (or linear scratches) in sediments or soils may signal the position of a downhill slope or the flow direction of a watercourse or sediment body (see e.g. Krumbein 1939, Rigsby 1960, Dietzel and Kleber 2012). And yet, while there are a number of excellent standard texts discussing the statistical treatment of so-called *circular data* (e.g. Fisher 1993, Jammalamadaka and Sengupta 2001), an up-to-date and detailed discussion of methods applicable to archaeological cases is generally lacking. In addition, while many, perhaps most, studies of orientation data in archaeology and related geographical sciences use a popular graphical technique known as a *rose diagram* to display and interpret the data, the technique has some pitfalls which are not commonly aired, and, we think, ought to be more widely known. Though several excellent alternative methods of displaying orientation data have been advanced in the literature (Wells 2000), rose diagrams are ideal for simplicity and clarity. However, a detailed discussion of how to use them appropriately in an archaeological context is long overdue. Finally, most studies of orientation go no further than the graphical depiction of the orientation measurements, complemented by an intuitive interpretation of significance or otherwise. Although a pattern may seem very clear from the diagram, the graphic is rarely accompanied by the necessary or suitable statistical testing

In this article we address some of these shortcomings and research gaps with application to a recent archaeological case study from the UK, where excavations in 2004 at Southfleet Road, Ebbsfleet, in advance of the High Speed 1 rail link revealed a fragmented specimen of the extinct straight-tusked elephant *Palaeoloxodon antiquus* in sediments dating to the Middle Pleistocene, c. 420,000

BP [years Before Present]. The skeletal remnants were associated with flint artefacts, and the site was interpreted as representing butchery of the carcass by a group of hominids (Wenban-Smith 2013). We begin by discussing the history of rose diagrams for displaying orientation data. We then briefly review the literature, discuss some of the difficulties of the technique and the data, leading us to make some recommendations for best practice. We then show the detailed application of the technique to the Southfleet Road elephant site data, and demonstrate the application of a pair of useful statistical tests that are robust and easy to apply.

Research Background

Orientation measurements were displayed in the form of rose diagrams, a form of representing circular or periodic data attributed to Florence Nightingale (see Fisher 1993), the nineteenth century medical reformer and founder of applied statistics. In Nightingale's work, the circular plot depicted months of the year, with class frequencies being the number of deaths recorded in the British army from various causes for each month of the year. Schmidt (1917), investigating the micro-crystalline structure of slate, analysed orientation data by dividing class frequencies into 5° groups, and plotting them as points on a compass circle at a distance from the centre of the circle equal to the class frequency. By joining the points, orientation data were expressed as spikes extending outward from a circle, preferential orientation being highlighted by the zones having the longest distance from the centre of the circle. The key difference between Nightingale's rose and Schmidt's diagrams relates to Nightingale's use of a wedge, rather than a spike, and that Nightingale plotted the area of the wedge as proportional to the class frequencies, while Schmidt made a decision that has resurfaced in discussion of orientation rose diagrams ever since (see Wells 2000, and discussion later on in this section), and plotted the petal length as proportional to class frequency. Numerous examples of rose diagram plots are found in geological, palaeontological and archaeological literature and the most usual form is essentially a combination of Nightingale's area wedge approach and Schmidt's radius distance method⁵; see, for example, Shipman (1981, also citing earlier material), Kreuzer (1987), Bertan and Texier (1995), Roberts *et al* (1997), Sahnouni and de Heinzelin (1998), McPherron (2005), Bernatchez (2010), and Allen *et al* (2015). Wells (2000), who has investigated in some depth the use of rose diagrams and other types of plots for circular datasets, cautions that rose diagrams are not appropriate for all orientation data, since they are rather sensitive to (usually arbitrary) decisions about class width (bin size) and starting

