THE EVOLUTION OF CUBIC DICE
FROM THE ROMAN THROUGH POST-MEDIEVAL PERIOD IN THE NETHERLANDS

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ABSTRACT

Cubic dice were brought by the Romans to the Low Countries, and are found in small numbers at many archaeological sites dating to the last 2000 years. We report on a systematic analysis of 110 well-dated dice from the Netherlands, showing that shape, pip configuration, and pip style changed significantly for bone and antler dice from the Roman to the recent historical period. Dice predating 650 CE are highly variable in all attributes, those dating between 1100 and 1450 are highly standardized, and those post-dating 1450 CE are standardized for some attributes, such as symmetry and configuration, but variable for others, such as material type. There is also a major shift from "sevens" to "primes" and back to "sevens" pip configuration across these temporal windows, and pip style was simplified over time from a dot-ring-ring pattern to simple dots. We compare these trends to a smaller set of well-dated dice from the United Kingdom and speculate on possible reasons for these changes. The information can be used in future studies in the Netherlands to help date sites and/or isolated finds, and more broadly, can be augmented with similar analyses of dice elsewhere in Eurasia to study ancient interaction networks and the cultural transmission of games involving dice play.

INTRODUCTION

Cubic dice are found in a wide range of archaeological contexts, including generalized garbage, domestic, and mortuary contexts in sites in the Low Countries of Northwestern Europe, and elsewhere in Eurasia (e.g. Hall 2016; Margeson 1993, 215-217). While cubic dice date to at least the third millennium BCE in southwest Asia (Dales, 1968; van der Heijdt, 2001), in the Netherlands, the first dice appear in the Roman period (0-400 CE). The archaeological record regarding dice in the Netherlands is very limited for the remainder of the first millennium (the Early Middle Ages, ca. 400-1000 CE), but dice reappear in the early part of the second millennium, when dice games were particularly popular. Indeed, hundreds of different game rules including those for dice have been recorded in historical documents for this period in Western Europe (e.g. Semrau 1909).

At the end of the Middle Ages, ca. 1300-1500 CE, the role of dice in games changed. In the second half of the fourteenth century card games became popular, first in Italy and France, and later reaching other regions and all layers of the population in the fifteenth century (Mehl 2009, 20–21; Murray 1952). Cards became more popular than dice as they were useful not only for gambling, but also for strategy games. In the fifteenth century CE Europe also saw the development of the lottery that reached the Low Countries around 1440 (Zollinger & Depaulis 2012). This suggests that Medieval game-playing transitioned into a new era around 1450 CE when dice were no longer the main material for gambling. As we show below, the archaeological record in terms of the number of sites and finds largely follows the division between Roman, Late Medieval (i.e. Late Middle Ages), and post-Medieval periods, but the possible changes in the physical appearance of dice has remained unclear.

Dice typically comprise a minor component of the materials produced in excavations. A few notable exceptions aside (e.g. Artioli et al. 2011; Brown 1990; de Voogt et al. 2015; Egan 1997; Krüger 1982; van der Heijdt 2001; Willemsen 2000), dice have not played an important role in either the dating of sites, site interpretation, or understandings of ancient human cultures in this part of Europe. Excavation reports typically mention the discovery of dice in passing, particularly if they are surface finds. They occasionally include drawings or photographs, and more rarely metrical data on die shape, and are then placed in an "other" or "small finds" category in

Fig. 1. Map of the Netherlands. Numerals indicate locations of finds of six-sided cubic dice in study and the number of samples from that location. Refer to Table 1 for site/area names.

archaeological reports. As a result, little is known about regional-scale morphological variation in dice, especially changes over time.

Although exacavations have produced small numbers of dice in many sites, their numbers are spread across numerous museums and archaeological depots, complicating a systematic comparison. Surface finds also tend to lack a reliable dating. In this paper, we present a synthetic analysis of the physical aspects of a large database of securely-dated dice, which offers the opportunity to catagorize these objects according to time period and/or region, creating a tool for dating dice and their associated sites. Although we shy away from larger interpretations regarding the context and use of dice in ancient human societies, the paper sets the stage for such analyses.

