The classification and analysis of spirals in decorative designs

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The candidate confirms that the work submitted is her own, except where work which has formed part of jointly-authored publications has been included. The contribution of the candidate and the other authors to this work has been explicitly indicated below. The candidate confirms that appropriate credit has been given within the thesis where reference has been made to the work of others.

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Abstract

Structure in decorative patterning has been used to identify perceptual preferences and broader social and cultural patterning of a society. This thesis proposes a new method of analysis and classification of decorative spirals as a test of whether the analysis of an individual type of geometric decorative motif in isolation can reflect social and cultural trends in a similar manner. The proposed analysis method, which takes a quantitative, bottom-up approach to classification, was compared with a top-down classification method used in previous studies based on mathematical spiral forms. Similarities were found across the two classification methods, both are clearly strongly influenced by the expansion rate of the spiral but the newly proposed method is felt to offer a more flexible approach to the classification of motifs which accommodates gradual variation and the decorative properties of the motifs beyond a simple mathematical curve.

The proposed method was tested on four archaeological case studies: Egyptian scarabs of the Middle Kingdom and First and Second Intermediate Periods, Cypriot Bronze Age painted pottery and gold-work, Shang and Western Zhou Dynasty bronze vessels, and Japanese Jōmon Period pottery. Quantification and cluster analysis of spirals in these studies identified variation in motif shape that could be attributed to the production method but the chief finding was one of homogeneity across the four cultures and a limited range of forms of decorative expression which suggests an influence of natural spiral forms on decorative examples across the cultures sampled. An analysis of the possible influence of spiral optical effects arising from disturbances in the functioning of the visual cortex on decorative spirals did not yield significant results.

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1 Introduction

The creation of decoration requires effort beyond what is essential for function at the most basic level and, over a prolonged period of time, social groups have been willing to support those engaged in the production of decoration (Eyre 1997, p.99). It must be assumed, therefore that the creation of decoration has an important purpose within human society. The ornamentation by humans of themselves and their environment may date back 350,000-400,000 years; scratch marks on an elephant tibia from Bilzingsleben, Germany of this date do not resemble butchery marks although their meaning cannot be known (Scarre 2005, p.118). Decoration can be applied to functional objects and cover a broad range of expressions from those which take minimal skill and little or no material cost and may have been intended to be ephemeral to creations using expensive or difficult to obtain materials; requiring substantial skill, specialisation and time investment; and intended as lasting statements, for example glorifying a deity or leader. Because of this diversity, the spread of decoration throughout society and the chances of its survival and retrieval are liable to be greater than for works of art.

The deliberate application of design rules underlying the production of decoration can be identified in many cultures (Washburn 1983a, p.4). Examples of these design rules can be seen in the non-random distributions of symmetrical transformations that have been identified in Japanese textiles (Hann 1992); in the standardised arrangement of design elements in relation to each other in Hopi pottery (Bishop, Canouts, De Atley, Qöyawayma & Aikins 1988) and in the set of transformational rules of symmetry, scaling, curvature and figure-ground configuration that govern the structure of *kapkap* motifs in New Ireland (Were 2003). Structure and patterning present in art and decoration can be replicated in other aspects of the culture such as settlement and house layout and language Washburn (1983a, p.4).

If the principles governing the structure of decoration, whether applied consciously or unconsciously, can be determined, they have the potential to shed light on the producing culture. They may, for example, highlight important symbolic meanings reflecting religious beliefs (Washburn 1983a, p.4); social structure (Fischer 1961);

perceptual and aesthetic preferences (Nisbett & Miyamoto 2005) and the phenomena which the society considered worthy of representation (Fischer 1961). Jablan (2002, pp.292-294), in his study of modularity in decoration, observed that some simple prototiles are very common across unrelated cultures. Although noting that the mathematical description of a pattern does not necessarily reflect how it was constructed or explain the origin of a design, Jablan suggested that the occurrence of the same prototile in different cultures could be used to study: the development of geometric designs; cultural interaction; and mathematical and technological knowledge. Decoration sets out a clear and static presentation of the regularities and patterning which may apply across more ephemeral aspects of a culture. As such, these patterns warrant identification and the analysis of their properties in geometric terms offers a useful tool for identifying and recording these patterns.

1.1 The analysis of design

The analysis of decoration has been put to a diverse range of uses including: the replication of historic designs (e.g. Bain 1951) encouraging the development of new designs (e.g. Jones 1856); in archaeological and ethnological studies (e.g. Leroi-Gourhan 1968; Washburn & Crowe 2004); and perceptual psychological studies (e.g. Boselie 1984; Vallentin & Nieder 2008). Informal design appraisal, in the sense of assessment and improvement or innovation, must have occurred for as long as decoration has been applied to objects. Sieveking (1971) cites examples of the transfer of decorative styles between cultures and the modification and incorporation of new motifs into existing design styles at least as far back as 11,000BCE.

The formalised recording of design analysis is more recent. To take European examples, the earliest known treatise that includes discussion of decorative techniques as part of architectural analysis is Vitruvius' work *De architectura libri decem* written around 33-22BCE. Systematic design analysis was established by the second half of the fifteenth century (Frings 2002; Andrey & Galli 2004). At this period, the deconstruction of decoration into simpler geometric forms was mainly found in guides for creating decoration, usually in the context of architecture or engineering. Dürer devoted one volume of his 1525 work *Die Underweisung der Messung* to the construction of curves including logarithmic and Archimedes' spirals (Strauss 1977, p.7). It is unclear to what extent publications relating to abstract geometry may have had an influence on decorative work. It seems very probable that many formalised systems for setting out or constructing decoration were unrecorded due to: the illiteracy of those creating the decoration; apprenticeship systems providing no need to record working methods which could be taught directly; and a desire to preserve trade secrets. Equally, many decorative productions may have been most strongly influenced in their structure by the nature of the materials and tools. Although the decorative product may be susceptible to retrospective geometric description, its production could be purely pragmatic.

The study of decorative arts to identify cultural change and transmission can be dated back to the late-nineteenth century anthropological study of 'primitive' societies with a view to proposing qualitatively assessed sequential developments of decorative forms within a culture. The concept proposed being that these societies represented early stages in an evolutionary perception of art running through Classical Antiquity to the Renaissance then to a highest state of development in contemporary Western society (Morphy & Perkins 2009, pp.2-4). Similar principles of the creation of sequences of design development were used to identify commonalities of decoration between cultures and propose routes of contact and cultural transmission (Morphy & Perkins 2009, p.5).

Early quantitative analyses of decorative design, which aimed to typify its characteristics from a psychological, ethnographic or theoretical aesthetic point of view focussed particularly on the underlying structure of the decorative design. Brainerd (1942) adopted the approach of using symmetry classification as a means of differentiating between the typical design styles of cultures and of identifying the copying of the motifs of one culture by another. The symmetry classification groups created by Brainerd allowed him to show a clear distinction between pottery types, from Chichen Itza and Rainbow Bridge Monument Valley, Arizona. Many experimentally-based studies have been carried out using sets of controlled motifs to assess cross-cultural differences in preferences for proportioning systems. Pittard, Ewing and Jevons (2007), for example, studied preferences for golden proportions in logos in Singapore, South Africa and Australia and found no significant difference between inclinations to favour golden proportions. In contrast to lab-based cross-cultural comparison of proportioning systems, studies of proportions of pre-existing artwork or ornament have tended to take the decorative schemes of individual cultures in isolation, or groups of cultures where a strong cross-cultural link is believed to have existed, to look for evidence of consistency in proportioning systems. Golden section proportions have been a particular focus of this type of study (e.g. Hambidge 1920; Tons Brunes (discussed by Kappraff 2000); Lynch & Hathaway 1993).

In design analyses, geometric constructs such as symmetry which affect the whole composition tend to be considered rather than specific motifs (e.g. Washburn & Crowe 1988). In the study of rock art, the relative positions of motifs to each other and their placement on the rock surface have been studied but these have often derived the significance of arrangement from the contours of the rock surface and the larger structure of the monument (O'Sullivan 1986) rather than an apparent formalised geometric scheme. Analyses of motifs have tended to focus on examples that are linked to particular cultures such as Islamic star tilings (Lee 1987), Celtic knot patterns (Kaplan & Cohen 2003) or Japanese abstracted fern patterning (Fuchigami 2001). In these examples, the decoration has very clear mathematical analogues and characterisation was more closely linked to re-creation or the potential for producing computer-generated variation on traditional designs rather than finding commonalities or differences between cultures.

Several evolutionary studies of decoration used spiral motifs as examples in qualitative studies of cultural interaction seen in decorative arts (e.g. Goodyear 1893; Mackenzie 1918, pp.248-250). These evolutionary studies used aesthetic judgements of the whole motif to identify commonalities and developments. The concept of analysing and characterising spiral forms in isolation from an architectural or design class and according to a set of geometric properties was influenced by the work of Theodore Cook (1914, Ch.15). Cook was primarily interested in spirals in biological forms but also noted commonalities between natural and designed forms. Cook's study was unusual in regarding mathematical analysis and characterisation of spirals as an end in itself as opposed to functioning as a guide to the synthesis of new designs. More recent studies of spiral motifs in decoration have drawn links to mathematical forms.

Work by Zhushchikhovskaya and Danilova (2008) used the arrangement of motifs and analogy to mathematical forms to assess three case studies: the Jōmon culture in Japan (13,600-900BCE), the Yangshao culture in eastern China (4000-2000BCE), and the Neolithic cultures of the Lower Amur River basin in far eastern Russia (mid 6th to mid 2nd millennium BCE) to identify characteristic regional patterns in the spirals. In the Jōmon case study, variation over time was also identified. Mamaní and Fernández Distel (2010, p.41) also drew parallels between geometric spirals and pre-Colombian petroglyphs and painted pottery decoration although they did not create class groups on this basis. Andrey and Galli (2004) and Takaki and Ueda (2007) used analogy to mathematical spirals most directly in measuring radii or curvature to fit mathematical spiral forms to decorative spirals.

1.2 Spirals in nature

The frequency of the occurrence of spirals in natural forms suggests that they convey an evolutionary advantage. There are common themes in the occurrence of natural spirals in grasping, protection and in efficient packing.

Animal horns show particularly complex spiralling structures, exhibiting logarithmic expansion of the horn and the spacing between twists as well as showing a spiral twist along the length of the horn (Cook 1914, ch.12). In plants, tendrils and stems of climbing plants exhibit helical and spiral forms (Figure 1.1a). In animals, spiralling grip is observed in cephalopod tentacles; in seahorses as a means of anchoring themselves; in the tails of climbing animals such as howler monkeys and chameleons; and in the coiling of chameleon tongues and elephant trunks as a means of gathering food.

Spiralling as protection allows linear structures such as butterfly and moth probosces (Figure 1.1b) to be retracted when not in use to minimise exposure to damage. In snakes and arthropods, spiral coiling as a response to threats allows the vulnerable underside of the animal to be protected. Similarly, the coiling of plant shoots (Figure 1.2a) allows the protection of the vulnerable shoot tip whilst it is growing. The coiling seed pods of some species of *Medicago* form spherical spirals (Figure 1.1c) which are believed to help in protecting the seeds from being eaten by insects (Small & Brookes 1984).

Spirals as a function of close packing occur in molluscs, spiral shells provide an efficient packing structure in a manner which can expand with the growth of the organism (Amodeo, Oliverio, Versacci & Marino 2012). Exponential expansion in logarithmic spirals as a growth patterns in flowers spiral whorls allows large numbers of seeds to be contained in a small area. Similar spiral whorl structures can also be seen in the leaf arrangement of some succulent plants (Figure 1.1d).

Other organic spiral forms provide mechanical advantage for example, to the distribution of wind-blown seeds (Cook 1914, pp.137-140) and the mechanical propulsion of seeds. Some spirals constructions in organisms appear to convey no evolutionary advantage that is dependent on the shape of the spiral such as the spirals in the tail feathers of mallard drakes. Possibly as intimidation or warning, some ringneck snake species coil their tails when threatened (Figure 1.2c) (Greene 1973).

Because many natural forms have evolved due to functional advantage, spirals occurring in the same natural context are often very similar in structure; horns and shells have expansive forms with or without spacing between the coils; most plant spirals show logarithmic growth both in the width of the spiral and the gap between coils. Spirals in contexts evolved for gripping tend to show a lower expansion rate and lower rotational length than solid protective spirals. These properties allow greater flexibility than would be possible with a broad base structure and maximise efficiency by keeping the need for coiling and uncoiling to a minimum. With reference to efficiency, plant tendrils which remain fixed once an attachment has been formed tend to have a longer rotational length than grasping spirals in animals which remain active. Consistency can even be seen in organic spirals with no functional purpose insofar as that these structures often conform to logarithmic growth patterns.

Naturally occurring inorganic spiral forms tend to have a low rotational length and so appear less obviously spiral than many biological spiral forms. Some of the most pronounced examples of inorganic spirals occur at a microscopic or telescopic level which demonstrate their existence in principle but would not have been accessible as an inspiration for decoration within the period of the case studies used in this research. Physical spiral forms that would have been visible occur in cracking during desiccation (Lazarus & Pauchard 2011) and vortices in fluid, clouds, dust devils and cyclones which would have been recognisable as very substantial spiral forms (Kappraff 1992, pp. 8-16).

a. b. c. d.

Figure 1.1 Natural spiral examples: a. vetch tendril. b. burnet moth proboscis. c. Medicago *sp.* seed. d. cactus leaf rosette

The occurrence of spirals in natural forms has undoubtedly influenced its representation in the decorative arts (Takaki and Ueda 2007; Coutil 1916, p.385). Shells have been modified into decorative or functional ceremonial items (Figure 1.2e) (Starzecka, Neich & Pendergrast 2010, p.67) or have been represented as sculpted forms (Masayuki 2009. p.150). The identification of conventionalised planar spiral representations of shells is less common in prehistoric art but can certainly be seen in more recent decoration (Figure 1.2f). Herbivores with spiralling horns would long have been of interest to humans in hunting or through domestication and the spiralling horns are a very striking feature of these animals which would be likely to remain in conventionalised depiction. The killing of the animals would also have made the horns available for use as functional items and there is evidence for their association with ritual both as vessels and musical instruments (Splitter 1952; Adler 1893) although the practical requirements of these generally means that these examples show little or no spiral rotation; depictions of horns as spirals tend to show greater rotational length (see examples in Table A2.16, Appendix 2). This extension of spirals is seen in other decorative instances for example in printing stamps and weaving from South America depicting monkey tails (Figure 1.2g). Snakes are a very common spiral representation (Figure 1.2d); they are known, or their presence suggested, as representational motifs in all of the case studies used in this research. Although they are conventionally represented as spiral, relatively few species of snake appear to assume organised coiled spiral forms so it is noteworthy that they are apparently more often represented as spirals than in forms that more closely resemble natural sinuous configurations. Other decorative representational examples are found that do not recreate the actual structure of the animal. Crocodiles are depicted with extended coiled tails on Asanti goldweights (Figure 1.2h). In both cases the coiling of an extended form in decoration could be an aesthetic decision or a practical consideration to make it more noticeable or avoid damage.

Maori woodcarving and tattooing feature spirals prominently. The most frequent Maori spirals in painting are associated with uncurling fern fronds and forms inspired by fern shoots are seen in Maori wood carving (Figure 1.2a and b) (Te Rangi Hiroa 1949. pp.316, 319-20). The other common representation of plants with spirals is in the grouping of spirals to represent the stem structure itself. Clusters of spirals provide an effective way of representing the fractal forms often seen in plant growth. Coiling plant forms in particular, are often represented as helices due to their spiralling growth structure.

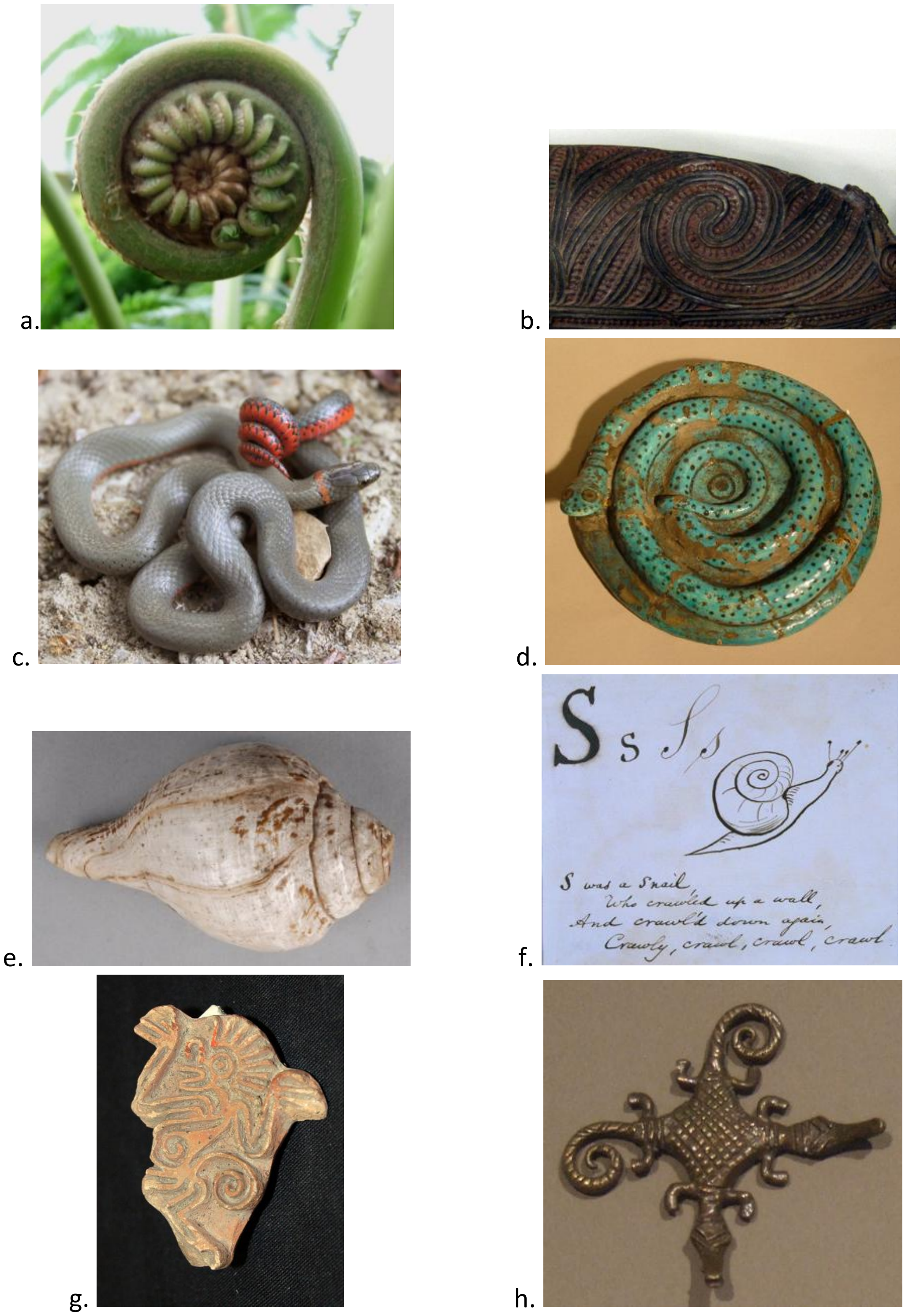


Figure 1.2 Decoration depicting or inspired by naturally occurring biological spirals a. fern shoot, b. Maori spiral carving, Leeds City Museum, acc.no.FL.1985.1.294. c. regal ringneck snake d. faience snake ornament from Late Period Egyptian coffin, BM, acc. no. EA30453. e. Indian C19th-20th conch shell modified for use as a trumpet, BM acc.no. AS1972, Q.135 f. Edward Lear illustration, V&A, acc.no. E.871-1951. g. Aztec printing stamp depicting a spider monkey BM acc. no. AM1946,04.1. h. Asanti gold weight depicting crocodiles with a curled tails, Liverpool World Museum.