5 Although see Dibble 1997 for an approach rather closer to Schmidt's original method.

position, and care should be taken, for example, if evidence of preference for a particular degree class is sought, rather than a generalized preference for a cardinal direction⁶. Wells' principal concern, however, relates to the frequent use of Schmidt's, rather than Nightingale's, approach to radius wedge lengths, whereby rose petals are scaled proportionally to class frequency rather than area (see also Fisher 1993), as this exaggerates the size of the rose petals giving a misleading impression of the degree of variation between the classes. It might be argued that this is not an error as such, rather an exaggeration of tendencies in the data, but nevertheless, given the limitations mentioned above regarding class width and starting position, it should be avoided, so as not to give the misleading impression of preferential orientation (patterned data), where the distribution in fact differs little from that obtainable by chance. Fortunately, this problem can be easily avoided by ensuring that the radii of the wedges are equal to the *square root*, not the *value* of the relative class frequencies. Many rose diagram plotting packages (e.g. GeoOrient) already take this into account though some (e.g. Rosetta) do not. In this analysis, which we carried out in the R statistical environment, we used the *CircStats* package module *rose.diag*, which allows for square root scaling⁷.

Some types of data, such as bone long-axes in a palaeo-channel, may be considered to have one of two possible orientations, depending on the starting point chosen by the fieldworker to record the bearing; these types of data are typically plotted as what Shipman (1981) refers to as "mirror-image" rose diagrams, that is, rose diagrams where one half of the compass circle reflects exactly the other; most of the archaeological and palaeontological examples from the literature, e.g. Kreuzer (1987), Roberts *et al* (1997), Sahnouni and de Heinzelin (1998) are of this type. The other type, which need not concern us here, are derived from measurements of vectors having a clear "direction from" and "direction to", such as wind data, or as in one recent study, of ice-rafted boulders whose location and "walk" orientation had been recorded year-on-year over several seasons (Allen *et al* 2015).

Statistical tests of significance for preferred orientations have, naturally enough, developed

6 Often, this may not present a problem. For example, in a recent paper on orientation data for ice-rafted boulders on the surface of Lake Hoare, Antarctica (Allen *et al* 2015), these considerations were found not to be relevant in the light of the clear grouping of orientations in the upper left hand section of the compass circle (preferential orientation toward the north-west).

7 Other rose diagram plotting modules are available in R, such as *rose* and *rose2* from the *heR.Misc* package. To our knowledge, neither of these modules offer an option available *as is* to draw petal radii according to the square root of class frequency.

alongside graphical plotting techniques such as rose diagrams. It will suffice to say here that virtually any statistical treatment of circular data is subject to various caveats, but in general, the most commonly used significance test, the chi-square test, where sample class frequencies are tested against a theoretical probability curve derived from the chi-square distribution, is nowadays regarded by most authors as inadequate, following criticism of the technique by, amongst others, Ballantyne and Cornish (1978), and Wells (1990). The main problem seems to be that by simply varying the point of origin for the class groupings, a wide range of chi-square values are obtained, such that no one value can be considered to represent the sample set, and meaningful results are not therefore obtainable. Various alternative options have been explored, such as Ajne's A_n statistic (Dale and Ballantyne 1980), comparison of sample data with idealized models (Shipman 1981), a modified chi-square test (Wells 1990), and the Rayleigh test (Bernatchez 2010).

Case study: the Southfleet Road elephant site

Ground works carried out in 2003 during the construction of the High Speed 1 rail link and Ebbsfleet International station (HS1) in the Ebbsfleet valley, northwest Kent (Figure 1) revealed a complex sequence of Pleistocene sediments. Controlled excavations carried out the following year revealed the remains of a partial skeleton of straight-tusked elephant *Palaeoloxodon antiquus*, in association with a dense cluster of mint condition lithic artefacts (Wenban-Smith 2013). Though subsequent detailed investigation of the elephant bones did not reveal any unequivocal evidence of cut marks relating to butchery, the condition of the associated flint artefacts indicates early human tool manufacture on the spot, strongly suggesting direct exploitation of the elephant carcass. Excavations recovered 47 fragmentary identifiable elephant elements, two molars, two substantial portions of the left and right tusks and 27 tusk fragments from an area of around 25m², with a separate scatter of articulating foot bones c. 15m to the northeast. The lack of duplication in the bones and consistency in size and ontogenetic age indicate that all the bones came from a single, extremely large adult individual. The main scatter had a linear form, orientated approximately northwest to northeast. (Parfitt et al 2013). Given that the bones belonged to a single individual, and that some were articulated, investigators were keen to investigate their orientation in order to understand site formation processes, and to consider the possible role of human behaviour as opposed to natural processes.