DATA SET

In 2013 we conducted a collection study at 18 museums and archaeological depots in the Netherlands in order to photograph and measure dice that pre-date 1900 CE leading to a set of 250 cuboid and ovoid dice. To this database a small number of dice was added from the literature that had secure dating and were described and photographed in excavation reports. These latter examples have missing

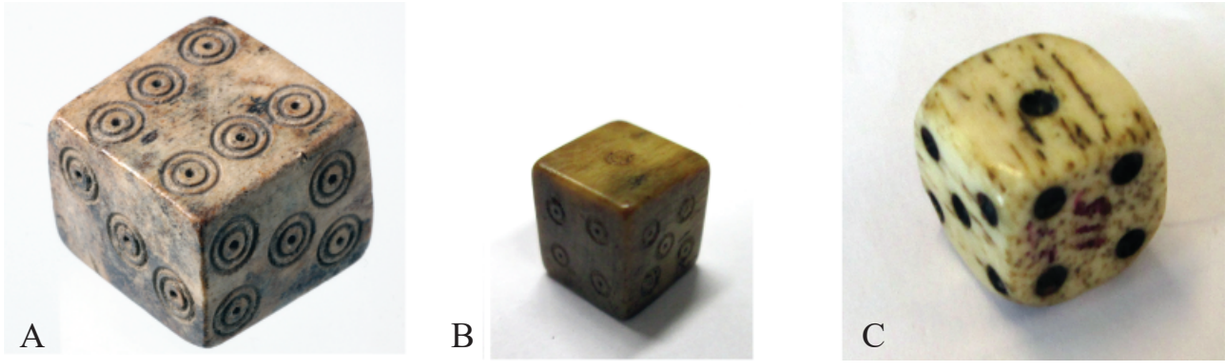

Fig. 2. Examples of dice from the Netherlands showing variation in pip style and symmetry: a) Roman die from Vechten; b) Medieval die from Nijmegen; c) Post-Medieval die from Rasquert.

data for some attributes (e.g., such as size or configuration), but were deemed complete enough for other attributes to complement the study.

Approximately one-fifth of the dice in the first dataset represent four-sided dice, especially "Westerwanna" types (Krüger 1982) from Friesland and Groningen, and are not included in the analyses below. As well, about half of the dice we examined have poor contextual information (e.g., only a general find location is reported or the chronological or stratigraphic association was unclear). In addition, we defined dating information only as sufficient if it stayed within a chronological window of 200 years or less. Those without adequate dating or contextual informaton were also omitted from the study. The final set consists of 110 six-sided cuboid dice.

Figure 1 shows the spatial distribution of our sample. Numerals in Figure 1 indicate the number of dice included in the sample from a particular site/area. These need not represent the exact same "site" or find location. Thus 24 dice from Amsterdam are in the sample, but represent a wide range of locations within the modern city. Indeed, most examples of dice from secure contexts include just one or two associated examples. On the other hand, 32 dice were measured from Amersfoort, 31 of which are from a single medieval period cache (Krauwer & Snieder 1994). The figure shows that the majority of dice in our sample are from the central portion of the Netherlands, from areas north of the Rhine. This is partly a reflection of the intensity of archaeological investigations associated with urban development in the Netherlands in and around Rotterdam and Amsterdam, with comparatively less excavation in more rural areas. Table 1 provides the site/area name and sample size by time period, ordered by geographic region within the Netherlands. Each row in the table corresponds to a location in Figure 1.

Our analysis focused on diachronic change in five attributes of dice: material type, configuration, pip style, and die size and shape. Each variable is explained below.

We discriminated five main materials for dice. The final sample of 110 includes one stone (marble), two glass, four metal (three bronze, one lead), seven fired clay (one glazed, six unglazed), and 96 organic (bone, antler, and ivory) dice. We grouped bone, antler, and ivory objects here because they are sometimes difficult to differentiate, especially among poorly-preserved examples. Future archaeometric analyses, such as Raman spectroscopy, could help determine or refine the material type for these items.

Die configuration denotes the relative position of the numbered faces relative to one another. With few exceptions, modern dice have opposite sides that tally to seven, such that the one is opposite the six, two opposite the five, and three opposite the four (commonly written 1-6, 2-5, 3-4). We refer to this as the "Sevens" configuration, but it is just one of many possible configurations. A quick calculation reveals that there are 15 unique possible configurations for cubic dice (Artioli et al. 2011; de Voogt et al. 2015), and as discussed below, many ancient dice do not follow the modern pattern of Sevens. Two additional configurations, "Primes" (1-2, 3-4, 5-6), where opposite sides add to unique prime numbers, and "Turned" (1-3, 2-4, 5-6), where the die is turned along one rotational axis to place the numbers sequentially, are also found in ancient dice worldwide in higher-than-expected frequencies if configuration was randomly determined (de Voogt et al. 2015).