Spirals in Maori decorative arts also appear on figurines depicting tattoos and highlighting joints and the contours of the body (Figure 1.3a) (Te Rangi Hiroa pp.315-

316). Spirals on joints also appear on Japanese prehistoric human figurines and Shang dynasty animal and bird figures. The depiction of spirals on the abdomens of pregnant figurines and on breasts and testicles could also be linked to contour representation although Gimbutas (1989, pp. 143, 282-283) links the use of spirals in these areas to an association between spirals and fertility (see section 1.3 below). Spirals on human figures have also been used to represent ears and hair (Figures 1.3b and c) (Coutil 1916, p.474) where the derivation from the natural form is more direct. Few elliptical spirals occur in natural forms but fingerprints do exhibit these forms and may have been noticed in a decorative context in the creation of handprints in pigment, although equally, elliptical spirals are uncommon as decorative forms.

a. b. c.

Figure 1.3 Spiral forms on humans: a. Maori figure, Leeds City Museum. b. South American figure, Cambridge Museum of Archaeology and Anthropology. c. Babylonian relief figure, Ashmolean Museum.

The interpretation of early prehistoric spiral decoration as having been inspired by inorganic natural forms is much less common than suggestions of a biological source. However, more recent art and decoration shows that spirals have been derived from or used in the depiction of physical phenomena. Historic Chinese decoration uses spirals to depict water and cloud effects (Figure 1.4a). Kappraff (1992, p.15) suggests that some examples of running spirals on Papuan shields are inspired by natural vortex forms. Whirlpools and, more recently, spiral galaxies have been represented in logos. As with organic representations, some representational depictions of natural inorganic forms have been conventionalised as spirals although their natural form is not spiralling. Figure 1.4b shows a conventional depiction of lightning in early-twentieth-century Japanese decoration.

a. 

b. 

Figure 1.4 Physical phenomena represented as spirals: a. Qing Dynasty panel with spirals in clouds and waves, ULITA, acc. no. 137. b. Japanese c.20th century textile printing stencil with conventionalised lightning depiction, ULITA, acc.no.189.

Two common themes emerge in natural phenomena depicted as spirals - plant shoots and new growth, and representations of threats. Bando and Hirabayashi (2004) suggested that the human visual system is particularly tuned to detect spirals because they are associated with natural forms which are potentially threatening to humans such as snakes and whirlpools. Spirals in spider webs might be added to these threat stimuli. These dangerous stimuli will provoke a strong response and may make their depiction in decoration more likely, as can be seen in the invocation of snakes as protective symbols discussed below.

An additional type of natural spiral which is believed by some to have been depicted in decoration is those generated within the visual system without objective external stimulus. Geometric motifs as internally generated structures can arise from illness, drug induced disturbance of brain function or even simply semi-wakefulness (Bressloff, Cowan, Golubitsky, Thomas & Wiener 2001, Ermentrout & Cowan 1979). Depictions of these forms have been proposed in Palaeolithic rock art (e.g. Bednarik (1986); Lewis-Williams and Dowson (1988 and 1993)) and contemporary examples of the representation of hallucination seen in trance states have been cited in ethnographic studies (Siegel and Jarvik 1975, p.138; Reichel-Dolmatoff 1978). The possible origins and mechanisms of geometric visions are discussed further in Chapter 2.

1.3 Symbolic meanings of spirals in decorative arts

The widespread nature of spirals in the decorative arts has led to a wide range of symbolic meanings being attributed to them; many of these are unique to a particular group or culture. The known symbolic meanings of spirals associated with the individual case studies are discussed in Chapter 4. The symbolic interpretations below, as representations of the earth, fertility and passing time, have been assigned to several cultures with no apparent link between them.

Two recurring, and apparently linked, interpretations are of spirals as symbols of the earth and of fertility and rebirth. A link might be drawn between spirals as symbols of fertility and their occurrence in the shoots of plants. The Hopi people use spirals to represent 'Mother Earth', *Tapu'at* (mother and child) or, rebirth (Doczi 2005 p.25). Doczi (2005 p.27) also suggested that spirals with two centrally linked coils, such as those in the Neolithic passage tomb at Newgrange, Ireland (3200BCE) represent death and rebirth – one spiral winding into the centre leading into another which winds out again. Petrie (1920, p.17) was highly critical of a similar interpretation applied to Egyptian spiral decoration, particularly in relation to linked spirals. Gimbutas (1989, pp.58-59, 121) linked spirals in early European art to snakes as a manifestation of a creative force.

The conceptual interpretation of a spiral as a sun symbol representing the path of the sun over the course of a day or year has been suggested as an alternative explanation for the carvings at Newgrange (Cook date, p.275) and for Southwest American petroglyphs produced by the Zia although Zeilik (1985) notes that this interpretation of spirals is unusual. Other interpretations of Zia spiral petroglyphs are as symbols of water or wind (Zeilik 1985). Spiral motifs on Postclassic Aztec spindle whorls have been interpreted as representing the passage of the sun during the day or night depending on their angular or curvilinear form or to seasonal transition (Brumfiel

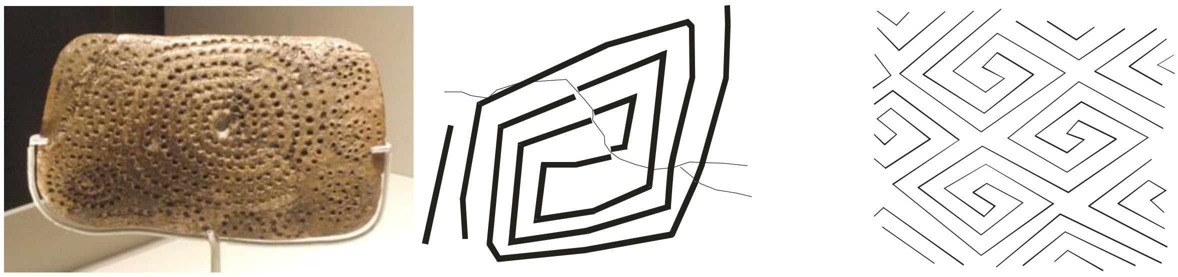
2007). On a similar principle, Gimbutas (1989, p.283) linked spirals to lunar symbols on prehistoric Balkan pottery. In a broader sense of the passing of time, Frolov (1983) suggested that numbers of dots in the Mal'ta spiral plaque represent a division of the disk into winter and summer seasons and draws a comparison with nineteenth-century spiral calendars used in Siberia.

These contradictory interpretations of motifs, when applied to cultures for which no written record exists have been much disputed. Even when the producers of the motifs can be consulted, it can be difficult to identify symbolic meanings. Neich (1993, p.36) observed that although the representational origins of Maori decorative motifs could be identified with relative ease by speaking to the producers and consumers of the motifs, symbolic meanings were often understood unconsciously within the culture and so required a greater understanding of the culture to grasp them. It would be of great interest if similar abstract conceptual meanings could be shown to have been assigned to spirals in cultures which had no contact with each other. It may be that common interpretations between cultures owe more to the cultural understanding of the interpreter than to real commonalities between cultures.

This thesis considers the spiral motifs in isolation from their context in an attempt to identify aesthetic commonalities between cultures which are isolated from each other. Because of the diversity of known meanings applied to spirals, attempting to identify symbolic meaning of the spiral in a prehistoric culture, in isolation from its context, would be inappropriate and the classification method proposed in this thesis considers only the physical shape of the spiral and representational interpretations where they can be securely identified. If applied as a classification system within a single culture it would be most appropriate to use the method alongside separate consideration of symbolic meanings either to discover if shape-based discrimination supported conceptual divisions or as a secondary level of analysis to attempt to subdivide class groups identified on a conceptual or representational level.

1.4 The choice of spiral motifs as a research focus

The use of decorative spirals covers a large time span. The earliest example of decoration which includes spirals are shells pierced with holes, probably to be strung, found in a 75,000 year-old layer in Blombos Cave in South Africa (Henshilwood *et al.* 2004). The earliest securely dated examples of created spirals come from Mal'ta in Siberia (Figure 1.5a) and Mezin in Ukraine (Fig 1.5b) both of which date back to the Upper Palaeolithic (State Hermitage Museum 2003; Iakovleva 2009). Spiral motifs appear to have become much more prolific with the start of the Neolithic period in a broad geographic spread of cultures (Table A2.1, Appendix 2). Coutil's (1916) extensive survey of spiral ornament focusing mainly on Europe from the Palaeolithic period to the Iron Age shows how frequent a motif spirals were across this area and highlights the range of contexts in which they appear.



a. b.

Figure 1.5 Early spiral decoration: a. Pierced plaque with spiral motifs from Mal'ta, Siberia c.21000-17000BCE, State Hermitage Museum. b spiral patterning on a tusk and an ivory bracelet from Mezin, Ukraine (adapted from Iakovleva (2009) figs. 12 and 37)

Spiral motifs were originally chosen as the focus of this thesis on the assumption that spirals could be precisely described using their mathematical equation as a means of creating a quantitative comparison of shape but, as review of the variety of spiral decoration progressed, it was found that mathematical descriptions were inadequate to fully, or accurately describe the shapes of decorative spirals. This is not necessarily a drawback as combining geometric and non-geometric properties in a single system has proved one of the most interesting aspects of this research.

It has been suggested that some stages of visual processing may be especially well suited to the detection of spiral shapes (Bando & Hirabayashi 2004; Ermentrout & Cowan 1979; Tass 1997) and that spiral forms have an innate aesthetic appeal. Hogarth (1753) attributed the appeal of spiral forms to their capacity to depict the volume of a form. Spehar, Clifford, Newell and Taylor (2003) suggested that logarithmic spirals occurring in the decorative arts of several cultures may be linked to a human liking for patterns containing fractals, and possibly a particular preference for fractal patterns with similar fractal dimension to those commonly found in nature –

within the range 1.3 to 1.5. More broadly, Pittard, Ewing and Jevons (2003), in their study of logo preferences, suggested that humans exhibit an innate preference for natural organic forms over non-natural shapes.

An advantage in considering geometric motifs in general in cross-cultural studies is their consistency between cultures. Washburn (1983a, p.2) noted that representational depictions are not exact depictions of the object under study but of the perception of the object and that the cultural background of the person creating the image may encourage certain aspects to be emphasised or minimised. It can therefore be difficult to find a set of variables which apply universally in the analysis of motifs according to their representational meaning. In terms of representation or symbolism, apparently dissimilar objects may have similar intent (Grabar 1992, pp.240-1) so the focus on decoration as geometric constructs about which certain fundamental assumptions can be made makes it more readily comparable than motifs linked by an abstract concept. Figure 1.6 shows examples of birds depicted in three cultures with contemporaneous spiral motifs from each culture highlighting the greater consistency between spirals than between the bird representations.

Figure 1.6 Representationally or geometrically similar motifs: a. Iznik, Turkey 16th century CE, BM, acc.no. G.165. b. British 7th century CE, BM, acc. nos. 1908,0217.1 and 1939,1010.110. c. Peruvian 1st century BCE-6th century CE, BM, Am1954,05.464 and Am 1954,05.568.

Geometric patterning plays an important or dominant role in the decorative schemes of some cultures (Roe 2004, p.239). Despite this, geometric decorative motifs have been the focus of less research than representational decoration. Washburn (1995, p.117) commented that symbolic meanings tend to be more often ascribed to, and more often studied in, representational decoration than geometric motifs. It was apparent during the literature review and data collection for this thesis that, where geometric decoration with no known representational meaning appeared on an object alongside representational decoration, geometric motifs were often not mentioned in catalogue descriptions of museum objects. Where spirals are a prominent motif in the decorative canon of a culture, for example in south-western Pueblo pottery decoration and the Bronze Age Aegean and Egypt, their development and transmission as a motif has been the focus of research (e.g. Barber 1998) and spirals have played a prominent role in qualitative classification systems of decoration within these cultures (e.g. Tufnell 1975; Jernigan 1986). Quantitative assessment of geometric motifs has, however been minimal even for cultures with a significant presence of spiral decoration and so there was potential and value in developing a new quantitative analysis method for spirals.

It is clear in a number of substantially separated cultures that spirals were, and continue to be, important decorative motifs even when allowance is made for the potentially subjective limits of what constitutes a spiral in decoration (discussed in Chapter 2). Of importance in this research, engaging in cross-cultural comparison, is the range of possible inspirations for the presence of spirals in decoration from natural objective and subjective phenomena. Also of the practical constraints imposed by the properties of the tools and materials used to construct the decoration. The variety of possible explanations for the production of spiral decoration offers the potential for a broad range of expressions of decorative variables within spiral motifs and also for identifiable consistencies running across cultural boundaries. These factors make spiral motifs well suited to testing whether the quantitative comparison of geometric motifs in isolation from their decorative context can be a useful tool in cross-cultural studies.

1.5 Overview of the thesis

The methodological basis of this thesis focusses on producing detailed quantitative descriptions of a single type of geometric decorative motif and using these as a basis for comparisons within and between cultures. Decorative spirals are, regardless of modification and elaboration, underlain by a universal geometric framework which provides potential for analysis within a more generic system. The method takes into account decorative as well as geometric aspects of spirals. Such a classification method has applications, as a non-culture specific method.

The principle that a generic classification system based on geometric properties could be a useful method of cultural comparison draws on Dorothy Washburn's statement that

> *"it should be possible to define art systems by describing the consistencies in their formal organization. However, too often the classifications are too culturally specific to allow cross-cultural comparisons or their units cannot be easily used for diachronic studies of change..."* Washburn (1983a, p.3)

Taking this principle, Washburn and Crowe (1988) proposed a symmetry classification system which has been applied to archaeological and ethnographic studies including temporal change and regional variation in the Neolithic Aegean (Washburn 1983b), the aesthetic properties governing Bakuba raffia cloth type groups (Washburn 1990). The method of analysis and classification proposed in this research is intended to be generic and tries as far as possible to ignore any culturally individual meanings. Complete disregard for cultural meaning is, in itself impractical or impossible to implement completely since 'geometric decoration', and even geometry itself, is not a culturally neutral concept. Fukagawa and Rothman (2008, p.2) note that, although the fundamental principles of Japanese geometry and that developed from a Classical Greek origin are the same, the manner of expressing them and the types of problems posed are substantially different.

In many ways, the analysis method proposed in this thesis takes a similar approach to that of Zhushchikhovskaya and Danilova (2008) in applying a quantitative analysis to spiral motifs. It differs in trying to draw away from the application of named geometrical shapes which may not have been used or known by the culture in question and, instead, using statistical grouping methods to attempt to build class groups from the measured variation of the decorative spirals themselves. This method of assigning groups does not necessarily identify the type groups which would be assigned by the makers of the decoration any better than mathematical spiral classes. However, it may be more flexible than externally defined classes in allowing real aesthetic differences in the decoration to guide the number and nature of the classes generated and provides a tool for consistent comparison rather than a means of creating classes which can reliably be assumed to have cultural meaning.

A positivist approach has been chosen to allow the broad scope of potential applications to different cultures although it is clear that this will come at the expense of some depth of interpretation. In the nature of analysing motifs primarily by their physical shape, symbolic, emotive and, to some extent, representational interpretations are excluded. To suggest the reasons for the production of the decoration under analysis and to use the decorative motifs as a means of studying social structure of societies, a broader consideration of the context of the decoration would be needed. For the purposes of this study the decontextualized approach is felt to be appropriate to the aim of designing a generic analysis method which, as with Washburn and Crowe's applications, may be given a more nuanced interpretation in the light of context provided by individual case studies to which it is applied.

1.5.1 Research questions

The view taken in this research is that analysis of decoration may provide a means of identifying perceptual and aesthetic similarities within and between cultures which reflect an origin of the motifs in naturally occurring spiral forms. A culturally invariant, if not neutral, analysis system was required to test the following questions.

1.5.1.1 Are comparisons of decorative spirals with mathematical spiral types useful as a classification tool?

The first research question posed relates to the functioning of the classification method proposed in this thesis. As discussed above, existing classification systems tend to use mathematical spiral type classes. Decoration analysed by this approach often appeared, subjectively, to show poor conformity to the mathematical class to which it was assigned or to be equally well classifiable to two or more classes.

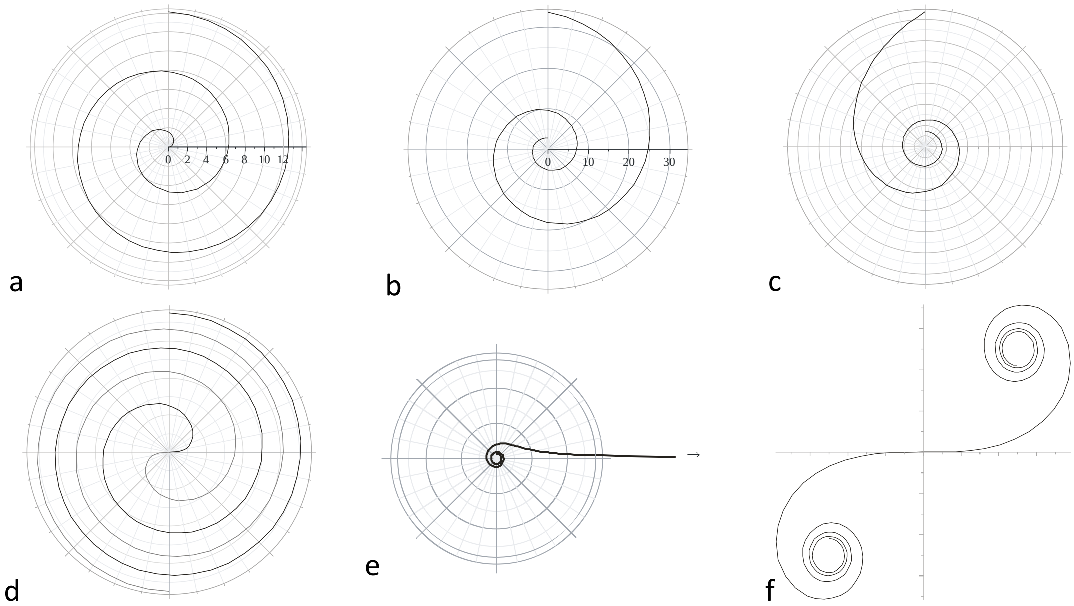


Figure 1.7 Mathematical spiral types. a. Archimedes' spiral, b. logarithmic spiral, c. hyperbolic spiral, d. parabolic spirals, e. lituus, f. Euler spiral.