Figure 1: Location of the Southfleet Road elephant site, Ebbsfleet Valley, Kent

Methods

Bone long axes orientations were recorded by excavators in the field using a compass. Since a bone can be said to point in either of two directions separated by 180° , no preference was given in the field to either compass mode, thus 1° and 181° represent the same angle of orientation. The data were manually recorded, hand-entered into spreadsheet software, and imported into R software (R Core Team 2016) for analysis (Table 1). R was then used to plot the data, using the *CircStats* package module *rose.diag* (Lund and Agostinelli 2018).

Table 1 (below). Data for orientation of elephant long bone fragments by 20 degree classes, showing class frequency. Data are axial, not vectorial (each measurement has two potential orientations separated by 180 degrees).

ID	class	frequency
1	0-20	4
2	21-40	2
3	41-60	14
4	61-80	8
5	81-100	13
6	101-120	10
7	121-140	6
8	141-160	6
9	161-180	3
TOTAL		66

The full R-command line output for the dataset is given in Appendix I.

The *aspace* library was required to convert the data to radians, and the *CircStats* library was used to plot the rose diagrams with the *rose.diag* module. As the data are axial orientations (each measurement has two potential orientations separated by 180 degrees) the data were combined with their mirror image, to produce a mirror-image rose diagram of 132 orientations (Figure 2). This common technique for representing axial data is acceptable visually, but is not suitable for statistical analysis. The appropriate techniques for statistical analysis of axial data are discussed in the following section.

After generating the plot, graphics software was used to flip and rotate the diagram to follow the standard conventions for geographical coordinates (*rose.diag* by default outputs to mathematical coordinate conventions, where angles turn anti-clockwise from zero at the right hand side of the circle). Alternate bars were filled following Kreuzer (1987). Figure 1 shows the results of this plot.

Figure 2: Mirror-image Rose Diagrams of elephant bone long-axis orientations from Southfleet Rd. Left hand plots in 10° bins, right hand plots in 20° bins. A & B: raw plots from R with angles turning counter-clockwise from 0° at the right; C & D: Rotated and flipped to turn angles clockwise from 0° at the top of the plot; E & F: Alternate bars filled for emphasis, after Kreuzer (1987).

Statistical analysis

As noted earlier, the standard chi-square test, often used for determining significant preference for membership of a particular class from sets of contingency tables, is not really appropriate in its unmodified form for circular data. Figure 2 appears to indicate that the assemblage may be preferentially oriented WNW-ENE, but without a reliable independent assessment of the degree of variation from a non-preferential (random) orientated sample set it is difficult to be sure. Thus a statistical test of some kind is needed. If all angles are represented with the same degree of probability in the data set, then we may describe the pattern as uniform, and a statistical test for circular uniformity against a possible alternative is appropriate. If the alternative hypothesis to circular uniformity is a unimodal distribution (strongly preferential orientation in one direction), then the most powerful and commonly used test is the Rayleigh test. Where the alternative hypothesis is not a unimodal distribution (for example preferential orientation along two or more separate axes), then Bogdan et al (2000) argue that a more general, or "omnibus" test would be more appropriate, such as Kuiper's, Watson's, Anje's or Rao's tests (Bogdan *et al* 2000). In this dataset, a preferential orientation along one particular axis is expected, so, provided we can get around the difficulty that each orientation is potentially represented twice in the dataset, the Rayleigh test is clearly appropriate.