Table 1: Sites/Areas and numbers of cubic dice in sample, by time period

Site/Area	0-650 CE	1100-1449 CE	Post 1450 CE	Total
Northwest				
Enkhuizen			1	1
Koedijk	1			1
Uitgeest	2			2
Heemskerk	1			1
Velsen	4			4
Amsterdam		2	22	24
Central				
Utrecht	1	3	3	7
Huis te Vleuten		1	1	2
Amersfoort		31	1	32
Nijmegen	6			6
Arnhem			4	4
Zutphen	1	2	3	6
Zwolle		1	1	2
Southwest				
Leiden		3		3
Den Haag	3			3
Nieuwenhoorn		1		1
Rotterdam			3	3
Dordrecht		2	1	3
Northeast				
Rasquert			1	1
Leermens			1	1
Ezinge			2	2
Southeast				
Borgharen	1			1
Total	20	46	44	110

Table 2: Distribution of material types by time period

Age CE	Organic	Clay	Metal	Glass	Stone	Total
Post 1450	39	1	1	2	1	44
1100-1449	45	1	0	0	0	46
0-650	12	5	3	0	0	20
Total	96	7	4	2	1	110

Pip style refers to the manner in which numbers are indicated on die faces. We recorded three main pip styles within the Dutch dice, including simple marks, or dots, dots with a single ring around them, and dots with two rings around them (see Figure 2). There are other styles for pips in ancient dice, including the use of Arabic or Roman numerals. However, dice in the latter styles did not occur in securely-dated contexts in the Netherlands.

Dice were also measured along their three major axes: length, width, and height. Each measurement was taken at the midpoint of a side (i.e., not diagonally). From these measurements, we calculuated the maximum/minimum side as a measure of symmetry (degree of departure from a true cube), and the average of the three sides as a measure of overall die size.

To evaluate change over time, both in average and in diversity (variation), we grouped the dice into three broad temporal windows. Our analysis focuses on those dating before 650 CE (with one exception, all were from the Roman period), those from 1100–1449 CE, and those after 1450 CE. These blocks were defined mainly through empirical means, based on general patterns in die style we noted within the data set, and on the historical record that informs our understanding of the use of dice in the Netherlands.

RESULTS

Material Type

Organic materials (bone, antler, ivory) are the most common medium for dice in all blocks of time (Table 2). Overall, there seems to be high diversity in material types prior to 650 CE (only 60% being organic materials), standardization between 1100 and 1449 CE (98% organic), and higher diversity again after 1450 CE (89% organic). Part of the standardization between 1100 and 1449 CE may relate to the sample, where 31 of the 46 dice are from a single cache from Amersfoort, all made from the same bone material. However, even treating this cache as a single find, 15 of 16 (94%) from this time period are bone, ivory, or antler.

Configuration

Consistent with results elsewhere in northern Europe (e.g. de Voogt et al 2015; Egan 1997; Brown 1990), two configurations dominate the Dutch dice, Sevens (1-6, 2-5, 3-4) and Primes (1-2, 3-4, 5-6). Of the 110 dice included in this study, all but seven are in one of these two configurations. The remaining dice include one Turned example, five irregular dice (in four different configurations), and one "false" die lacking a pip for five but two sides with pips for three.

Figure 3 plots the different configurations by date. Plotted are the minimum and maximum age estimates (vertical bar) and median age (horizontal bar) based on stratigraphic evidence for each die. Barring one early example, the figure suggests that dice in the Primes configuration date mostly to a narrow window of time between 1250 and 1450 CE (median dates), where they dominate all other configurations. Sevens configurations, on the other hand, comprise a large proportion of the samples predating 650 CE, are rare between 1250 and 1450 CE, and dominate again from 1500 through 1900 CE.

The figure also shows that the Primes and Sevens configurations were contemporaneous in the Late Medieval period (1200–1450 CE), but that the latter ultimately replaced the former as part of a technological shift. Primes were dominant between 1250 and 1450 CE (90%, or 37 of 41 dice, in our database), lost popularity between 1450 and 1600 CE (31%, or 4 of 13 dice), and disappeared thereafter. During this same interval, Sevens configuration increased from 5% between 1250 and 1450 CE, to 62% between 1450 and 1600 CE, and were the only configuration (100%) found after 1600 CE.