Andrey and Galli (2004) used radial measurements as a function of cumulative spiral length to test ruler-and-compass based construction methods proposed in the Renaissance for constructing Ionic volutes for conformity to mathematical spirals. They found that three of the four spiral constructions they analysed which were composed of segments of a circle did not conform sufficiently to any mathematical spiral curve to make any valid identification of a spiral type. The fourth spiral construction showed the gradual change which is typical of a spiral so could be tested for conformity to a mathematical type. However, attempts to fit a spiral equation to this curve showed that it conformed equally well to several mathematical spiral types. In contrast, an exploratory study Takaki and Ueda (2008) used cumulative path length and the radius of curvature to compare decorative and mathematical spirals. They attempted to match the decorative spirals to a general mathematical type rather than identifying the equation of the curve. Takaki and Ueda felt that there was sufficient conformity to mathematical spiral types to propose that decorative spirals tended to fit into one of three mathematical classes although they noted that some spirals fell between type classes and that further analysis with a larger data sample might suggest an alternative division of type classes.

The natural occurrence of spirals which closely conform to logarithmic curves (Figure 1.7b) as a possible source of inspiration for decoration (Kappraff 1992) and the potential for some methods of decorative spiral construction to show close conformity to Archimedes' spirals (Figure 1.7a) made the hypothesis that conformity to these mathematical forms would be found in decorative forms worth testing. Besides Archimedes' and logarithmic spirals, four other types of spiral curve - Euler, hyperbolic and parabolic spirals and lituus (Figure 1.7c-f) have also been identified by visual assessment of decorative spirals. Euler, hyperbolic and parabolic spirals were also included as test templates. The reversal of curvature of the lituus is excluded from consideration in this method and, without this feature the lituus was felt to be too similar to the Euler spiral to be included as a separate form. The comparison method employed used the same standard of conformity as Takaki and Ueda, searching for trends of conformity to mathematical spiral types rather than exact or very close match of individual curves.

1.5.1.2 Does the quantification of decorative spiral motifs in isolation create meaningful intra-cultural type groups?

It is not the intention of this thesis to suggest that any single geometric decorative motif type can reliably be used in isolation from its context to assign an object to a particular regional or temporal cultural group. There is no need to make such an attempt when further useful contextual data will always be available, at the very least in the form of material and technique. Also, the potential for coincidental similarities between the motifs on a single object and the range of decoration within several different cultures is too great to make this type of classification worth attempting.

It was however, considered to be worth testing whether spiral motifs considered as groups displayed consistent characteristics which allowed a sample to be subdivided accurately by period within a culture or into separate cultural groups from a cross-cultural sample. If divisions of this sort could be obtained there might be potential to identify perceptual preferences in a culture, although the effect of medium and technique on spiral shape would also need to be considered. If strong differentiation between cultures were found it would also reflect on research questions which assess the presence of cross-cultural similarities.

1.5.1.3 Is there consistency across cultures in the shape of spirals according to representational subject?

Some spiral decoration can be securely traced back to a representational origin and there is clear evidence of close observation of natural forms in prehistoric representational decoration. Because of this, it is hypothesised, firstly that spiral decoration from different cultures with a similar representational subject may show cross-cultural similarities based on the objective spiral source. Additionally, it may in some cases be possible to suggest an objective spiral source for decorative spirals without a known representational origin. This second hypothesis would rely on strong class groupings and unusual characteristics to be effective. As Layton (1988) commented, in reference to identification of subjective and hallucinated origins for decoration, it is necessary to be able to assess the probability of alternative sources having been the inspiration for the motifs.

1.5.1.4 Is there evidence for the influence of subjective, internally generated, spiral forms on decorative spirals?

This question considers the influence of subjective spiral visual effects arising from the structure of the visual cortex on spiral decoration. There are no decorative spirals which are sufficiently well accepted as having been influenced by subjective imagery to make a cross-cultural assessment in the manner employed for objective representational spirals. Before an assessment could be made of influence on decoration the question was posed of whether one, or more, typical subjective spiral shape can be identified based on the analysis of contemporary drawings of these phenomena.

Dominant spiral types identified were then tested against the cultural case study spirals to measure conformity to the subjective types. The analysis of a single motif on its own could not be used to confirm the depiction of subjective spiral forms in decoration. However, a strong conformity to a subjective spiral template could be used to support the suggestion of the depiction of subjective visual phenomena in decoration. Especially so if other geometric decoration which also resembles cortically generated visual effects were present within the culture.

1.5.2 Thesis structure

The following chapter discusses the definition of spirals and the perceptual basis for the variables used in the description of the motifs within the classification proposed in this thesis. The second theme of Chapter 2 provides a background to the occurrence of geometric visual disturbances arising from the structure of the visual cortex and discusses how these visual effects have been studied and classified as well as briefly reviewing existing studies which have proposed or identified the decorative or artistic representation of these phenomena in ethnological or archaeological contexts.

The method, developed in this research, of classifying and analysing spirals is detailed in Chapter 3. This chapter discusses the problems associated with initial data processing in ensuring that it could cope with the variation found in decorative spirals in a consistent and aesthetically appropriate manner. As far as possible, rules needed to be set down for the identification of the start and end points of the spiral and which part of the spiral to analyse when potential confusion arose between lined spirals and figure-ground configuration. Analysis variables described the basic shape of the spiral, the decorative elaboration of this curve. The measurement of individual variables is described. Finally, this chapter covers the conversion of the raw data into a format suitable for collation and the creation of the class groups using cluster analysis.

To assess the perceptual importance of the variables employed in the classification system a survey was conducted on perceptions of a range of motifs. Participants were asked to mark centre and end points on motifs, to judge the similarity of motifs when one, or more, perceptual variables was altered and to describe spirals and other geometric motifs so that the terminology used could be evaluated. Results from the survey were also used to guide the development of the analysis method and the limits of identification of a spiral. The results of this survey are presented in Appendix 1 and discussed in Chapters 2, 3 and 4 in relation to relevant perceptual variables and considerations in the method.

The classification method proposed in this thesis was tested against two pairs of case studies. The first pair, in East Asia, focusses on the Shang Dynasty further to the east of China and the Neolithic/pre-Neolithic Jōmon culture in Japan. The second pair is centred on the Eastern Mediterranean and focuses on Middle Kingdom Egypt and the Cypriot Bronze Age. Chapter 4 introduces these studies giving a brief background to the structure of the cultures; the main sites which were the source of the material analysed and the occurrence and symbolism of decorative spirals in the culture.

In Chapter 5 the analysis and classification method is evaluated. Improvements that might be made to precision and to the measurement of the irregularity and curvature of spirals are proposed. Alternative methods of classification and statistical analysis are also considered. The findings of the application of the classification system to the case studies and the comparison of the case study data with mathematical and subjective spiral forms are presented. Following this, the results of the four research questions are discussed.

Chapter 6 summarises this research, covering the development of a new analysis method and the results of its application to the case study data. Possible future developments of the method which might allow it to analyse spirals in three dimensions and cover a broader range of unclosed geometric motifs are suggested. An overview is provided of the links that were drawn between classes of spiral motifs based on their originating culture and representational origin. Future work in extending the scope of the case studies and the potential to re-evaluate the presence of subjective spiral influence with an expanded dataset is discussed.

2 Definition of terminology and variables and discussion of spirals as subjective visual phenomena.

The potential scope for defining a decorative motif as a spiral is broad; as even the few examples shown in Figure 2.1 demonstrate and clear defining boundaries need to be drawn. This chapter discusses existing mathematical definitions of spirals and sets out the criteria used in this thesis for identifying a decorative spiral. Since the contention of this thesis is that mathematical definitions are inappropriate to the description of decorative spirals, the second part of this chapter introduces an alternative set of aesthetically based variables and uses the results of the survey of perceptions of geometric motifs carried out during this research (Appendix 1) alongside literature review to provide a perceptual basis for their inclusion within the classification system as valid measures of difference in decorative forms.

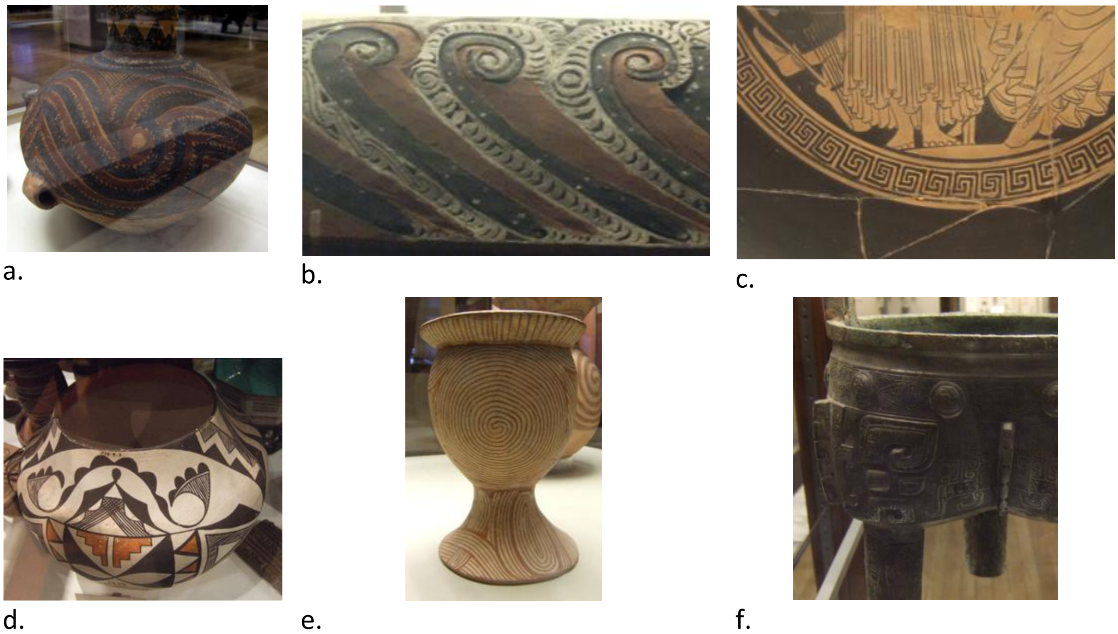


Figure 2.1 Variety in decorative spirals: a. Neolithic Chinese vessel, 2500BCE, British Museum, acc. no. 1966,0223.1. b. lintel board, Trobriand Islands, Cambridge Museum of Archaeology and Anthropology, acc.no. Z10036. c. Greek kylix, c.490BCE, British Museum, acc.no. 1836.0224.25. d. North American jar, Pitt Rivers Museum, acc.no. 1928.9.2. e. jar, Ban Chiang (N.Thailand), 2000-1BCE, British Museum, acc. no. 1972,0919.1. f. Chinese Shang Dynasty bronze vessel, British Museum, acc. no. 1947,0712.429.

The second part of the chapter discusses the possibility that there is a basis in the structure of the human visual cortex for spirals to be a preferentially noticed form in the natural environment and the occurrence of spiral visual effects generated within the brain as a potential inspiration for decorative spirals.

2.1 The definition of a spiral

Definitions of spirals found in the literature tend to operate in terms of the rotation of a line or point around a fixed point (e.g. Thompson 1942, p.748; Sharp 2002, p.59). These definitions exclude angular spirals and key patterns which, in a decorative context, have been accepted as legitimate spiral forms (e.g. Hull 2003, p.102; Dunham 2004). The results of the perceptual survey also supported this definition with 12 participants describing angular motifs as spiral.

In order to include the broad range of spirals found in decorative design, the following definition is proposed for what will be considered a spiral in this research:

> “A spiral is a line on a plane which winds or bends in a coiling form towards or away from a point without crossing over itself and in such a way that the line would entirely surround the point after travelling through 360 degrees and that the distance from the centre shows a decreasing trend.”.

Generally, the participants in the perceptual survey assessing aesthetic responses to geometric motifs (Appendix 1) showed a low use of the term 'spiral'. Participants were asked to describe the shape of 18 motifs, nine of which would conform to the definition of a spiral given above. For each 'spiral' motif, at least one participant gave a description which included the word spiral or a term felt to be synonymous (terms included 'angular spiral', 'rudimentary spiral', 'coil', 'helix', 'irregular spiral', 'squiggle spiral', 'jagged spiral') but only one motif (Fig. 2.2) which was the most regular of the spirals and the only curvilinear example attracted a high number of descriptions of its shape as a spiral (92%). All the others had spiral identifications of 50% or lower. As the intention of this test was to identify the limits of what could be perceived as spiral, other motifs tested were highly irregular so the low rate of identification as spiral is not surprising.

Figure 2.2 High spiral recognition motif (test motif 100).

In a second experiment, when asked to give a free description of a different set of motifs, four out of the five motifs tested scored much more highly for spiral identification with 78-100% of participants identifying the motifs as spiral. These motifs (Fig. 2.3a-d) might be considered more 'traditionally' spiral than the test motifs discussed above in that the rotation is greater and the expansion rate is regular. The fifth motif (Fig 2.3e) , which only one participant identified as spiral, has a low rotational length and a high expansion rate, both factors which mitigated against identification of curves as spirals.

a. b. c. d. e.

Figure 2.3 Pictorial test motifs nos 154, 155, 156, 157, 157b.

Theoretically, a curve of any arc length could be tested for conformity to the above definition of a spiral, studies of golden proportioning have identified very short lengths of curve as spiral (e.g. Doczi 2005) but, when asked to identify motif shape by choosing amongst four supplied keywords in the perceptual survey, there was a significant drop ($p=0.01$) in the number of participants who identify motifs as spirals when less than one full rotation was completed. No significant difference was found in the identification of motifs as spiral between rotations of less than 270 degrees and 270-360 degrees or those of 360-450 degrees and >450 degrees. These findings suggest a minimum curvature of 360 degrees to count a motif as spiral.

There is a strong indication in the chronological development of decorative motifs in a number of cultures that spirals occur on a continuum with non-spiral motifs (Fig. 2.4)

(Bagley 1996, p.19). The trend to find spirals of greater than and less than one full rotation in apparently similar decorative contexts appears particularly where two or more spiralling forms meet as running spirals or whirls (Figures 2.5 and 2.6) possibly due to the implied rotational motion increasing a sense of rotation length (Lidwell, Holden & Butler 2003, p.34).

a. 

b. 

Figure 2.4 Similar spiral and non-spiral motifs: a. Papuan drum, linked spiral and non-spiral curves, Leeds City Museum, acc.no. FL.1987.1.1. b. scarab with spiral and non-spiral links, (© Petrie Museum of Egyptology, University College London), acc.no. UC11151.

Petrie (1920, pp.20-21) identified spirals in the context of running patterns with linked pairs of spirals where each spiral typically only completes around 270 degrees rotation although this identification was not well supported by the results of the perceptual survey in which the angular non-spiral key pattern motif (test motif 112, Appendix 1) was only identified as spiral by two out of 22 respondents and the curvilinear equivalent motif (test motif 113) by only eight out of 22 respondents (Fig.2.5).

Figure 2.5 Test motifs 112 and 113 representing low-rotation key patterns.

Some cultures appear to show evidence of development from non-spiral forms into spirals (Bagley 1996, p.15) so the inclusion of these earlier forms is relevant in considering the development of the motif. The initial intent of this research, to study spirals in complete isolation from other geometric motifs, was therefore shown to be inappropriate and this highlights one of the difficulties of applying constructs from outside a culture which is discussed further in Chapter 4.

For the purposes of this study, to allow for the continuum of change, motifs which fulfil the criteria of spirals but are of 270-360 degrees rotation have been included and are described by the term 'spiraloid'[1] (below 270 degrees rotation, only one motif (Figure.2.6) was identified as spiral and its perceived rotation may have been enhanced by being part of a whirl structure).

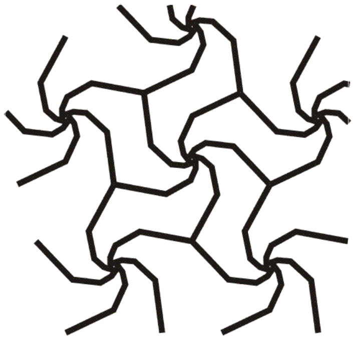


Figure. 2.6 Whirl motif of low rotational length (test motif 110).

Although this restriction on rotation will exclude some examples of decoration and of natural forms (such as flower heads) where spirals might be perceived, some limit on rotation is needed within the definition of a spiral for the term to have meaning.

When concentric circles are tightly packed and numerous, or when spirals have a low and constant expansion rate and high rotation, an optical illusion is created which makes the two forms visually readily interchangeable. Finally, in defining the spiral, mention must be made of ‘false spirals’ – groups of circles or concentric circles joined by tangential lines in a manner resembling interlinked spirals (Figure 2.7). To limit the scope of this research, false spirals have been excluded from analysis.

[1] Unless otherwise stated, the use of the term spiral in this thesis includes qualifying spiraloids.


Figure 2.7a. False spirals on a scarab, Liverpool World Museum acc. no. 56.20.297. b. A spiral resembling concentric circles on a Cypriot barrel jug, British Museum acc. no. 1876,0909.74.

2.1.1 Mathematical spiral forms

Mathematical spiral definitions have provided a basis for classification of spiral types in a number of previous studies of decorative spirals (e.g. Takaki & Ueda 2007; Zhushchikhovskaya & Danilova 2008; Banakh, Verbitsky & Vorobets 2010). Key tenets of a mathematical spiral are that the distance of the path from the pole can be related to rotation and that a single equation can be used to describe the full extent of the curve. Six mathematical spirals have been identified for which close equivalents have been found in the decorative arts. Archimedes' spiral, logarithmic spiral, hyperbolic spiral, parabolic spiral, lituus, and Euler spiral (Figure 1.7, p.31). With the exception of the Archimedes' spiral, for which the equation was known by the end of the third century BCE (Pickover 2009, p.66), the knowledge of these spirals as mathematical forms is more recent, only dating back to the seventeenth and eighteenth centuries CE (Sharp 2002, Wassenaar 2009, Weisstein 2010).

Assigning decoration to predetermined classes has less relevance than in the classification of objects where the form is related to physical function in the way that, for example, the shape of a ceramic vessel might be constrained by ease of pouring. Function may exist in decoration – invoking gods or indicating status but these functions are not determined by extra-cultural laws. Where function is affected by physical laws, types of object made for a particular purpose are more likely to have defined limits of shape beyond which they cease to function. These would have clearer class divisions than in decoration, which could be on a smooth continuum. There is also less reason to expect commonality in type groups of decoration between cultures due to the lack of restraints; so where commonalities between cultures do exist this point may be used to strengthen arguments for cultural transmission when commonality is detected since an analogous link cannot be argued.