To do this, we see that the procedure used for plotting the rose diagram, (generating a second set of "mirrored" measurements, and adding them to the first) should be avoided in this case, as this artificially generates a polymodal distribution with twice the number of measurements actually recorded. Thus a different approach is required that will aggregate the measurements with their opposites on the compass circle without creating duplication, thus generating a unimodal distribution appropriate for the test. This can be accomplished with the following equation (after Berens 2009; see also Fisher 1993, p. 37), see also Table 2.

$$\alpha_i = \rho \alpha_i \pmod{2\pi} \quad (1)$$

Where α_i represents the new angle, and ρ is the number of modes (in this case 2, for 2-dimensional axial data). Thus the measurements are first multiplied by 2, and then adjusted (Modulo 2π) for the whole circle. Table 2 (below), shows this process for the first 5 bearing measurements. Note that as both modes give the same result; it is only ever necessary to calculate one mode.

Table 2 (below), adjustment of axial data to a unimodal distribution (See Appendix I for complete data)

mode 1			mode 2		
bearing	radians	$\alpha = \text{mod}(\alpha * p, 2\pi)$	bearing	radians	$\alpha = \text{mod}(\alpha * p, 2\pi)$
1	0.017	0.035	181	3.159	0.035
1	0.017	0.035	181	3.159	0.035
27	0.471	0.942	207	3.613	0.942
31	0.541	1.082	211	3.683	1.082
46	0.803	1.606	226	3.944	1.606
47	0.820	1.641	227	3.962	1.641

The Rayleigh test is applied by calculating the average bearing of the adjusted angles using a standard trigonometrical procedure for vectors of unknown magnitude known as Mardia's method or the unit vector average approach (Mori, 1987). The sum of all unit vectors is then used to derive a mean direction vector for the dataset, known as the *mean resultant* (r) by the Pythagorean equation. The step-by-step process is as follows:

First, each orientation measurement (θ) is treated as a unit vector (v) with direction θ and magnitude (m) = 1 and transformed into component form (i, j) by simply taking $\cos \theta$ (i) and $\sin \theta$ (j). All i and all j for each vector are then summed to produce I and J as shown in equations 2 and 3.

$$I = \sum_{x=1}^n m(\cos \theta_x) \quad (2)$$

$$J = \sum_{x=1}^n m(\sin \theta_x) \quad (3)$$

The mean resultant (r) is then calculated as follows:

$$r = \frac{\sqrt{I^2 + J^2}}{n} \quad (4)$$

Finally, the critical value for the test, or Z score, is computed by:

$$Z = nr^2 \quad (5)$$

Where n is the number of observations and r is the mean resultant as calculated above. The Z value is then compared to a table of critical values for Rayleigh's z, such as that given by Zar (1999). For a step-by-step tutorial for the Rayleigh test, see Forrest (*undated*). In this case, the Rayleigh test was computed in excel and subsequently in R, using the *rayleigh.test* routine contained in package *circular*. The test Z score of 6.342 allowed the null hypothesis (uniform orientation) to be rejected with a significance level (p-value) of <0.002 (in fact recorded by R as 0.0018).

Table 3: Results of the Rayleigh test for Southfleet rd elephant bone fragment orientations.

Number of observations	66
Sum of all i	1.222
Sum of all j	-20.423
i squared	1.493
j squared	417.102
Mean resultant (r) by Eqn 4	0.310
The Rayleigh test: to calculate the critical value (Z) for the test, we use $Z = n * r^2$, where n is the number of observations and r is the mean resultant calculated above	
Z	6.342
Compared with tables in Zar, J. H. 1999. Biostatistical Analysis, 4th ed. Prentice Hall, Upper Saddle River, NJ gives a significant result at a probability of < 0.002	
R gives 0.0018	