Finally, Turned and other irregular configurations (see de Voogt et al. 2015) are distributed throughout time. They occur in slightly higher frequencies prior to 650 CE, comprising 25% of all dice, but drop below 10% in later time periods.

Pip Style

Three pip styles are present within the database: a single hole that is usually circular ("dot"), a dot surrounded by a single concentric circle ("dot-ring"), and a dot surrounded by two concentric circles ("dot-ring-ring"). Figure 4 shows the age distribution of these three styles. Dice predating 650 CE show considerable variation, with all three styles present in significant numbers (25%, 50% and 25%, for the three styles respectively). By contrast, the dot-ring style dominates between 1100 and 1450 CE, representing 93% of all examples (dots comprising the remaining 7%), and dots dominate after 1450 CE, representing 82% of all dice (with dot-ring accounting for 16% and dot-ring-ring 3%).

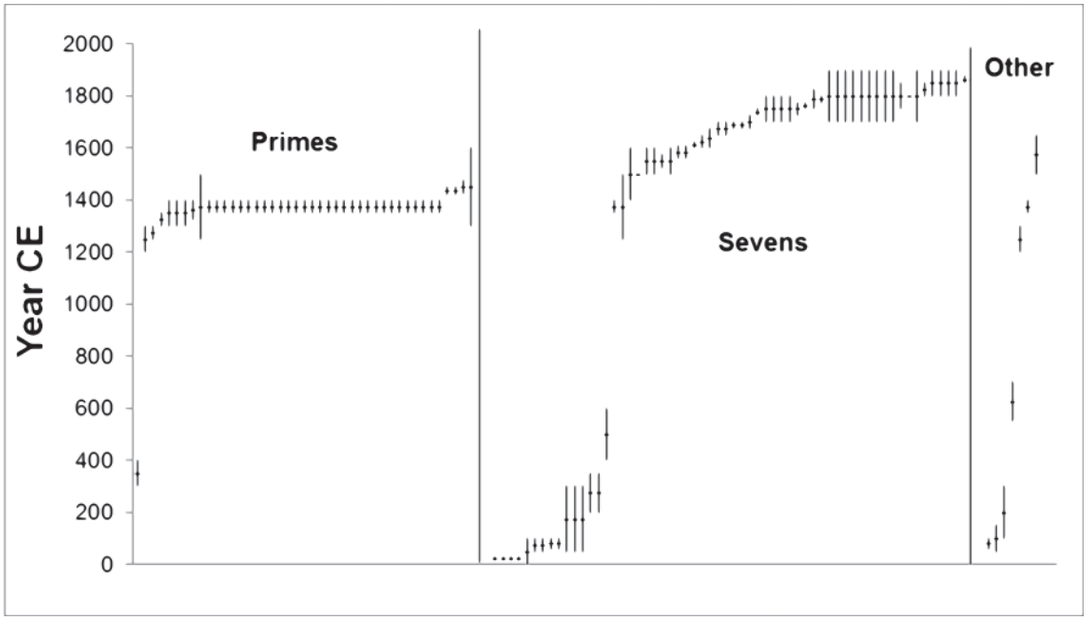

Fig. 3. Distribution of Primes, Sevens, and other configurations over time.