Since some natural spiral forms show apparent close conformity to mathematical spiral types, the use of these categories to classify decorative spirals has a reasonable basis in the possible origins of decorative forms but raises problems with the potential relevance of applying mathematically based classes which may not have been deemed significant. If mathematical classes are taken to accommodate the full range of decoration, there is a risk of pushing decorative spirals into mathematical classes to which they do not conform to such an extent that the use of mathematical terms becomes meaningless and implies a precision which is not present. Assessed from a purely visual standpoint without measurement there are many decorative and natural spirals which might be reasonably assigned to more than one mathematical class and even with measured values, Andrey and Galli (2004) found that construction systems for some volutes might equally well be said to approximate logarithmic or parabolic spirals. Mathematically a straight line could be described using the equation of a logarithmic spiral with an infinite expansion rate. Using ruler and compass-based construction techniques, there is almost bound to be ambiguity since it is not possible to draw a perfect spiral using these tools. The ambiguities that arise from attempting to match irregular decorative curves to mathematical spirals are felt to be one of the key drawbacks in attempting to use mathematical spirals to describe decoration. The variables of the alternative analysis system proposed in this thesis are discussed below.

2.2 Decorative spiral classification

An effective classification system needs to take into account the range of variation in forms and styles of decorative spirals or, at the very least, acknowledge and justify any variables which are excluded. An initial set of variables considered for inclusion within the classification system was identified from a review of decorative spirals in museum collections, attempting to cover a diverse range of cultures and subjectively noting the ways in which the spirals encountered appeared to differ.

Nine potential variables were identified:

- overall shape (form);
- style
    - curvilinearity;
    - direction of turn;
    - orientation;
    - rotational length;
    - diameter;
    - width of lines and gap between lines (path width and spacing);
    - irregularity;
    - colour and patterning applied to wide lines.

The proposed variables were divided into two types - form and style. The term form is used to describe the gross curvature of the spiral regarded as a notionally infinitely thin path shorn of all decorative attributes. The decorative variables relating to a single spiral were considered to be variables of style. Style is taken to describe all aspects of a single spiral coil which are independent of the underlying curvature.

For the identified potential variables, evidence was sought from the perceptual survey and from literature review of studies of perceived motif similarity and grouping to establish whether they were appropriate for inclusion within the classification system. Evidence that an attribute made a significant difference to assessment of similarity was taken as indicating that the variable was valid in creation of class groupings.

Some criteria for perceptual grouping employed by humans have been observed in other primates (Kayaert, Biederman and Vogels (2005) identified that macaques could differentiate according to irregularity and curvilinearity and rhesus monkeys, tested under laboratory conditions, showed the ability to distinguish proportions of rectangles at an average accuracy of 85.56% (Vallentin & Nieder 2008)). It was believed that the creation of perceptual groups was a low level process so relatively unlikely to be influenced by cultural variation, more recent work has, however, suggested that perceptual grouping is a higher level visual process (Palmer, Neff & Beck 1996). There is contradictory evidence as to whether assessment of constancy (invariance relative to viewing conditions) occurs before or after grouping (Palmer & Rock 1994; Beck 1975). Studies of uniform connectedness (physically linked motifs), and amodal completion (filling in of missing elements) suggest that these processes precede the formation of groups (Palmer & Rock 1994; Palmer *et al.* 1996). The interaction of perceptual variables and the strength of their expression can affect their perceived importance in grouping (Kayaert & Wagemans 2010). Prior knowledge and learning can also influence the strength of grouping effects (Beck & Palmer 2002). This last aspect, in particular, creates problems with suggesting that a classification based on perceptual grouping can be considered culturally independent. The further a set of classificatory criteria are removed from a primitive physiologically-based interpretation of a visual stimulus, the greater the risk of cross-cultural non-equivalence.

That perceptual grouping judgements do not appear to operate fully at a pre-attentive level and may be influenced by learning does not necessarily imply that they cannot attain wide cross-cultural relevance particularly when dealing with the properties of geometric constructs which are found widely in the natural environment and can be perceived from the structure of the human visual system. It is suggested that underlying principles governing perception are learnt at an early age to an extent where they can operate at a subconscious level (Kunst-Wilson & Zajonc 1980; Pittard *et al.* 2007). However, Pittard *et al.* (2007) suggest that some preferences are learnt from natural forms, and that the exposure of different cultures to similar natural forms (such as the proportions of the human body) produces universal learnt preferences although the significance of golden section as a universal preference, which was the focus of Pittard *et al.'s* study, has been contradicted by other research (van Damme 2000, p.261). Attempts to find universal aesthetic preference values have produced mixed results and the idea of such universal values existing tends now to be considered unlikely in reference to specific variables (van Damme 2000, p.258) There have, however, been sufficient studies which show cross-cultural agreement in preferences (e.g. Berlyne 1975; Pittard *et al.*2007) to suggest that some basis for agreement might be identified. Van Damme (2000) suggested that universal values might be found in the incentives for preferences, such as variable expressions deemed to indicate good health, but not necessarily in the variables which are considered to exemplify these values. Some contexts in which spirals naturally occur may acquire associations with danger and power (snakes, cracking patterns, aberrant mental imagery) or with new life and potential food sources (plant shoots). Both of these concepts would have had substantial evolutionary importance and there is reasonable evidence to suggest particular sensitivity to them within the visual cortex so it seems credible that spirals may be amongst the natural constructs which have a fundamental influence in early development on decorative preferences. If the basis of criteria for grouping is derived from a common natural input then the variables remain valid even if their expression is changed by other cultural influences as Pittard *et al.* (2007) results appear to suggest in a preference for 1:1 proportions in abstract logo designs in contrast to a preference for golden proportions in organic based designs which they attribute to a learnt preference from exposure to common brand logos with 1:1 proportions.

The evidence of this review shows that it is necessary to treat the proposed variables as an artificial and incomplete system. Even when a variable can be shown to be significant in perceptual grouping in cross-cultural studies, it is not possible to know their relative importance for the cultures studied or to know if variables, which the cultures in question would have considered more perceptually important, have been missed. The claim for the validity of the variables used in this classification system is, therefore, that they provide a fuller description than one based solely on curve shape and that they measure variation in consistent and quantifiable terms not that they create the same type groupings that the members of the cultures studied would have created. One aim of the perceptual survey was to test whether the potential variables identified for inclusion in the classification system were seen to describe aesthetically important aspects of spiral motifs and whether they were valid differentiators to be used as a basis for creating type classes of motifs. To test variables as a means of differentiating spirals, survey participants were asked to rate the similarity of 53 pairs of spirals on a scale of one to ten (Appendix 1 Tables A1.1 and 2; test motifs 131-153, 158-165, Table A1.6).

2.2.1 Form

Of the identified variables, form most closely approximates the spiral classifications based on mathematical groups but because of the deviations in the form of decorative spirals from smooth mathematical curves form and the potential for limitless variation in form, the identification of those variations of form which are expressed in decoration comes to be of aesthetic importance.

In the perceptual survey test of similarity, nine of the motif pairs tested form differentiation. Of these, only one pair yielded a significant result. As discussed in Appendix 1, all significant similarity test results returned results indicating high similarity and there are methodological reasons to suggest that the structure of the survey may have skewed results towards high similarity scores. The form similarity test registered as the most important differentiating variable in the perceptual survey with a dissimilarity score of two but, with only a single significant result, the relevance of this result needs further checking. The experiment asking for free description of motifs supported more strongly the aesthetic importance of form - all participants provided at least one form-related descriptor for four of the five test motifs (85% gave a form description for the fifth, Figure 2.3e, p.38).

Washburn (1983a, p.2) asserts the primacy of shape in the identification of objects and the ability of humans to abstract an underlying shape from complex objects. Studies of constancy in the ability to identify objects under rotational transformations have shown that form can be detected in the face of considerable distortion of the retinal image (Jolicoeur & Humphrey 1998) and have suggested that the extraction of an object's form occurs at an early stage in the processing of a visual image. The survey results and the evidence from literature review of the facility of the visual processing system to identify form both support the inclusion of this variable within the classification system.

Two of the variables of style discussed below might, in principle, be considered to fall within the scope of the form variable: irregularity and curvilinearity. These two variables were separated out because of a potential loss of resolution in these variables if considered as part of form arising from abstracting the decorative spiral down to a single line.

2.2.2 Stylistic variations in decorative spirals

Stylistic variables are included in the proposed analysis system because decorative spirals, exhibit aesthetic traits which render the description of the spiral form, by itself, insufficient to characterise and differentiate them. The examples shown in Figure 2.8

have a form correlation of 0.997 but the stylistic variables create a marked difference between them and in analysis they were eventually grouped in separate type classes on the strength of these differences. The potential variables for the description of style are discussed below.

Figure 2.8 Shang Dynasty spirals with a high form correlation but low style match.

2.2.2.1 Curvilinearity

As a stylistic variable, curvilinearity is determined by the number of line segments making up the spiral – a spiral composed of only one line segment is necessarily curvilinear. The group of angular spirals covers those formed from straight line segments meeting at angles rather than continuous curves (Wassenaar 2009). Irregular spirals may combine angular and curvilinear elements as can be seen in the Shang Dynasty examples above.

In the decorative arts, angular spirals are rarely found as individual motifs. They usually form elements of border and all-over patterns such as key (or meander) patterns (Figure 2.9). Their linear structures make them well suited to reproduction of woven textiles and they are a common element of Central and South American woven decoration (Figure.3.15, p.81). The known use of spiral key patterns as a decorative motif dates back 14-15000 years at Mezin in Ukraine (Iakovleva 2009).

Figure 2.9 Angular spiral meander pattern on a ninth-century cross, St.Illtyd's Church, Llantwit Major.

Pittard *et al.* (2007) suggested that angular shapes may have a symbolic significance as representing conflict and that this may affect preferences for such forms across a culture with societies more inclined to conflict-avoidance more likely to favour smoothly curving forms. It seems likely though that they are most often deployed because they can create an all-over covering of a surface without large gaps between either motifs or individual lines. It is only in this context that they appear to be used preferentially to curvilinear forms.

In the perceptual survey, four similarity pairings tested curvilinearity as a differentiator, none of these yielded significant results. Curvilinearity featured more prominently in tests of the aesthetic importance of the variable. In an experiment asking participants to describe the shape of 23 motifs (Appendix 1, Table A1.3), nine of the 31 participants gave responses which included the words 'angular', 'jagged' or 'curvy'. In the free description of motifs, three participants used the terms 'curvy', 'curly' or 'loopy'. These descriptions cannot be given a strength rating as a measure of importance but indicates that the degree of curvilinearity of the motifs under examination was noted and considered to be a valid descriptor.

Kayaert *et al.* (2005) found that irregular shapes in which contours were composed of entirely curved or entirely straight lines provided a very strong stimulus for differentiation. Regular shapes, some of which were composed of curved and straight sections were less strongly differentiated from the angular set than from the entirely curvilinear set suggesting that the ability to find straight lines within a motif may be a significant grouping factor.

Although no conclusive results were obtained from the perceptual survey, the results of literature review were felt to indicate that curvilinearity should be considered a significant differentiating variable and included in the analysis.

2.2.2.2 Orientation

Zhushchikhovskaya and Danilova's (2008) study also supports the inclusion of orientation as a variable on cultural grounds since they found cultural commonalities in the vertical or horizontal orientation of double linked spirals.

Orientation was found to be the second most important differentiating variable within the perception survey. Surprisingly, of the three significant test results, spirals with markedly different perpendicular axis lengths (test motif 158A) showed the lowest differentiation based on orientation. The highest differentiation was between groups of spirals with ordered and disordered orientation (test motif 164A) and may relate more to the potential to find symmetrical associations within the clustered elements than to the value of orientation as a differentiator. Considered only on the comparison of individual spirals, orientation was the least important differentiator. The majority of the motifs were presented singly and in a neutral context where the impact of absolute or relative orientation would be likely to be minimised. The only instance in which orientation related terminology was used in description was in relation to test motif 90 which was described by six participants as an upside-down L. Seven participants, however described the motif as having an L-shape without commenting on it being upside-down so had 'corrected' the orientation without noting it as important.

Beck (1966a) found that orientation was a key differentiator in grouping when there was a difference in the angle of the primary axis. Indeed, this registered as a stronger grouping variable than form. However, the value placed on form and orientation as differentiators conflicted according to context and orientation variation which did not show difference in the primary axis was sometimes subsidiary to form. This variable was included in the analysis although, for some objects analysed in the case studies, it was not possible to record orientation since the object itself had no single correct orientation. This meant that approximated values had to be substituted for some objects in order to include them in the analysis as discussed in Chapter 3.

2.2.2.3 Rotational length

Beyond the minimum rotational length limit discussed above, the rotational length of spirals showed some of the highest extremes of variation of the style variables in the chosen case studies. Mamaní and Fernández Distel (2003, p.39) suggest that spirals in pre-Colombian decorative arts show sufficient consistency in the number of rotations that this must have had some symbolic significance but no evidence for a known meaning assigned to the number of turns in a decorative spiral has been found. Evidence has been found in concentric circle motifs of consistency in the number of circles produced when representing a particular phenomenon (the use of four of five concentric rings to represent a sacred water hole in Australian Aboriginal ground-paintings (Nicholson & Firnhaber 2003, p.61) though it is not clear that the number of circles is seen as significant.

Within the perceptual survey, this variable did not rank highly as a differentiating variable (Appendix 1, Tables A1.1 and 2). Significance of rotational length was assessed in eight tests, of these only two yielded significant results both with a modal similarity score of nine. No descriptive terms were used in survey responses which had a bearing on the rotational length of the spiral.

A study of the similarity of gestures, represented by the animation of the creation of various linear patterns, found that line length had a low bearing on perceptions of similarity (Long, Landay, Rowe & Michiels 2000). The gestures used to test line length significance in the experiment by Long *et al.* would, in the terminology of this study, be regarded as spirals and spiraloids so this study offers a relevant comparison to the results of the perceptual survey. It is interesting to note that Dronfield (1996b) used the number of full rotations of a spiral as a measure of its 'intensity' in the analysis of Irish prehistoric tomb rock carvings. In this context, he derived the intensity measure from an estimation of the amount of material which would have needed to be removed to carve the motif as an index of the time taken over the creation of the motif. Although this measure would apply much less strongly for the production of spirals in less labour intensive media, it might reflect the time available for the production of motifs and therefore be used as a means of assessing mass production of objects and their decoration in contexts where each motif has to be produced afresh.

Although rated as a variable of low significance through literature review and survey, the extremes of variation within the case study data was felt to warrant the inclusion of rotational length as a potentially relevant variable in classification.

2.2.2.4 Path width and spacing

The width of lines and the gap between them was also found to be highly variable within and between cultures used as case studies. Evidence from literature review supported the view that path width and spacing show considerable variability in decorative expression. Several of the different methods of drawing Ionic volutes vary according to the width of line and gap between lines (Andrey & Galli 2004). As well as recording average widths, these variables measured changes in the trend of width and included decorative embellishments to the ends of spirals such as the 'trumpet spiral' (Figure 2.10) (Hull 2003, p.113).

Figure 2.10 Celtic or Anglo Saxon hanging bowl escutcheon with trumpet spirals showing path width variation, British Museum, acc.no.1870,1013.16

Within the perceptual survey, only one out of 13 tests, which included spacing as a variable, yielded significant results. The significant test indicated that spacing did not rank highly as a differentiating variable but both spacing and rotational length were varied in this test so reliable results could not be obtained for the spacing variable alone. The spacing variable is specific in application to spirals whereas the other variables used in the classification system might be relevantly applied to a broad range of unclosed motifs. No significant results were obtained for path width as a differentiator in similarity tests. Three survey participants used descriptive terms for spiral motifs which reflected on path width and spacing. Across the free description motifs they used the terms 'tight', 'evenly spaced' and 'concentric' for Figure 2.6b and contrasting descriptions of 2.6c as 'varied in width and 2.6e as 'expanding'.

Beck (1966b) found that increasing line width produced a greater perceived contrast with dark on light patterns but no significant result with light on dark patterns. Similarly, variation in spacing affected figure-ground contrast but no evidence was found to suggest how important these variables are as differentiating factors in perceptions. Studies of target identification have found that line width variation can be a significant factor in the rate of rejection of potentially matching motifs (e.g. Becker 2011) suggesting that in these studies, line width is playing a role in creating an impression of similarity. Pinna (2004), incidentally to her main study focus, also found that line width commonality was relevant to the creation of similarity groups. In contrast with the spirals drawn to represent endogenous visual phenomena (section 2.4), few of the decorative spirals encountered in this research showed overlapping lines. This implies, particularly with tightly packed spirals, that care was taken in the creation of the motifs to regulate the expression of this pair of related variables. Because of the variability seen in decoration and the findings from literature review that line width could be a significant grouping variable, these variables were included within the analysis.

2.2.2.5 Irregularity of coil

Irregularity is taken to refer to deviation from the path of the identified primary curve due to unsystematic ‘wobble’ or decorative patterning. In many cases, apparently random wobble will be an unintentional product of freehand drawing but there may be instances, such as Figure 2.11a below where the apparently random irregularity represents a deliberate decorative effect as much as more obviously regular patterning (Figure 2.11b). For this reason patterning which affected the outline of the spiral was included in the analysis of irregularity.

Figure 2.11 Patterned or random irregularity. a. Plate with freehand spiral 1950's-60's designed Teddy Millington Drake (Victoria and Albert Museum acc.no. C.54-1991); b. Detail of an octopus tentacle from a jar from Crete, 1450-1400BCE, Ashmolean Museum, AN1911.608.

The influence of irregularity on the perception of similarity was tested in nine motif pairings in the survey of which three yielded significant results. These placed irregularity behind form and orientation and of equal importance with all other included variables as a significant variable within the perceptual survey. As with the other similarity results from the survey, consensus tended to be greatest on those motifs that might be deemed to be most similar – those comparing similar magnitudes of irregularity that only differed in exact expression. Comparisons between smooth and irregular motifs and between systematic and unsystematic irregularity, did not yield any significant results. Nine participants used 'regular' or 'irregular' as shape descriptor or in free description terms for motifs. However, these responses related to smooth near-circular spirals and to motifs with changes in direction of curve on a large scale which were covered by the form variable within this method. Minor irregularity due to wear seen in Figures 2.6a and b was not apparently registered as important, both of these spirals were only described as regular.

In contrast to the similarity results of the survey, Kayaert *et al.* (2005) found that the strength of separation between regular and irregular shapes was high and similar to that between irregular curvilinear and angular shapes as mentioned above. Because the survey results tended to register similarity more strongly, possibly unduly strongly (see Appendix 1), priority was given to the literature review results and irregularity was included within the analysis.