The Rayleigh test seems to indicate a non-uniform distribution, supporting the impression given by the rose diagram that the data are preferentially oriented WNW-ENE. To confirm these results, a second classic statistical test for circular data, the Kuiper test, was applied. In the Kuiper test, a variant of the Kolmogorov-Smirnov test adapted for periodic data, empirical data (the sample of

long bone orientations), are compared against an ideal distribution representing uniform data. Since the test involves cumulative distribution functions, it is not easy to replicate in an excel spreadsheet, and the test was carried out in R, using the *kuiper.test* routine contained in package *circular* with the same adjusted angular dataset as used for the Rayleigh test. According to Kuiper's test (Test Statistic: 2.4422), the null hypothesis (uniform orientation) can be rejected at a significance level of <0.01 , less convincingly than with the Rayleigh test, but still much better than the <0.05 significance level commonly accepted in scientific literature. Within reasonable doubt, a preferential orientation for this data sample may be inferred.

Conclusion

This article has illustrated what we consider, on the basis of careful study of the technique and detailed examination of the relevant literature, to be “best practice” for preparing rose diagrams and applying statistical tests to orientation measurements from archaeological sites, be they mammal bone assemblages from Palaeolithic sites like the case study example, or alignments of monuments, architectural features or burials relating to the archaeology of later periods. In particular, three important lessons emerge from our study; 1) rose diagrams should be square-root scaled, as Wells (2000) has previously recommended, but which is still not always accounted for in software packages; 2) axial or “mirror image” orientation measurements need to be adjusted as shown in the article to produce a unimodal distribution suitable for analysis, and finally, 3) the popular chi-square test, so useful in many situations, is not recommended for orientation data since the results are very dependent on the choice of bins, which is usually arbitrary. While Wells (1990) has proposed a workaround, the simple Rayleigh test (which can be carried out in an excel spreadsheet) is a probably a better alternative as long as a single preferential orientation is expected. If there is a suggestion that multiple preferred orientations are possible, omnibus tests like Kuiper's (used here), Watson's, Anje's or Rao's tests are recommended.

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Appendix I, raw orientation data, adjustments for axial data, and component form

PI	P (# of modes)	n (# of observations)			
3.141592654	2	66			
Raw orientation data (degrees)	Radians	Corrected for axial data (Eqn 1)	i and j components		
			i	j	
1	0.017	0.035	0.035	0.999	
1	0.017	0.035	0.035	0.999	
27	0.471	0.942	0.809	0.588	
31	0.541	1.082	0.883	0.469	
46	0.803	1.606	0.999	-0.035	
47	0.820	1.641	0.998	-0.070	
47	0.820	1.641	0.998	-0.070	
48	0.838	1.676	0.995	-0.105	
49	0.855	1.710	0.990	-0.139	
49	0.855	1.710	0.990	-0.139	
52	0.908	1.815	0.970	-0.242	
52	0.908	1.815	0.970	-0.242	
53	0.925	1.850	0.961	-0.276	
53	0.925	1.850	0.961	-0.276	
55	0.960	1.920	0.940	-0.342	
65	1.134	2.269	0.766	-0.643	
70	1.222	2.443	0.643	-0.766	
71	1.239	2.478	0.616	-0.788	
75	1.309	2.618	0.500	-0.866	
77	1.344	2.688	0.438	-0.899	
80	1.396	2.793	0.342	-0.940	
84	1.466	2.932	0.208	-0.978	
86	1.501	3.002	0.139	-0.990	
88	1.536	3.072	0.070	-0.998	
90	1.571	3.142	0.000	-1.000	
93	1.623	3.246	-0.105	-0.995	
97	1.693	3.386	-0.242	-0.970	
99	1.728	3.456	-0.309	-0.951	
100	1.745	3.491	-0.342	-0.940	
105	1.833	3.665	-0.500	-0.866	
111	1.937	3.875	-0.669	-0.743	
113	1.972	3.944	-0.719	-0.695	
120	2.094	4.189	-0.866	-0.500	
121	2.112	4.224	-0.883	-0.469	
123	2.147	4.294	-0.914	-0.407	
124	2.164	4.328	-0.927	-0.375	
134	2.339	4.677	-0.999	-0.035	
137	2.391	4.782	-0.998	0.070	
141	2.461	4.922	-0.978	0.208	