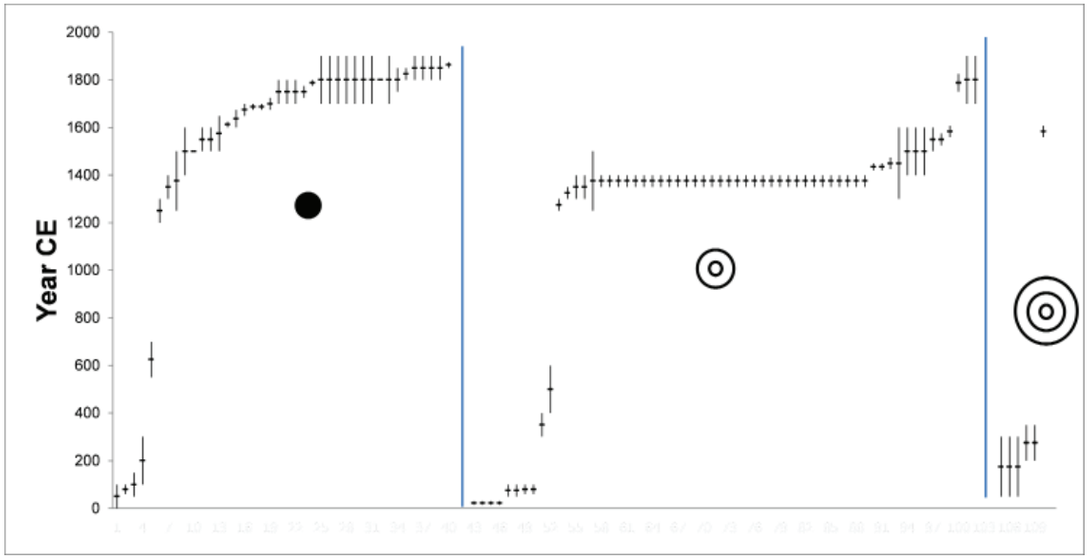

Fig. 4. Distribution of pip styles over time.

Overall, this pattern suggests a process of increasing simplification, from dot-ring-ring, to dot-ring, to simple dots, over time. As well, there seems to be a trend towards increasing standardization, with highest variation before 650 CE, least variation between between 1100 and 1450 CE, and low variation thereafter. Part of this is explained by an interaction between pip style and configuration. In particular, all but one of the dice in the Primes configuration, which dominates between 1100 and 1450 CE, show the dot-ring pip style. This association may account for the dominance of dot-ring in the Late Medieval Period.

Die Symmetry

We summarize symmetry in dice by calculating the ratio of the longest to the shortest side. Borrowing from the "minimum noticeable difference" criterion for size in the psychology literature, summarized in Eerkens (2002), we were especially interested in dice where the longest side differed by more than 5% from the shortest side. Such dice should be visually asymmetrical to most individuals. By contrast, dice differing less than this threshold will generally appear to be symmetrical to most individuals, without careful inspection or use of a ruler.

Table 3 shows that die symmetry increases steadily over time. Nearly 90% of the dice in our database that date before 650 CE have maximum sides that are more than 5% larger than the minimum (max/min > 1.05). After 1450 CE, less than 40% of the dice are similarly lopsided.

Die Size

Finally, we calculated the average size of dice for which we had measured all three dimensions, by averaging the length of the sides (length, width, height). Table 4 shows the average and standard deviation by time period, revealing that dice start out, quite large and variable prior to 650 CE, decrease in size by over half and are also quite standardized between 1100 and 1449 CE, and then increase in size and variation again after 1450 CE. Figure 5 plots these results by material type (one large stone die with an average size of 71 mm on a side not shown). The plot shows that metal and glass dice, on average, are rather small (not surprising, given the higher cost of metals, and metal and glass working), while ceramic dice tend to be larger. Organic dice are more variable in size.

COMPARISON TO DICE FROM THE UK

As in the Netherlands, dice are found in small numbers at many Roman and later sites in the United Kingdom. As in the Netherlands, there are relatively few comparative studies of dice (though see Clarke 1970; Egan 1997; Jay 2000). Here we compare the dice from the Netherlands to 62 securely dated dice from the United Kingdom (49 organic, 2 metal, 7 stone, and 4 indeterminate for material type). This information was assembled from a wide range of excavation or survey reports dating after 1970. Not all reports provide enough information or depict dice with illustrations in enough detail such that we could measure every attribute. As a result there is some missing data, especially pertaining to die size. Nevertheless, it is possible to make a first comparison based on the same attributes with this dataset.

Table 5 provides data for configuration and pip style for the UK dice. As shown in Table 5, these attributes mimic the patterns found in the Netherlands. All eight Roman period dice are fashioned in the Sevens configuration and are dominated by the dot-ring-ring pip style. During the Medieval period (1100–1449 CE), the Primes configuration becomes more common, comprising just under half of the dice. As well, pip styles are simplified and dot-ring is most common. After 1450 CE, the sevens configuration again dominates (93% of dice), and simple dots are the most common pip style.

Table 6 shows size and symmetry data for the UK dice. Although similar in broad strokes, the data are a bit more variant from the Netherlands. This may be due to much-reduced sample size of dice with complete size and symmetry data (n=22 dice from the UK). As in the Netherlands, the reduction in size from Roman to Medieval period is evident in the UK dice, with die size diminishing over 35% from 13.5 to 8.8mm (average of three die dimensions). However, unlike in the Netherlands, Medieval dice are not less variable in size, and post 1450 CE dice to not rebound in size.