2.2.2.6 Colour and patterning

Colour and patterning are of clear aesthetic importance in decoration. Phillipps (1949) used patterning on the spiral to distinguish type classes of Maori spirals, prioritising it above other style variables and overall form. Herner (1989), studying spirals on Bronze Age Scandinavian brooches, and Zhushchikhovskaya and Danilova (2008), studying East Asian Neolithic pottery spirals, also noted culturally significant differences in spiral patterning. An example of the importance of colour as a distinguishing variable can be seen in the emotive and symbolic terminology used by Yörük weavers to describe both the choices of colour and colour harmony in their work (Daugherty 2004, p.331).

None of the perceptual tests of patterning as a differentiator yielded significant results but in describing the two photographic images that included patterning, five participants made explicit reference to the patterning of test motif 88 and six to that of test motif 157b (Figures 2.12 and 2.3e, p.38). Three participants made explicit reference to the texturing of the stone and bone spirals (Figure 2.6a-c). In reference to both patterning and texturing several other descriptors were used which may indirectly relate to the surface patterning and texturing; in reference to motif 88 descriptions of it as a fossil or sun and in reference to the stone and bone spirals, descriptors relating to technique or material must have made reference to texture.

Figure 2.12 Test motif 88 showing surface patterning.

All three tests of similarity by colour in the survey yielded significant results with a high level of similarity being reported (modal value of nine). This result may have been influenced by the emphasis on shape throughout the rest of the survey. In the free description questions, eight participants used colour as a descriptor at least once.

Quinlan and Wilton (1998) found that in most tests colour was more important grouping variable than shape in consideration although some grouping combinations could counter this effect. Cultural variation in the preferences for and the importance placed on colour may also vary. Hirschfeld (1977) studying the aesthetic preferences amongst the Kuna[2] found that embroiderers preferences for applique designs found that properties of form – complexity and symmetry ahead of colour were more important than colour in determining preferences.

Although both colour and pattern are important descriptors the decision was made to exclude both variables from the classification system because neither attribute is inherent to the nature of the spiral as a motif – similar patterning or colouration might appear on any planar surface.

2.2.2.7 Diameter

Diameter was felt to be the most appropriate variable to represent the absolute size of spiral motifs. The size of the decorated object is clearly an important limiting factor on motif size so measurements of diameter would need to be made in proportion to object size.

In the perceptual survey, the size difference of pairs of, otherwise identical, motifs with no background context was ranked as equally important as direction of turn, rotational length, irregularity, spacing and colour as a significant differentiator so the exclusion of this variable is not ideal. The key reason for excluding this variable was one of practical difficulty in a lack of known measurements for analysed examples drawn from publications or online museum catalogues.

2.2.2.8 Direction of turn

The cultural meaning of spirals can be dependent on how a culture interprets their physical shape. Perceptions of direction of turn depend on whether the spiral is regarded as coiling inwards or outwards; on which way up the object is; and on whether the spiral is regarded as being static or revolving.

There may be a physiological element to the direction of turn of spirals in the decorative arts; due to the arrangement of the muscles in the arm it is easier to rotate

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[2] Indigenous group of the San Blas Islands, Panama.

the right hand in a clockwise direction and the left hand in an anticlockwise direction (McManus 2002 pp.46-48). Depending on the handedness of the artisan a natural tendency to draw spirals in one direction or the other might be expected although this would also assume a consistent tendency for people to draw spirals from the outside inwards or the inside outwards. It appears that the influence of the handedness of the sculptor on the direction of spirals is evident in a statue on which the curls of hair are carved in opposite directions on either side of the head (Cook 1914 p.241).

One of the four tests of direction of turn as a similarity measure yielded a significant result. with a modal similarity score of nine although three participants used direction of turn as either a shape descriptor or as a free description turn.

Although it can be shown that symbolic significance is sometimes placed on the direction of turn (Cook 1914, p. 30), the lack of perceptual importance placed on this variable and the likelihood of a physiological influence on its expression led to this variable being excluded from further analysis.

2.3 Perception of spiral forms

Two questions posed in this research aimed to identify possible motivating factors in the production of spiral decorative motifs by comparison with naturally occurring spirals as possible sources of inspiration. As noted in Chapter 1, spirals can be found in a wide range of naturally occurring structures and varied studies have attributed the use of spirals in decoration to the reproduction of natural forms (e.g. Takaki & Ueda 2007; Lewis-Williams & Dowson 1988) but the fact that spirals are frequently copied from natural forms does not explain the reason for the particular selection of this structure for reproduction. Bando and Hirabayashi (2004) found that spiral motifs were given preferential attention when compared with concentric circle and radiating line patterns both in terms of which motifs first received attention and in the length of attention devoted to them. An explanation for this may be found in the structure of the human visual cortex. Graziano, Andersen and Snowden (1994 cited in Bando and Hirabayashi 2004) identified that the V5 region of the visual cortex which is associated with the detection of movement is structured to respond most strongly to particular patterns of motion and found that spiralling movement is one of four fundamental motion types which are detected by neurons in the V5 region. An innate tendency to recognise spiral shapes and their association with natural forms which are important either as a potential food source or as a threat may go some way to explain the depiction of natural real spiral forms.

A second possible naturally occurring inspiration for spiral decoration considered in this research addressed spiral visual effects generated within the brain. Since the nineteenth century, optical effects which occur during periods of unusual brain activity such as migraines and before epileptic seizures have been studied and recorded (Ermentrout & Cowan 1979). It was observed that, in addition to hallucinations of real objects, a recurring set of geometric light patterns could be identified in these visual effects. Psychoactive drugs can induce similar effects and the availability of these for experimental study under controlled conditions allowed attempts to be made to record the nature of the geometric patterns across a number of subjects. The concept of the 'form constant' was introduced in 1928 by Heinrich Klüver (1967 cited in Ermentrout & Cowan 1979) to describe the geometric visual phenomena generated within the optical system independently of external visual stimuli. Klüver divided the visual phenomena into four classes (tunnels, webs, lattices and spirals (Figure 2.13)).

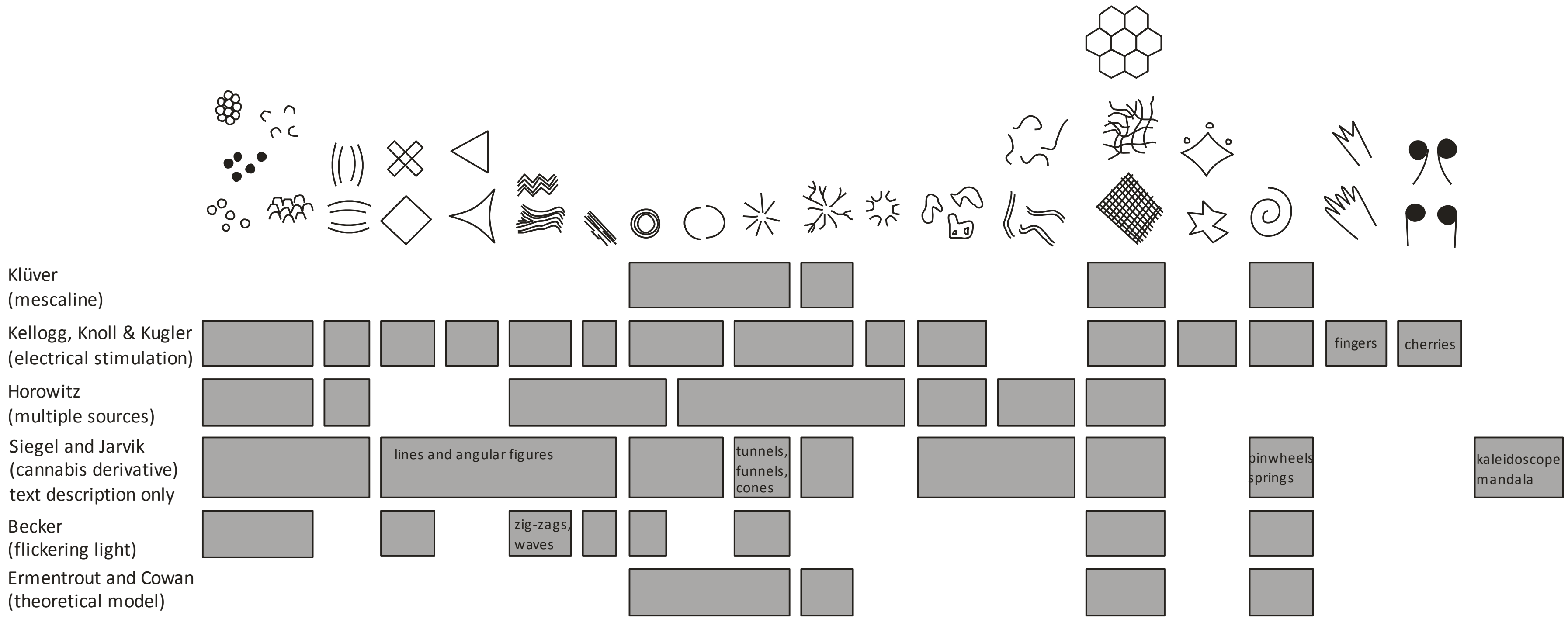


Figure 2.13 Class groupings of geometric visual phenomena.

Ethnographers studying the use of psychoactive drugs in ritual observed that the decorative styles of the cultures they were studying included geometric patterning which resembled the classes of geometric visual phenomena observed by Klüver and others. On some occasions, informants expressedly linked the decorative style to representation of visual effects seen during trance states. Using ethnographic analogy, later studies have drawn a link between the presence of motifs resembling form constant types in rock art of prehistoric cultures and the use of trance states in religious practise. Lewis-Williams and Dowson (1988), in particular have suggested that the presence of these motifs is indicative of shamanistic practises within the cultures that produced them. This association is controversial as others have proposed alternative explanations for the use of abstract geometric motifs or have suggested that these motifs do not appear in contemporary shamanistic societies with sufficient consistency to make a link (see comments on Lewis-Williams and Dowson (1988); Bednarik (1990); Bradley (1989)). The use of the spiral classification system proposed in this research aimed to test whether the concept of such a link could be supported by measured analysis of spiral shape and to search for these forms in a wider range of cultures than those with explicit links to shamanistic practise on the assumption that if these physiologically engendered effects were represented in decoration, their presence would be likely to be widespread (Hodgson 2000). This section discusses the mechanisms of production of the geometric visual effects; types of trigger and the shape classes of visual phenomena identified.

Internally generated visual phenomena have variously been termed ‘phosphenes’ ‘entoptic phenomena’ and ‘subjective visual phenomena’ and have been subdivided into two classes: hallucinations, which partially draw on memory to create non-real imagery, and endogenous phenomena, arising from the structure of the visual system (Dronfield 1996a). This research is solely considering the second class which will be termed 'endogenous visual phenomena' (EVP). Although some of the spirals analysed as representations of subjective visual phenomena were given representational interpretations by those experiencing them, the drawings produced appear to accord more closely with forms typically identified as endogenous, Horowitz (1964) noted a marked contrast between the representational language used in describing visual phenomena and drawings of the same phenomena.

Klüver's (1967) study induced EVP using the psychedelic drug mescaline. Similar types of geometrically-patterned EVP can be triggered by deliberate or unintentional sensory deprivation (La Barre 1975, p.11); they may occur before epileptic fits, in the transitional stage of falling asleep, during migraines and can be induced by other psychedelic drugs (Ermentrout & Cowan 1979).

The concept of classifying the patterns identified in EVP has been developed from Klüver's original set of four form constant patterns in subsequent studies employing a wider range of natural and drug induced occurrences of EVP. Knoll and Kugler (1959) used electrical stimulation to induce EVP and found that stimulation at differing frequencies could create differing typical pattern types (Fig.2.13). This suggested that the type of EVP represented by form constants originate in the optical cortex rather than the eye itself and arise as a result of neuronal activation or inhibition patterns usually established when an external visual stimulus has been removed (by a darkened environment or closing the eyes) (Siegel & Jarvik 1975, p.143); the occurrence of EVP is attributed to a disinhibitory effect on the brain stem permitting increased levels of cortical excitation causing instances of hypersynchrony in neuronal firing to arise from the normal low level excitation state (Ermentrout & Cowan 1979). The exact location of generation of EVP within the visual cortex remains uncertain – the striate (V1) visual cortex has been suggested as an origin point. Bressloff *et al.* (2001) suggest a cellular structure of the V1 cortex which could account for all the form constant patterns identified by Klüver with the various form constant structures being translated from a radially symmetrical form occurring in the retina to a translationally symmetrical form in the cortex causing circular tunnel effects to be represented in the cortex as vertical lines and spiral whorls as diagonal lines. However, since spiral and tunnel EVP are often associated with movement, the V5 visual cortex (which receives input from the V1 region) may be either the source or a necessary additional structure for the perception of these types of EVP (Dronfield 1996b) as well as the locus of detection of external spiral structures.

Causatory factors of EVP have been divided into three types: toxically induced - arising from exposure to psychedelic substances, endogenous – arising from an internal disturbance of the nervous system and exogenous – arising from an external stimulus to the nervous system involving, for example, electrical impulses applied to the temples or pressure on the eyeballs (Becker 2005, p.4). In discussing studies of spiral EVP it must be noted that there is not necessarily consistency between studies in what is meant by 'spiral' – some use whorls of low rotational length and others single spirals of greater rotation and it is not always clear what participants have described, what terminology participants used and what assumptions were made by the researchers. Siegel and Jarvik (1975, p.112) assigned nine groups based on verbal descriptions of imagery seen by subjects taking cannabis derivatives (Figure 2.13); this categorisation included complex representational imagery as a single class. Once an initial set of constants had been identified Siegel and Jarvik trained participants in subsequent tests to use these groups and so may have influenced the variety and identification of descriptions.

Spiral EVP groups have been identified using all three causatory factors (e.g. Siegel and Jarvik 1975 (drugs), Horowitz (1964) (schizophrenia) and Becker (2005) (high frequency flickering light)). Siegel and Jarvik's results from studying toxically induced subjective visual phenomena suggest that spirals and webs were the least frequently reported geometric EVP both in controlled tests with trained subjects and in reported experience of Huichol participants in rituals (Siegel & Jarvik, p.129 Fig 12, p.139 Table 4). Classifications were ambiguous and spirals may have been reported within the much more frequently occurring class of tunnel imagery compare Siegel and Jarvik (1975) Figs. 8 and 21; Nicholson and Firnhaber (2003, p.58)). Kellogg, Knoll and Kugler (1965) only identified 14 spirals amongst 520 electrically induced geometric EVP patterns, ranking them tenth in frequency in a class system of 15 EVP types. In contrast, Becker's (2005, p.47) experiments recorded a higher frequency of spiral observation with 22% of visual effects classed as spiral. The classes identified within any of these systems are not clearly differentiated, EVP can merge, fragment, overlap and multiply in a manner which makes absolute boundaries between classes difficult or impossible to establish (Lewis-Williams & Dowson 1988). The presence of a static spiral EVP class has been doubted by some analysts; Horowitz (1964) does not identify spirals as a specific geometric EVP class but associates them instead with the tendency to see circular shapes and parallel lines. Lewis-Williams and Dowson (1988) exclude spirals from consideration on the grounds that they are a 'special case', but present spirals in Coso rock art (of the California Great Basin) within the class of web patterns (Figure 2.13).

Siegel and Jarvik (1975, p.110) suggest that drug induced EVP of the geometric type identified by Klüver as form constants are more intense than those produced by other stimuli and may take different forms. It may be the case that geometric EVP induced by events other than drug taking feature spirals more frequently; Feinberg (1970, p.126) identified that the presentation of dream imagery, schizophrenic hallucinations and those induced by mescaline differed in their typical presentations. Tass (1997) modelled different types of neuronal activation or inhibition pattern to show that if these were varied by the agent causing the cortical excitation different types of EVP might be expected. Also, there might be variations in whether spiral EVP are static or rotating, their direction of turn, number of arms and curvilinearity. This variation must be seen as speculative because studies of variation in EVP according to trigger type have not been found. Siegel and Jarvik (1959, pp.134-136) cite two examples of frequent spiral imagery experienced by people with schizophrenia. Horowitz (1964) studied the subjective visual phenomena associated with schizophrenia and recorded some spiral effects being drawn either as individual images or as components of larger drawings. Panayiotopoulos (1994) and Schott (2007) identify typical migraine and epilepsy related imagery spiral EVP do not appear to be characteristic of these disorders. The limited and consistent forms of migraine-related EVP may indirectly give support to the idea of variation according to stimulus type. Oster (1970) noted that light or harder pressure on the eyeballs also produced differing and consistent patterning.

2.4 Endogenous visual phenomena and their occurrence in decoration.

The physiological origin of EVP patterns should provide a sound basis for cultural comparison but Bahn (1988) raises the question of whether there is yet sufficient evidence to suggest that geometric EVP can reliably be considered universal and consistent over time. Hodgson (2000) suggested that the necessary neural pathways to generate EVP's would have evolved by the time of the creation of the earliest marks resembling them in the Lower Palaeolithic. The likelihood of physiological consistency is supported by the generation of EVP proposed by Ermentrout and Cowan (1979) occurring in the part of the visual cortex first reached by signals from the retina with minimal higher level visual processing having taken place; inter-species consistency has been shown in the basic process of mapping a received visual image onto the V1 cortex as an array (Stewart 2011, p.173). Butterworth (1967 cited in Siegel and Jarvik 1975) found notable consistency even in the occurrence of representational imagery between individuals in some studies which suggests similar underlying mechanisms in their production. Laboratory tests have not, however, covered a broad ethnic span and study of change over a relevant timescale would not be possible, so this assumption of physiological consistency has not been tested.

There are several factors which might be expected to introduce inconsistency in decoration inspired by EVP, the manner of expressing of the patterns in an outward form will be culturally variable (Siegel & Jarvik 1975, pp.137-8) and reactions to psychedelic drugs can differ between cultures (Siegel & Jarvik 1975, p.136). A further complication is introduced in that two stages of subjective visual phenomena may be observed, the first involving geometric EVP and the second developing into hallucinations involving more complex representational images (Siegel and Jarvik 1975, p.111). Lewis-Williams and Dowson (1988) added a middle stage marked by a transition between rapidly changing EVP which those experiencing them have difficulty describing and the attempt to assign representational meaning to the EVP being experienced. This middle stage could be a property of the subject gaining experience and learning to observe and describe recurring images or of the interference of hallucinatory imagery from the last stage encouraging a representational interpretation of the abstract EVP structures. Representational language is frequently used in the description of geometric EVP by those who have experienced them (Horowitz 1964) and this interpretation will necessarily be restricted to the cultural experience of the individual (Siegel & Jarvik 1975, p.137) and may affect their interpretation and recollection of EVP observed in the first stage especially given the gradual process of change from abstract/geometric to representational imagery (Maclay & Guttmann 1941).