144	2.513	5.027	-0.951	0.309
148	2.583	5.166	-0.899	0.438
155	2.705	5.411	-0.766	0.643
160	2.793	5.585	-0.643	0.766
165	2.880	5.760	-0.500	0.866
176	3.072	6.144	-0.139	0.990
193	3.368	0.454	0.438	0.899
196	3.421	0.559	0.530	0.848
233	4.067	1.850	0.961	-0.276
234	4.084	1.885	0.951	-0.309
235	4.102	1.920	0.940	-0.342
252	4.398	2.513	0.588	-0.809
260	4.538	2.793	0.342	-0.940
264	4.608	2.932	0.208	-0.978
266	4.643	3.002	0.139	-0.990
267	4.660	3.037	0.105	-0.995
272	4.747	3.211	-0.070	-0.998
278	4.852	3.421	-0.276	-0.961
287	5.009	3.735	-0.559	-0.829
288	5.027	3.770	-0.588	-0.809
294	5.131	3.979	-0.743	-0.669
295	5.149	4.014	-0.766	-0.643
295	5.149	4.014	-0.766	-0.643
297	5.184	4.084	-0.809	-0.588
311	5.428	4.573	-0.990	-0.139
321	5.603	4.922	-0.978	0.208
350	6.109	5.934	-0.342	0.940

Appendix II, command-line output from R for rose diagrams and statistical tests

#load required libraries

```
library(aspase) #necessary for conversion to radians
library(CircStats) #necessary for rose diagram plots
library(circular) #necessary for statistical tests
```

#set working directory location

```
setwd("E:\\publications\\ongoing\\JAS\\R")
```

#plot rose diagrams

```
eleforient <- read.table("eleflongorient.csv",sep="," , header=T)
> head(eleforient,5)
  orient
1      1
2      1
3     27
4     31
5     46
> elefrad <- data.frame(lapply(eleforient,as_radians))
> head(elefrad,5)
  orient
1 0.01745329
2 0.01745329
3 0.47123890
4 0.54105207
5 0.80285146
rose.diag(elefrad, bins=18, main="Southfleet road elephant bone long axis orientations", prop=0.25,
pts=TRUE, cex=0.5, pch=16, dotsep=20, shrink=1.3)
svg("rose_mirror_18bins.svg",width=20,height=20)
rose.diag(elefrad, bins=18, main="Southfleet road elephant bone long axis orientations", prop=0.25,
```

```
pts=TRUE, cex=0.5, pch=16, dotsep=20, shrink=1.3)
dev.off()
```

#statistical tests

```
elefadj <- read.table("elefrad.csv",sep=",", header=T)
```

```
> head(elefadj,5)
```

```
Corrected.for.axial.data
1          0.035
2          0.035
3          0.942
4          1.082
5          1.606
```

```
> rayleigh.test(elefadj)
```

```
Rayleigh Test of Uniformity
General Unimodal Alternative
```

```
Test Statistic: 0.31
```

```
P-value: 0.0018
```

```
Warning message:
```

```
In as.circular(x) :
```

```
an object is coerced to the class 'circular' using default value for the following components:
```

```
type: 'angles'
```

```
units: 'radians'
```

```
template: 'none'
```

```
modulo: 'asis'
```

```
zero: 0
```

```
rotation: 'counter'
```

```
conversion.circularxradians0counter2pi
```

```
> kuiper.test(elefadj,alpha=0)
```

Kuiper's Test of Uniformity

Test Statistic: 2.4432

P-value < 0.01

Warning message:

In as.circular(x) :

an object is coerced to the class 'circular' using default value for the following components:

type: 'angles'

units: 'radians'

template: 'none'

modulo: 'asis'

zero: 0

rotation: 'counter'

conversion.circularxradians0counter2pi

#save R workspace and data, save command history

save.image("elefroze.RData")

savehistory()