Likewise, the majority (n=3 of 6) of Roman period dice are more than 10% larger on their maximum vs. minimum side, leading to visually asymmetrical objects. The percentage of asymmetrical dice decreases over time, with 78% (7 of 9) of those dating after 1450 CE being very close to cuboid in shape.

Table 3: Die asymmetry by time period

Age CE	Max/Min < 1.05	Max/Min = 1.05-1.10	Max/Min > 1.10
Post 1450	61%	18%	21%
1100-1449	48%	38%	14%
0-650	11%	32%	58%

Table 4: Average size by time period

Age CE	Average (mm)	Standard Deviation	Coefficient of Variation
Post 1450	12.2	4.4	.36
1100-1449	6.7	1.2	.17
0-650	13.0	4.2	.32

Table 5: Configuration and pip style for dice from the UK

Age CE	Configuration			Pip Style		
	Sevens	Primes	Other	Dot-ring-ring	Dot-ring	Dot
Post 1450	26	2	0	1	8	12
1100-1449	11	11	3	7	11	4
0-650	8	0	0	6	2	0
Total	45	13	3	14	21	16

Table 6: Size and Symmetry for dice from the UK

Age CE	Size (mm)			Max/Min		
	Avg	Stdev	CV	< 1.05	1.05-1.10	> 1.10
Post 1450	9.1	1.5	.17	78%	0%	22%
1100-1449	8.8	2.7	.31	29%	29%	43%
0-650	13.5	2.8	.21	33%	17%	50%

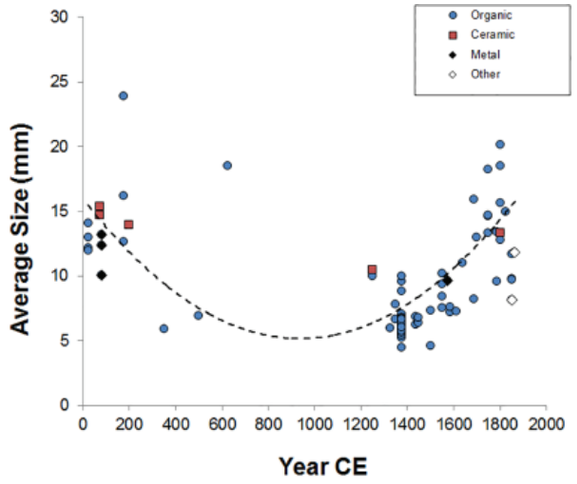

Fig. 5. Average size over time, showing different material types.

DISCUSSION

Results from the analysis document a number of changes in cubic dice attributes in the Netherlands between the Roman period and 1900 CE. Most of these patterns also hold in the UK, suggesting they are part of broader changes in northwest Europe. Below we highlight these patterns and speculate on possible reasons for such shifts. We aim to test some of these ideas in future research.

In general, dice predating 650 CE seem to be highly variable in nearly all attributes, including attributes related to function (i.e., asymmetry, size) and style (i.e., pip type, configuration). This is consistent with Roman dice found in other parts of the Europe and the Meditteranean (e.g. Brown 1990; Krüger 1982; Schädler 2007), and suggests that there may have been many dice makers who produced objects on an individual as-needed basis, rather than by centralized "dice makers". Clearly, the transmission of information regarding die appearance was not rigid for these attributes, and production of a wide range of forms was generally acceptable.

In terms of function, many pre-650 CE dice are visibly asymmetrical, appearing as a slightly flattened cube. Such asymmetry would have affected how the die rolled (i.e. which face comes up). The majority of the asymmetrical dice have the 1 and 6 on opposite sides of the flattened cube in positions more likely to roll "up". Whether this was intentional, as a way to manipulate the roll, or deemed unimportant to die function (i.e. because die rolling was controlled by some pre-determined fate), is unknown to us.

In contrast, dice dating between 1100 and 1449 CE are much more standardized. The modal die is a small, nearly cubic bone, antler, or ivory item in the Primes configuration with pips in the dot-ring style. This high degree of standardization suggests either that there were a small number of die producers, with each manufacturer producing similar forms of dice (e.g. Barthel et al. 1979; Pigozzo 2012), or that manufacturers adhered carefully to culturally transmitted rules about die production.