The perceptual survey responses highlighted the problem of language constraints on interpretation of motifs. Most participants felt able to answer tests that did not require a high degree of reference to an external set of concepts (e.g. mark the centre) but response rates were lower when asked to describe a motif and some participants responded that they did not know what shape the motif was. This suggests that EVP forms for which the language and culture do not provide a convenient descriptive term are more likely to go unreported. External stimuli can, in some cases, influence the hallucinated imagery (Siegel & Jarvik 1975, p. 130) which might, again, lead to a culture-specific effect. The potential for cross-cultural inconsistency in the reporting of EVP lowers the likelihood of their identification from analysis of the decoration itself. From the approach taken in this research, starting from the motifs rather than their causatory factors it also limits comparability if two cultures influenced by EVP produce different sets of motifs. However, if an underlying physiologically derived form can be consistently observed, the variation around these forms which makes their identification difficult is likely to be driven by culturally specific factors and so to be potentially informative and to provide a basis for comparison.

The presence of EVP-related decoration has been identified in ethnographic studies and historical sources from a wide range of cultures. Mural and pottery decoration produced by the Tukano people of Colombia uses geometric imagery resembling EVP and explicitly linked by the local populous to visual effects associated with the consumption of the psychedelic drug yagé, obtained from *Banisteriopsis* vines, during divination and healing rites (Reichel-Dolmatoff 1978, p.297). Reichel-Dolmatoff (p.301) also notes that the Colombian Chocó people who are geographically separated and, in many ways, culturally distinct from the Tukano also consume yagé and have a similar geometric decorative style. Similarly, the Huichol people of Mexico recreate geometric EVP (*nieríka*) observed in the first stage of trances (induced by the consumption of peyote cactus) in woven and embroidered textiles (Schaefer 1997, pp.156-157). The Huichol produced stylised representations of the peyote cactus in forms that are typical of geometric EVP, usually as a tunnel or web motif but depictions as spirals are also found (Lumholtz 1900, pp.199-200; Siegel & Jarvik 1975, p.137). Lewis-Williams and Dowson (1988) identified depictions of trance dances of medicine men associated with EVP in southern African San rock art and that the San medicine men identified themselves in EVP they saw in a trance state which included spiral forms. Delluc and Delluc (1976) observed that a case has been made for the influence of EVP in the work of Paul Klee and Joan Miro and Keeler (1970, p.206) studying Max Ernst although the example proposed to illustrate spirals *Young man intrigued by the flight of a non-euclidean fly* does not, in fact include any spirals that complete a full rotation and better illustrates the confusing illusory effect created by close concentric curves as the eye jumps between lines. Contemporary usage of spirals to indicate hallucination or disorientation can be seen as a convention of comics and graphic novels.

Links have been suggested between prehistoric rock art and geometric EVP in European Palaeolithic and Neolithic rock art (e.g. Lewis-Williams and Dowson (1988); Dronfield (1996a and b; Hodgson 2000). Bednarik (1986) made the same association in Australian rock art and Mamaní and Fernández Distel (2010) suggest that EVP may be visible in pre-Colombian petroglyphs and ceramics. Lewis-Williams and Dowson (1988) proposed a model, derived from ethnographic studies, for the identification of EVP-linked imagery in prehistoric rock art. Owing to the physiological origin of EVP, they argued that the model can be applied to the archaeological record with a greater confidence than socially or culturally-based ethnographic observations. The model proposed for the identification of imagery arising from trance states in rock art requires:- the presence of a range of types of EVP (they identify seven classes from literature review); imagery linked to the later stages of visions as well as EVP; and evidence of seven types of interaction of motifs including merging, splitting and repetition of EVP which characterise subjective visual phenomena.

The idea that EVP inspired rock art motifs has been disputed or caveats raised as to the scope of its application suggesting that it could only be used to account for some Palaeolithic art (e.g. Bahn 1988; Martindale 1988; Mirimanov 1988) and suggesting that the collation of EVP derived motifs from the full range of Palaeolithic imagery may be drawing together motifs which only have a coincidental association (Layton 1988). Bahn (1988) argued that only a limited number of basic shapes of the type attributed to EVP exist and questions whether these could not arise widely simply from doodling. It is true that some of the supposed EVP could arise from basic hand movements –

back and forth to create zig-zags and lines, circling and, up and down to create dots (Mirimanov 1988). This link to mechanical movement cannot be ruled out as an explanation for the motifs but they often accompany sophisticated and controlled drawings and were produced by cultures capable of considerable dexterity in tool production. Turner (1988) suggested that simple rock art motifs may be the work of children. Kellogg *et al.* (1965) also noted a strong similarity between the types of drawing produced by children around the age of two to four and the form constant classes identified in subjective visual phenomena in adults. Hodgson (2000) also noted the similarity to children's drawings of geometric patterns in Lower and Middle Palaeolithic marks but suggested that this represented a stage in learning to create representational art that resembled that seen in young children. If, as Martindale (1988) suggests, the drawings produced by young children are influenced by a focus on different stages of image processing from the reproduction of replicas of real objects, the drawings would be likely to reflect the same structures as EVP experienced by adults so could probably not be reliably differentiated by the end product alone but might still be considered valid representations of EVP. The overlap with motifs that might be generated from non-EVP stimuli and the possibility, noted by Lewis-Williams and Dowson, that the representations of EVP, if they are such, may not have been produced by those who experienced the EVP creates considerable potential for ambiguity in the interpretation of the origins of these motifs.

Lewis-Williams and Dowson (1988) state that the presence of a single type of motif which is associated with EVP is not sufficient to argue that EVP influenced the artwork of a particular culture. The intention in this research is not to dispute that statement but rather to take the assertion that EVP have influenced the decorative schema of numerous cultures as a plausible explanation for at least some geometric decorative motifs and to focus on a single type to establish whether a detailed study of the manner in which it is produced can aid in identification of possible EVP influence or the influence of objective sources on the decoration. Bahn (1988) noted that one of the challenges in the work of Lewis-Williams and Dowson is to define the limits of a motif which can be considered to be related to an EVP on a continuous scale of decorative variation.

2.5 Construction techniques

The manner of constructing decorative spirals can have a considerable impact on the form and style of the outcome. Geometric layouts can be used to construct regular spirals or approximations to them but there is little evidence for complex geometric constructions being used in the layout of decorative spirals. The earliest evidence for compasses, necessary for the majority of geometric spiral constructions comes from the eleventh to tenth centuries BCE, their origin is thought to be in Attica (Lemos 2002, p.81) but the use of string compasses would leave little archaeological evidence (Herner 1989, p.135) so could predate this time. Herner (1989, pp.133-4), in her study of Scandinavian bronze spiral engraving, found evidence of compass point marks in the centre of spirals suggesting the use of concentric circles as layout guides. This might be expected to produce spiral forms with a low and constant expansion rate to match best the circular guides.

The number of spirals typically linked together may reflect geometric frameworks underlying the decoration for example, particular grids or polygon layouts lend themselves to the linking of particular numbers of spiraloid arms (Fig 2.14). In spirals laid out by geometric techniques, imperfections in the spiral form might indicate the underlying framework used to construct the spiral (Hull 2003, p.110). Analysis of spiral forms therefore has potential to highlight both the mathematical and technological knowledge of the culture although with very close approximations such as the whirling rectangles golden spiral (Sharp 2002) minor deviations from an exact spiral form might be masked within the margin of error in analysis.

Figure 2.14 Spirals and spiraloids within a hexagram construction. Detail on a Mamluk incense burner, British Museum acc. no. 1878,1230.682.

The nature of the decoration can be similarly affected by the medium and the technique employed. The path width (or spacing if a negative impression is created by casting) necessarily has a minimum value of a single stroke or cut of the implement used to create it and some techniques naturally lend themselves to particular patterns of spacing – wire coils tend to have spacing of zero or low and irregular variation whereas patterning created by engraving or painting tends to have higher spacing to differentiate the coils. In consideration of line width and gap, spirals created by physically coiling an element such as wire, clay or fibre are more easily created with no gap between the coils (and will therefore tend to have a similar form with a constant expansion rate) whereas painted spirals, will tend to have a gap between coils to make the shape clear. Form variations can be introduced by the type of tool used. Wrought iron spirals created around a former will often have a straight segment at the centre of the spiral where the rod was gripped and cold bending with a jig tends to require a thinner metal strip than hot-wrought spirals; iron spirals curved freely on an anvil can curve smoothly all the way to the centre (examples of the three techniques can be seen at Artisans of the Anvil (2005); Vega (2008) and Shop Outfitters (2010)).

Straight sided spirals have few natural analogues, one of the theoretical models of cortically generated spirals produced by Tass (1997) gives rise to a rotating angular spiral form with rounded corners but reports of these visual phenomena suggest that they are difficult to focus on clearly (Horowitz 1964; Maclay & Guttman 1941) and as a rotating form, the detailed shape of the modelled form might be difficult to register even assuming that the modelled form arises in reality. It seems likely that highly angular spirals in decoration may arise largely from the manufacturing process. Woven textiles, in particular, are better suited to the use of angular rather than curvilinear forms. A contrast of the effect of medium and technique on spiral form can be seen in Mexican San Sebastián Culture ceramic figurines (Figure 2.15) which have depictions of angular spirals, which would be easier to weave than curvilinear spirals, painted on the representation of the fabric loincloth whereas those over the breasts believed to represent painted skin patterning (British Museum gallery object label: Am,Hn.121) are often curvilinear. The type of linkage may also be influenced by the technique for example, key patterns lend themselves better to weaving than whorls.

Figure 2.15 San Sebastian ceramic figurine, 2nd century CE, Metropolitan Museum of Art, acc.no. 2005.91.14.

However, the majority of angular spirals found during this research were either filling spaces around other decoration or appeared as linear or two dimensional key patterns on media that do not inherently appear to lend themselves to the use of straight over curved lines so in some cases, the production of tessellating patterning that fully and evenly covers the ground appears to be a stronger motivation in the creation of angular spirals that the constraints of technique.

The idea that medium and technique may be significant in the decision to create spiral decoration is supported by the common restriction, even in cultures in which spiral decoration is frequent, to restrict it to certain types of material or technologies. Shang Dynasty jade ornaments rarely feature spirals although they are commonplace on bronzes and in Middle Kingdom Egypt spirals were common on scarabs made of soft materials such as steatite or faience but rare on scarabs carved from hard gemstones. In both these cases, the difficulty of carving fine detail into hard stone may be offered as an explanation for the occurrence of spiral decoration. Other choices of technique, although clearly delineated, are less easy to explain. Examples of painted spiral decoration on pottery are common in pre-Dynastic Naqada II period Egypt and again in New Kingdom mural painting but painted spirals are not found in Middle Kingdom contexts.

2.6 Summary

In the development of the analysis system used in this study, the concept of the basic form of a spiral as a universally known, if not necessarily formally defined, construct was expanded to consider other aspects of the decorative embellishment of the underlying construct. An initial group of eight possible variables of style were derived from a review of spiral decoration on museum objects. The set of five variables of style added to this analysis were chosen on the basis of their apparent significance as means of differentiating and classifying decoration assessed from literature review of studies of perception; from evidence for their cultural or symbolic significance and from the results of the perceptual survey of spiral motifs carried out for this study. The set of variables discussed in this chapter forms the basis of the proposed spiral classification system and of its application in testing for evidence of a recurring form constant structure across disparate cultures.

Spirals have been identified as a type of EVP which can arise, independently of culture, from the structure of the optical system. The prevalence of spiral decoration across a wide range of cultures has been attributed, particularly in reference to early rock art, to the occurrence of EVP spirals although these assertions are not universally accepted.

3 Development of the classification and analysis method

The analysis method proposed in this research needed to provide a quantitative description which represented the visual attributes of the spiral motifs. Analysis took three stages: digitisation of the motif; quantification of the variables; and comparison and the creation of class groups. In initial recording the spiral motifs, the spiral definition as applied needed to be clarified to ensure that equivalent motifs were being compared. Requirements of the quantification stage were that it should describe each motif on the same terms and in a manner which allowed descriptions to be stored and comparisons to be made. The classification system needed to be objective in its operation and to accommodate the high number of variables used in form and style description.

This chapter sets out the method of data collection, characterisation and analysis of spirals which was developed for this research using the example of a single spiral (Figure 3.1), shown through each stage of the method.

Figure 3.1 The specimen spiral CSBM17.9 from a Western or Eastern Zhou Dynasty *you* (ritual vessel), British Museum, acc. no. 1983,0202.1.

3.1 Data collection and processing

3.1.1 Sources of data

This thesis focuses on decorative design - designs applied to the surface of a functional item which are not essential to its practical function. The identification of what is functionally necessary does not take into account what the maker of the object may have considered necessary for function in religious or symbolic senses and, from this point of view, the interpretation of functionality is an external imposition but a division can be drawn between culturally independent and culturally dependent functions which allows consistency of selection of sample material. Spirals serving a primarily functional purpose themselves such as springs in brooch pins were excluded from analysis. Even when it appeared possible that they also played a decorative role it was felt that the main criterion governing their shape would be likely to be functional rather than decorative requirements.

Data for the cultural case studies were obtained from direct access to objects in museum collections; and from online and hard-copy catalogues of museum collections. In using data obtained from published records, priority was given to the analysis of spirals on objects where distortion due to camera angle or angle of the object was lowest.

Data used in the creation of template EVP spirals were obtained from illustrations in publications and academic papers. The identification of a typical geometric EVP shape is clearly hampered by having to rely on the description of the shapes rather than direct access to the imagery being seen. Siegel and Jarvik (1975, p.115) noted that participants in their experiments had difficulty in describing what they were seeing. Schott (2007), in discussing the identification of the causes of migraine aura felt that illustrations provided a much more powerful tool than written description in that they highlight a consistency in the aura seen which cannot be identified so effectively from written description. He distinguished between the types of illustration in their value to analysis. The most effective illustrations were those made by conscious observation whilst the subject was experiencing the aura. However these could be constrained by other effects of the EVP cause such as lack of concentration. Useful information could also be obtained from drawings made after the fact provided that the intention of these was to record the aura objectively. Artistic works influenced by the experience of migraines, including aura, were deemed to be of less analytical use in identifying the causes of migraine aura but works displayed in an exhibition of migraine art did include characteristic hallucinatory effects and showed consistency in these effects between pictures (Schott 2007).

To attempt to approximate form constants, artwork and diagrammatic representations stated to be directly inspired by subjective visual phenomena, along with theoretical models of EVP, were analysed as a sample set. Both technical depictions and artists' representations from the reports of others clearly introduce greater potential for their own subjective interpretation to influence the manner in which EVP are represented. This secondary representation may, however, reflect more accurately the process of production of decorative representation of geometric EVP. The participants in a study by Becker (2005) of EVP induced by flickering light made up the majority of spiral EVP source images. Participants were asked to look for and draw geometric forms derived from earlier free descriptions by research participants which had been classified by the researchers into nine form groups (Becker 2005, p.46). All participants were asked to look for a specific EVP type at the start of each test run and three of the participants had been shown template images (Becker 2005, pp.107,154). The use of verbal and visual stimuli would have had a training effect both in causing the subject to be more ready to see the form in question and in the way in which it was reproduced. When asked to draw spirals, only participants who had not seen stimulus cards drew helices (highlighting the ambiguity in the interpretation of the term spiral). Two of the six participants drew spirals in response to non-spiral verbal stimuli and there was considerable elaboration in decoration and line width away from the basic stimulus card motifs present (Becker 2005, Appendix H). Since Becker's subjects did not conform exactly to reproduction of the stimulus cards, it is likely that the drawn responses represent the geometric imagery that the subjects saw so can be considered usable data. Given the shortage of EVP data available, the drawings by Becker's subjects were felt to be acceptable although not ideal.

Specimen mathematical spiral forms for comparison were obtained within the analysis software by plotting the equations of the spiral and tracing them using a point which had its trajectory fixed to the curve so removing human tracing error from these comparison examples.

3.1.2 Data collection

Initial identification of spirals during data collection was based on visual assessment employing a minimum rotation estimate of 225 degrees at this stage to allow some spiraloids to be rejected during analysis and to reduce the possibility of failing to record spiraloids which should have been included according to the minimum rotation criteria.

Where it was possible to take photographs directly from objects, the spiral or the middle of a field of spirals was centred in the field of view, to minimise distortion, using a guide grid on the camera screen. Photographs were taken as jpeg images at a resolution of 9 mega-pixels.

For each culture studied, a minimum sample size of 100 spirals was aimed at although for the Jomon case study, only 94 spirals were obtained. Two spirals were sampled from each object (where two or more were present). Where 25 or fewer spirals were present, the sample was chosen at random by assigning individual numbers to the spirals. For objects with more than 25 spirals, the sample was chosen by overlaying a grid and selecting the spirals closest to the two chosen grid square numbers. Spirals that were subjectively assessed to be too damaged for analysis (Figure 3.2) or which were not fully visible due to the angle of a published photograph were excluded from the sample.

Figure 3.2 Scarab showing spirals damaged beyond analysis (indicated by arrows), World Museum, Liverpool acc. no. 44.19.357).

The initial stage of data collection focussed on contextual data which was used in cross-cultural comparison of the analysed spirals. The essential contextual information is summarised below:

Contextual variables	**Data for the specimen spiral**
Assigned number	CSBM17.9
Current location / publication	British Museum
Museum's accession number / publication page and figure number	1983,0202.1
Date of object	mid-late Western Zhou/early Eastern Zhou
	800-700BCE
Place made (or found)	south/south-west China
Associated culture/ethnic group	n/a
Type of object	*you* (ritual vessel)
Medium	bronze
Technique	cast
Symbolic or representational meaning of the spiral	snake

Table 3.1 Contextual data collected for the spirals

The assigned number consisted of a two letter code identifying the case study; two letters identifying the museum or publication; and a running number for the object with a decimal for the number of the spiral sampled. For several objects, some aspect of the contextual information was unknown. In these cases, the object was recorded to be used in analysis as far as was appropriate.

3.1.3 Data processing

Data processing involved the digitisation of the spirals to permit analysis; and the recording of contextual data and measurements in a suitable format for comparison.

Contextual data and measurements were recorded in separate database tables linked on the primary keys of object and spiral number.

3.1.3.1 Image distortion

The first issue arising in the digitisation of the spiral was perspective and lens distortion in the photographs. The effect of lens distortion was tested by digitising photographs of a ruler from heights of 100, 125 and 200mm (Figure 3.3). The images were divided into vertical and horizontal quadrants and the ruler photographed vertically in each of four horizontal quadrants vertical error measurements were made by comparing the apparent length of the ruler within each vertical quadrant with the length measured from the digitised image. This process was then repeated with the ruler placed horizontally in each vertical quadrant. The average error per millimetre was calculated for each vertical and horizontal offset (Table 3.2). The maximum error encountered was ±0.008/mm this was used as the margin of error for calculation (see section 3.1.5, p.86). Average vertical error was ±0.003/mm and average horizontal error was ±0.001/mm. Distance from the camera did not have a large effect with average error of ±0.002/mm at 100 and 200mm and ±0.001/mm at 125mm.

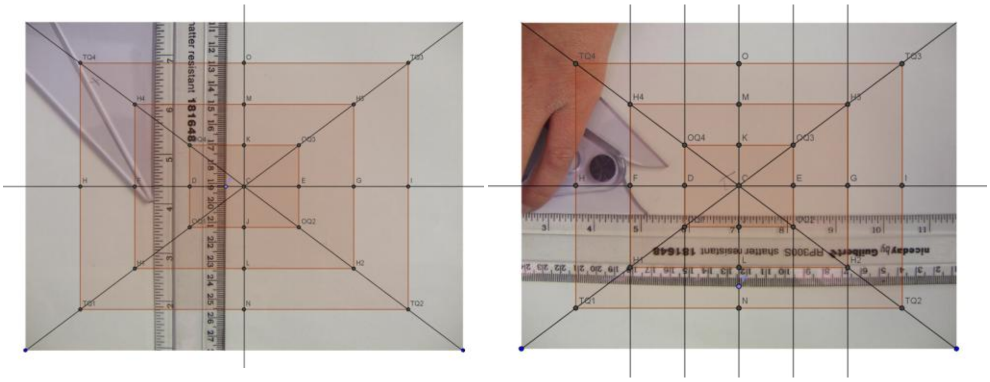


Figure 3.3 Sample image rectification test images.

vertical quadrant	Vertical camera height	H frame 1/4	H frame 1/2	H frame 3/4	H frame 1
V 0 (centre)	100	0.002	0.002	0.003	0.003
	100	-0.001	0.000	0.001	0.001
	125	0.002	0.002	0.002	0.003
	200	0.001	0.001	0.002	0.002
	200	0.001	0.001	0.002	not measured
V 1/4	100	0.002	0.002	0.002	0.002
	125	0.006	0.004	0.003	0.003
	200	0.002	0.002	0.002	0.002
	200	0.002	0.002	0.002	0.002
V 1/2	100	0.004	0.002	0.002	0.003
	125	0.008	0.003	0.003	0.003
	200	0.003	0.002	0.002	0.002
V 3/4	100	0.006	0.005	0.004	0.003
	125	0.008	0.005	0.003	0.003
	200	0.004	0.003	0.002	0.002
V 1	125	0.004	0.003	0.003	0.002
	200	0.006	0.004	0.003	0.002
	100	V1 values could not be calculated at 100mm			

Table 3.2 Image rectification tests average error/mm

horizontal quadrant		V frame 1/4	V frame 1/2	V frame 3/4	V frame 1
H 0 (centre)	100	0.001	0.000	0.001	0.002
	100	0.002	0.001	0.001	0.002
	125	-0.001	-0.001	0.000	0.001
	200	0.000	0.000	0.001	0.001
H 1/4	125	-0.001	-0.001	0.000	0.001
	125	-0.001	-0.001	0.001	0.001
	200	0.000	0.000	0.000	0.001
H 1/2	100	0.001	0.003	0.002	0.002
	125	-0.001	-0.002	0.000	0.001
	200	0.000	0.001	0.001	0.001
	200	0.000	0.001	0.001	0.001
H 3/4	100	0.001	0.005	0.004	0.004
	125	-0.001	0.001	0.001	0.001
	200	0.002	0.002	0.002	0.001
H 1	125	-0.001	-0.002	-0.001	0.000
	200	0.000	0.003	0.002	0.002
	100	H1 values could not be calculated at 100mm			

A second set of pilot studies tested image rectification software and mathematical correction methods to see whether improvement could be achieved on the best image produced as a photograph using Adobe Photoshop CS3 and Corel PhotoPaint 12. The best result using image manipulation was obtained from Adobe Photoshop's lens correction filter. A good, but not perfect, correction of rectilinear grids was achieved but these results were achieved by visual assessment of regularity which would be much more difficult to apply to the artefacts themselves with fewer straight line or right angular visual cues, so correction would be likely to be less successful for these. Since error of the distorted images was slight the images were left uncorrected so that error could be estimated rather than attempting image correction with the available software which would produce variable results with unknown distortion errors.

Spirals on curved surfaces caused considerably greater distortion in the image. Excluding any spiral that is not completely flat from classification would have been extremely limiting but if the spiral is at all three-dimensional, its cross sectional shape becomes an additional variable and difficulties may be introduced into the assessment of its form. A compromise was reached in which spirals where the increase or decrease in height between any two successive coils is less than half the change in the width of the coil were included in the study. Given that these spirals were being regarded as notionally flat and that, in the majority of cases, the third dimension was introduced by vessel curvature, the height and cross-sectional shape of the spirals were not used as variables in this analysis system.

Spirals with obvious warping or distortion (Figure 3.4a and b) were excluded from analysis.

a. 

b. 

Figure 3.4 Damage and distortion to spiral decoration. a. Cypriot gold mouthpiece with warping, British Museum, acc. no. 1897,0401.448. b. Scarab with cracking, Liverpool World Museum, acc. no. 56.20.423.

3.1.3.2 Software implementation of the method

One of the objectives of this research was to develop a method which was easy to apply. With this in mind, the measurement of form and style variables was implemented using an applet written in JavaScript within the dynamic geometry software Geogebra. This software was chosen as it is freely available and so does not limit accessibility. The method functions independently of the software implementation and could be automated with other mainstream geometry software which allows scripting.

3.1.3.3 Creation of a digital tracing

To create a digital copy of the spiral, both sides of the line of the spiral were traced with the tracing lines ending at the point where the edge of the spiral line turned to finish the line or reached a decorative end point.

Spirals were digitised by manual tracing of printed spirals using a digitising tablet and stylus (Wacom Intuos GD-0608-R). This method was chosen in favour of automated edge detection because the tracing of the motifs required an understanding of the definition of the shape - it was insufficient to simply follow the line to its end when the spiral formed part of or joined a non-spiral path (see p.80). Also, available edge detection software was not effective in identifying low contrast spiral boundaries (Figure 3.5).

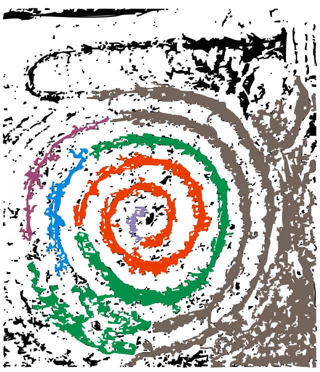


Figure 3.5 The spiral line segments obtained by the best automatic edge detection result for the specimen spiral (indicated by change of colour).

Tracing of printed spirals yielded lower tracing error from tremor than using the tablet to follow the outline of the image on screen. The printed spiral image was aligned to one edge of the tablet tracing area and taped to the tablet's surface rather than being placed under the film covering the tracing area of the tablet as the stylus point was less prone to slipping on the paper than on the film surface. This stage of the analysis had the most variation in precision since the degree to which irregularity in the spiral curve was recorded depended on the resolution of the image and on the perception of the analyst as to what constituted significant irregularity. Following the method of Liu, Carroll, Wang, Zajicek and Bain (2005), each side of the spiral line was traced in both clockwise and anti-clockwise directions and the average line calculated for both sides of the spiral path to minimise tracing error (Figure 3.6). Subsequent analyses were based on the results of tracing returned as Cartesian coordinates for each recorded data point.

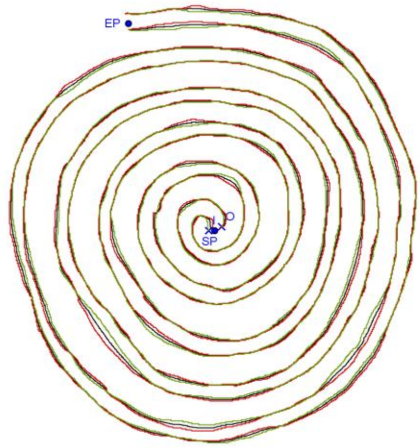


Figure 3.6 Tracing of the specimen spiral in two directions of the spiral outline in green (anticlockwise) and red (clockwise) and the averaged lines in black.

One of the main difficulties encountered in the development of the analysis method was to find consistent and appropriate means of identifying the spiral path which should be traced.

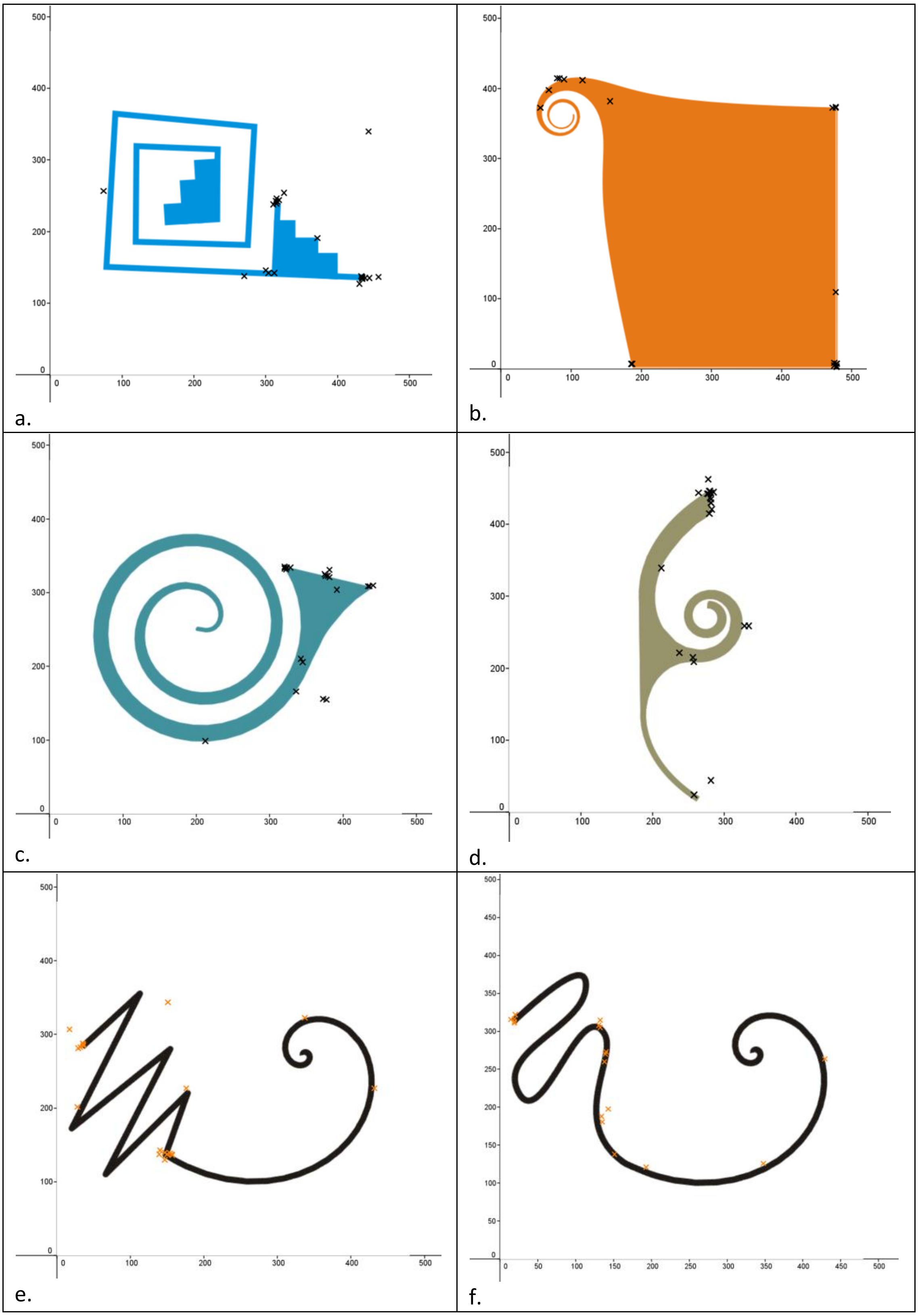
Identifying start and end points of tracing

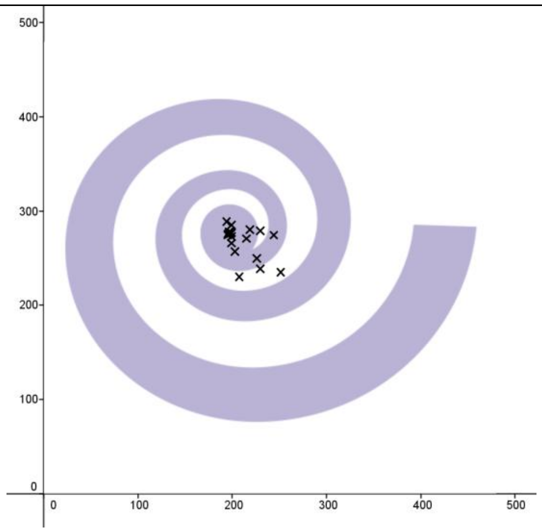
Decorative spirals often have embellishments of the start or end of the spiral line for example, 'eyes' at the centre of the spiral seen in Maori and Bronze Age and Classical Mediterranean examples and foliate decoration (Figure 3.7a-b) and outer end decoration (Figure 3.7c-d) which is often characteristic of a particular cultural style as with Celtic 'trumpet' ends and the extended flaring of spiral ends in some Southwestern Pueblo cultures (Figure 3.7d). These additions to the basic spiral line can cause ambiguity over the start and end points of the spiral line.

Figure 3.7 Spirals with end embellishments and central eyes. a. Mycenaean flask, Ashmolean Museum AN1938.196. b. Uzbek tile panel c.1359CE, Victoria and Albert Museum, acc. no. 574 to B-1900. c. feeding bottle from Crete (1300-1190BCE), Ashmolean Museum AN1967.528. d. Zuni olla, New Mexico, Cambridge Museum of Archaeology and Anthropology, acc. no. Z43115.

To make an objective assessment of whether these decorative ends should be traced as part of the spiral curve, participants in the perceptual survey were asked to mark the centre points and outer ends of spirals with decorative embellishments. Where changes at the end of a spiral involved the sudden broadening of the spiral path (motifs 62-65), a significant majority of participants ($p=<0.001$) felt that these elements should be included within the spiral (Figure 3.8a-d). Where the decoration involved a sudden change in direction of an otherwise unchanged path, there was less consensus and the test motifs did not yield significant results (Figure 3.8e-f).

Figure 3.8a-f. Placement of end points by survey participants. g. Placement of centre point in a spiral with an eye. (Figure runs over two pages.)





g.

Figure 3.8g yielded a slight tendency to place the centre in the centre of the eye suggesting that the spiral path around the eye was perceived to be a continuation of the spiral. Only one participant clearly placed the centre of the spiral at the junction between the eye and the spiral path which might imply that they were excluding the eye.

Internal and external end points for analysis were placed between the two traced lines to mark the maximum extent of the spiral at the halfway point between the two tracing lines. For spirals with eyes, the internal end point was placed at the point at which the spiral path joined the eye (Figure 3.9).

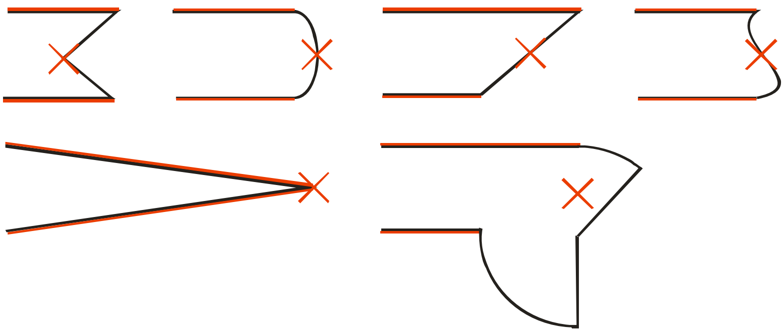


Figure 3.9 Examples of spiral ends with the tracing lines and end points marked in red.

When two spirals were linked together at the outermost end, the end point was taken to be halfway along the line that linked them (Figure 3.10a). The approach chosen for determining the maximum extent of the spiral path of a single spiral was to work from the maximum possible extent of the spiral in both directions. The end of the spiral was taken to be the first point where either: a line perpendicular to the path runs through the incircle[1] of the spiral (Figure 3.10b) or the osculating circle (a circle with radius equal to the radius of curvature) of the path encompasses the centre of a spiral which is contiguous with the path, discounting minor breaks in the path as detailed below. Straight line sections were not deemed to have an osculating circle (Figure 3.10c). A second requirement was that the spiral ran in an unchanging direction of turn around the incircle between these two points. If this were not the case, the end point was adjusted inward accordingly (Figure 3.10d). To allow for irregularity, it was not required that either of the first two criteria should pertain along the whole of the spiral path.

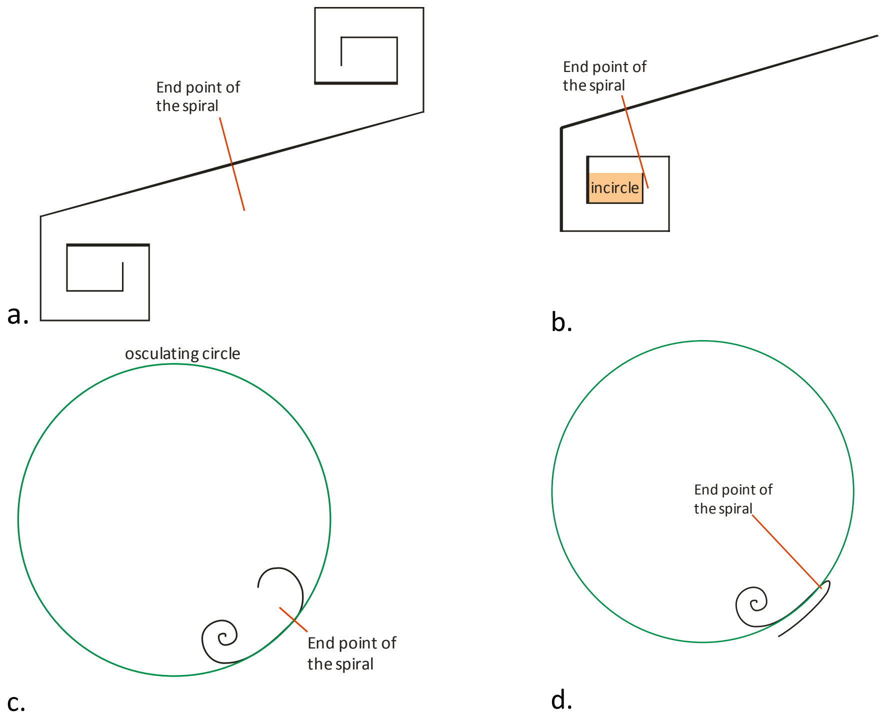


Figure 3.10 Spiral end point determination. a. End point at midpoint of two linked spirals. b. End point determined by a line through the incircle. c. End point determined by the osculating circle. d. End point determined by the osculating circle and the direction of turn.

Further ambiguity occurred with regard to the end point where a spiral joined an unclosed line, other than at its start or end point (Figure 3.11a) or where two or more spirals had sections of their paths in common (Figure 3.11b and c).

[1] Although not strictly an incircle, this term was used to refer to the area of the centre of the spiral defined by a line drawn from the innermost tip of the spiral through the end of the inside tracing line (see 3.1.4, p.92).

a. b. c.