Greater standardization in dice, especially in the form of more symmetrical shapes, may indicate that consumers sought objects that were more "fair" in how they rolled for different numbers. Yet, understanding of the physics behind die rolling may have been poor. Thus, whether an attribute, such as pip style, contributed in a significant manner to the odds of a particular roll (e.g., 1 vs. 4 coming face up) may not have been known or understood by the average player. Standardizing the attributes of a die, at least those measured here, may have been one method to decrease the likelihood that an unscrupulous player could manipulate the dice to change the odds of a particular roll. Finally, a decrease in size probably prompted a change in pip style. Space for two rings around the central dot would have been limited, perhaps causing a simplification to one ring. Size changes seem to have a regional characteristic to them and comparisons with areas elsewhere in Europe may further elucidate this issue.

Finally, after 1450 CE dice became more variable once again in some attributes, such as material type, pip style, and size, but remained or became more standardized in others, including configuration and symmetry. During this time, dice games appear to have lost popularity to card and lottery games, especially when it came to gambling (e.g. Lapina 2013; Munting 1993). With the introduction of probability theory, particularly by Blaise Pascal in the late 1600s, an increasing awareness of "chance" as opposed to "fate" when using dice arrived (Hacking 2006). This may have prompted increased attention to die properties that affected, or at least were percieved to affect, function. Thus, symmetry increased such that nearly all dice were visibly shaped like cubes. Further, by "balancing" larger and smaller numbers (i.e., 1 opposite 6, 2 oppostie 5 and 3 opposite 4), die consumers may have thought they were further ensuring a fair die, resulting in standardization in configuration. Regardless of whether

configuration actually affected the odds of different rolls, adhering to a particular rule of balancing the numbers may have been percieved as an improvement in a "fair" die. Cultural transmission processes then may have ensured that die makers adhered to this particular rule. At the same time, it may have been recognized that as long as a die was symmetrical and balanced in configuration, it did not matter what material it was made from or how large it was. This may account for increasing diversity in material types and size of dice within the Netherlands, but decreasing variation in asymmetry and configuration.

CONCLUSIONS

Our analyses focused on an artefact category that is common, but typically found in small numbers in archaeological sites in northwest Europe, and has not been subject to systematic study and analysis. We believe our results are significant on two fronts. First, on a more local scale, documenting the changes in dice over time may be helpful to future researchers in dating archaeological sites or stratigraphic or other components of sites, especially when other materials suitable for dating are lacking. Of course, this study is only a starting point and future studies may elucidate more fine-scaled regional variation. In particular, because the modern-day Netherlands was largely outside the control of the Roman empire directly, a larger sample of Roman period dice from areas to the south of the Rhine would be a useful contribution.

Although all time periods show some variation in die style and shape, there are clear modal changes throughout the last 2000 years. Roman period dice are typically large and asymmetrical in the Sevens configuration with dot-ring-ring pip styles. Medieval dice through 1450 CE, are smaller and more symmetrical, but are typically in the Primes configuration with dot-ring pips. Finally, dice post-dating 1450 CE are larger again but highly symmetrical in shape, in the Sevens configuration with simple dots as pips.

Second, and more generally, the data inform on cultural transmission processes in northwest Europe. It appears that initial introduction of dice during the early Roman period resulted in a rather variable technology in practice. The earliest dice show high variation, especially in shape and configuration. This could be due to many individual dice makers who were following a general template of a cuboid object with numbers on each side, but inserting significant individual variation during die manufacture. At some point at or just before 1100 CE, a major transformation took place, with increasing standardization, a decrease in size, a simplification of pip style, and a dominance of dice in the Primes configuration. In the Later Medieval period dice in many areas were made by tradesmen who had access to specific tools and materials (e.g. Barthel et al. 1979; Erath 1999; Pigozzo 2012). Occasional series or mass production is attested as well, a practice not commonly known in Roman times.

After 1450 CE the prominence of dice games weakened. Combined with new understandings about probability in the late 1600s CE, gamblers may have sought new attributes and aesthetics in dice. In particular, gamblers may have seen dice throws as no longer determined by fate, but instead as randomizing objects governed by chance. There seems to be a relaxation in adherence to the modal form in some attributes, such as material type and size of dice, but increasing standardization in attributes associated with performance (e.g., symmetry) and "balance" (e.g., configuration).

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