Figure 3.11 Spirals joining a line or sharing part of their curve. a. Detail from a textile design by Guido Marcini, ULITA, acc.no. 2010.295. b. Detail from an Asante wrap, Nigerian, Leeds City Museum. c. Jar fragment, Crete, Ashmolean Museum acc.no. AE.788.

Five tests were used in the perceptual survey to assess whether a consistent choice of path end could be made. The strongest result was shown in the selection of a spiral which had good continuity of curvature over one with a sharp angle in an otherwise curved line (Figure 3.12e). Segregation by curvature or by curve length (Figure 3.12a-d) only yielded statistically significant results in the test with the most extreme absolute line length difference (Figure 3.12d) where the longer and more curved path was preferred ($p<0.05$). However, the longer path end was favoured in all four tests and a gradient of preference was seen according to path length difference which was not apparent in curvature so path length was used as the identifier of the spiral path to be traced.

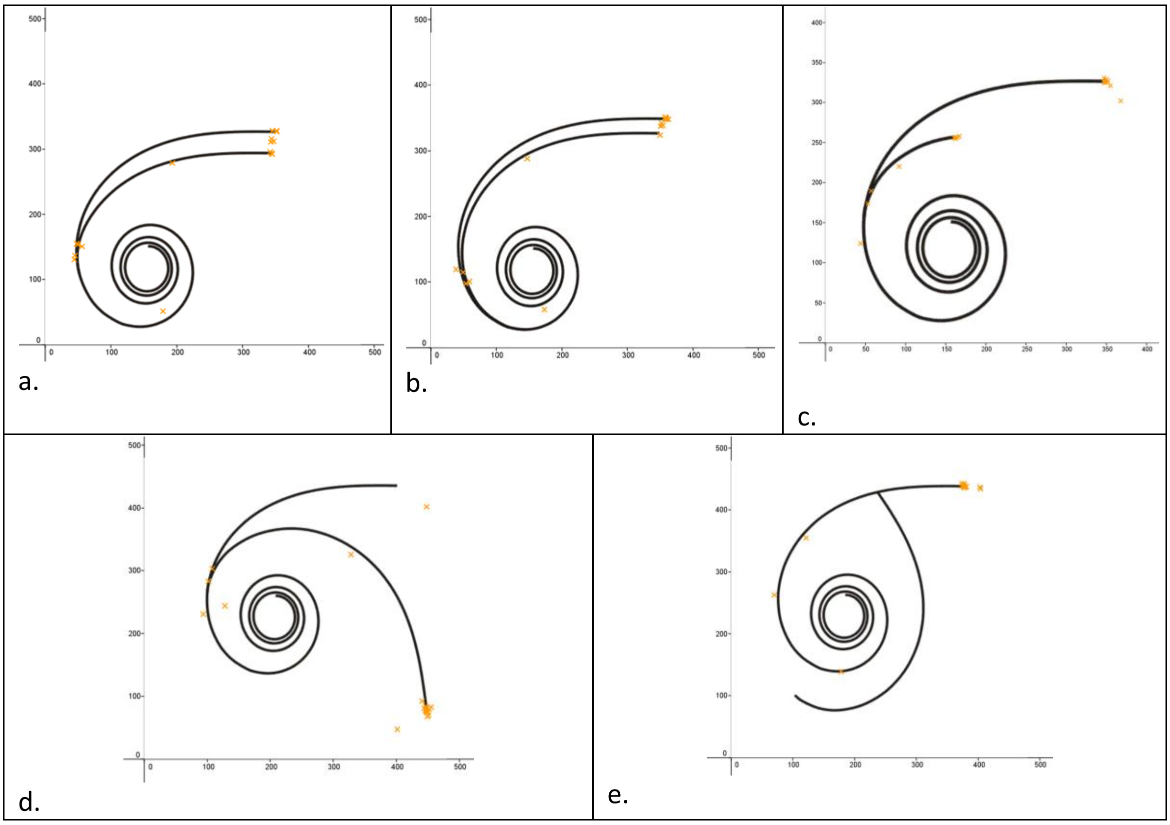


Figure 3.12 Tests of path continuity with end point estimations marked.

In the light of the perceptual survey results, decorative features which did not follow the spiral path such as the snake's head on the specimen spiral (Figure 3.1, p.71) were excluded from analysis. In spirals with an ambiguous path due to splitting or joining a line, priority was given to the curve which showed best continuity then to the longest spiral curve. Spirals joining a non-spiral line were deemed to continue along that line provided that they later broke away to continue the spiral path and subject to the definitions of end points described above.

Identifying the spiral line

Two issues arose in the identification of the spiral line, the discrimination of figure from ground and the interpolation of missing sections of the spiral path.

Several examples of decoration were found during analysis where there was ambiguity over which line should be traced as the dominant spiral figure (Figure 3.13a). There is no inherent reason to suppose that figure/ground differentiation is culturally independent indeed, experimental results suggest that there is cultural variation in the interpretation of this variable (Parush, Sharoni, Hahn-Markowitz & Katz 2000). Bagley (1996, p.12) noted that there may be deliberate intent to create ambiguity between figure and ground. He cites the spirals on Mimbres pottery as examples of this phenomenon (Figure 3.13b).

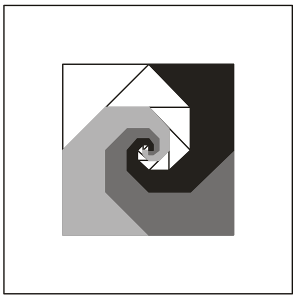
a. 

b. 

Figure 3.13a. Shang bronze vessel with ambiguous figure/ground configuration, Ashmolean Museum acc.no. b7,LI1301.6. b. Mimbres pottery with ambiguous decoration, British Museum, acc. no. Am1979,08.23.

Three possible methods were considered for differentiating figure and ground. The first took the spiral which was distinct in colour or patterning from its surroundings as the foreground curve to be traced (Figure 3.14 a-d). This would not always be effective as, on some objects, the ground colour as the dominant spiral form (e.g. Figure 3.14e)

a. Three spirals are counted as distinct from the background.



b. Four spirals are distinguished from the ground by patterning or colour.

c. Two foreground spirals

d. Four spirals are counted – there is no sense that the dark grey is a ground colour.

e. Atchana ware goblet, Ashmolean Museum, acc. no. AN1938.201

Figure 3.14 Figure/ground differentiation.

Secondly, where two fields of colour or patterning met in a way that formed a spiral, the intersection point of the two fields could be taken as a single linear spiral (rather than two planar spirals) (Figure 3.15).

Figure 3.15 Peruvian textile with two balanced fields of colour meeting, Manchester Museum acc. no. 0.4036.

Finally, when there was no means of identifying a single spiral path by distinction of patterning or colour, the path followed by the tool was taken to be the foreground path. This would mean that the raised line in Figure 3.13a would be traced as the vessel is cast so the raised lines represent incisions into the clay. This approach could be problematic where, what would be taken as the ground of the image was worked leaving the spiral shape to show through from the underlying layer as is found with Mimbres pottery decoration (Bagley 1996, p.13) and may also be seen in some carving techniques.

Since no culturally consistent formula could be determined for identifying the foreground spiral path, decisions on this point were made individually taking into account the three methods proposed above and the context provided by other decoration on the object (for example, whether identifiably representational imagery was present which could indicate the foreground decoration) (Figure 3.16).

Figure 3.16 Decorative context used to identify the foreground spiral line of the sampled spiral line (indicated with arrow) as the wider line. Late Shang/Western Zhou *hu* (ritual vessel), British Museum, 1956,1016.1.

Spirals with broken paths due to minor damage; to cutting by the edge of the object or cutting by another decorative element (Figure 3.17) posed two problems in analysis – their identification as spirals and, subsequently the issue of whether and how to interpolate the missing curve section.

a.  b. 

Figure 3.17a. Cypriot painted spiral requiring interpolation due to damage, Medelhavsmuseet, acc.no. E.003:210. b. Cypriot mouthpiece with the path broken by another decorative element, BM acc.no. 1897,0401.376.

Ideally, a base data set would include no motifs with any degree of interpolation but this would rarely be practical. Studies of contour completion have shown a greater than 50% identification of broken or interpolated objects when twenty per cent of the outline is present (distributed in fragments around the outline) (Panis, De Winter, Vandekerckhove & Wagemans 2008). Kellman and Shipley (1991) use the concept of "relatability" to describe the ability to join two sections by a smooth monotonic curve including mathematical spirals. This offers an explanation for the ability to interpolate spirals but possibly also suggests that such an interpolated curve is likely to be more inaccurate in decorative spirals where a smooth curve cannot always be relied upon. Also, when two or more potential curve paths are close together assessment of which curve elements should be linked requires considerably more of the curve to be present. This need to consider the context of the missing section means that interpolation by the analyst is more appropriate than attempting to automate assessment at the first stage of identifying the path as a spiral.

Tests of curve continuity within the perceptual survey which assessed breakage of the curve with blocks and lines; with sharp or smooth changes in curvature under the obscured section; and with multiple possible continuations of the spiral path showed that there was a significant inclination to continue the spiral across the break point ($p=0.003$) (Figure 3.18).

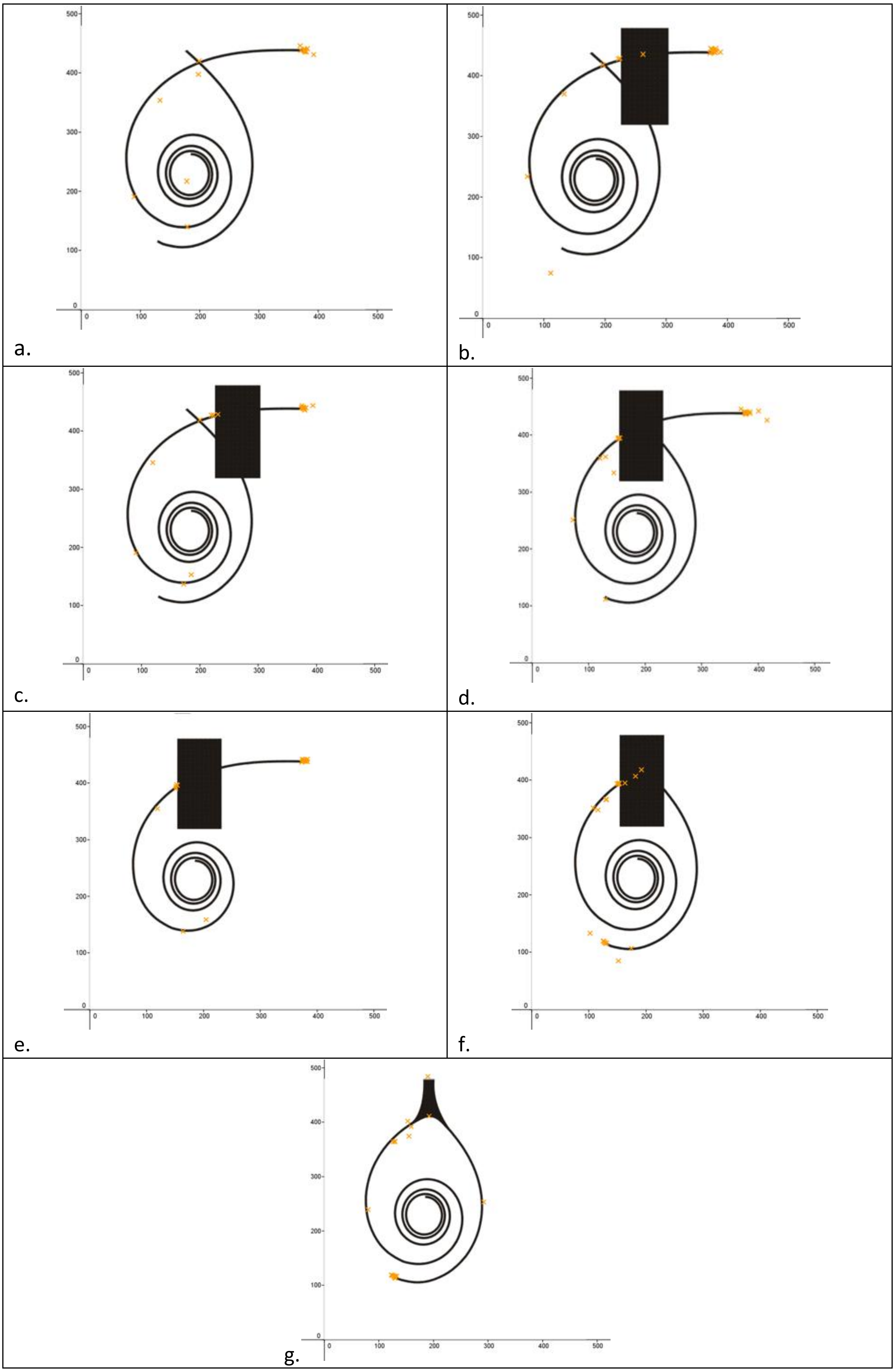


Figure 3.18 Test motifs for interpolation of the spiral path.

The only instance where the majority of participants ended the spiral at the break point (Figure 3.18g) was when a sharp change in curvature was obscured under the block which seems more likely to reflect a desire for good continuity in the spiral than an inability to conceive that the spiral path could continue past the obstruction.

When asked to place the centre of an unclosed motif which did not complete more than one rotation, the majority of participants marked the centre of a planar shape rather than the line indicating that they were interpolating a closure for even an irregular shape (Figure 3.19) or even extrapolating a circle from a quadrant given a curve with good continuity of curvature.

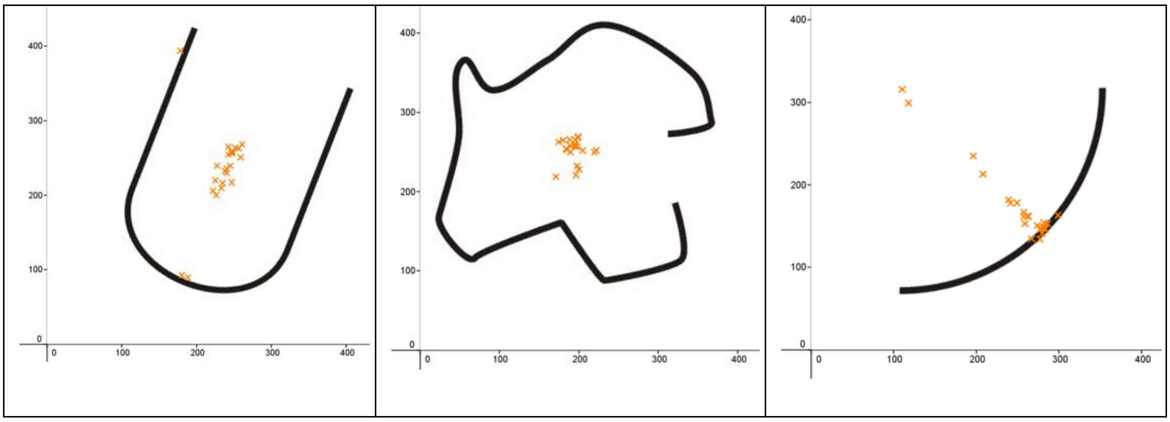


Figure 3.19 Test motifs for centre placement of an unclosed shape.

To allow for a poorer quality of interpretation in a non-smooth decorative spiral the maximum allowable interpolated section was taken to be 30% by rotation of a single rotation. Spirals with longer contiguous missing sections were excluded from the study. Where the decorative technique employed resulted in a broken path (e.g. Figure 1.5a, p.26), the spiral was deemed to continue as long as the length of the each missing section measured as a straight line did not exceed the maximum spacing between consecutive rotations. In this case, interpolation of sections between decorative points was not recorded. Where longer sections were interpolated these were noted.

Kernel regression (Teknomo, 2007) was tested as a means of standardising interpolation during the quantification of the spiral path. Due to the irregularity of decorative spiral curves, this approach showed a deterioration in estimation quality after a few points to a proposed curve which differed so substantially from the spiral path of similar complete spiral motifs that this interpolation method was deemed to be inappropriate to use. For this reason, estimation by the analyst was used to interpolate missing sections of curves. This introduced a greater level of subjectivity into the method than was desirable but allowed the interpolation to be guided by the context of the individual spiral curve using the curvature of the sections preceding and following the missing section and that of coils immediately inside or outside the missing section. Where interpolation arose because of damage, fragmentary traces of the spiral path within the interpolated section could also act as guides. More importantly in respect of decorative spirals, the analyst could make comparison with other spirals on the object and similar spirals on different objects to guide interpolation.

3.1.4 Identification of the centre

The method chosen for the identification of the spiral centre was to use the centroid of the polygon created by intersecting the curve with a ray drawn from the start point through the beginning of the innermost tracing line (Figure 3.20). The centroid is the centre of gravity of the central polygon (Kempton 1981, p.155).

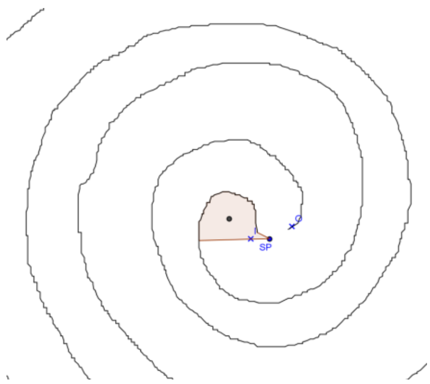


Figure 3.20 Spiral centre within the incircle of the specimen spiral.

Hel-Or, Peleg and Avnir (1991) demonstrated that the chiral centre of a spiral (the point at which the highest proportion of the curve shows either clockwise or anticlockwise increase in distance from the centre) approximated its mathematical centre better than the centroid, however, the concept of a centre based on the mathematical equation of the spiral is irrelevant to many decorative spirals. For the application of this method it was only necessary that the placement of the centre was consistent and repeatable and, for the functioning of the applet as written, that it was inside the innermost rotation of the spiral. The calculation of the centroid fulfilled both these criteria and could be carried out within the applet more rapidly than the calculation of the chiral centre. For spiraloids the area of the innermost rotation was created by joining the start and end points of the spiraloid.

3.1.5 Precision

Tracing sampled the spirals to an average precision of one recorded data point for every 0.038mm of the real curve length. Some longer spirals, mostly from the Cypriot case study, had to be sampled at a lower resolution to prevent the applet crashing. These are noted in the raw data tables in Appendix 2 (Tables A2.2-A2.5).   The minimum recording resolution was one point for every 0.14mm of the curve. To ensure maximal comparability of form measurements, each spiral ideally needed the same number of sampling points. The problems with achieving this are discussed in section 3.4.1 (p.101). The effect on precision of the chosen solution of reducing the number of sampled points was to reduce resolution to a minimum of one point for every 0.78mm of the curve. Style variables were measured using the highest resolution available rather than the reduced form resolution. Image distortion tests showed that the contribution of parallax to the margin of error was 0.008mm/1mm at worst. The contribution of erratic hand movement to error was tested on three spirals and an average was found of 0.34mm deviation either side of the true line (Figure 3.21).

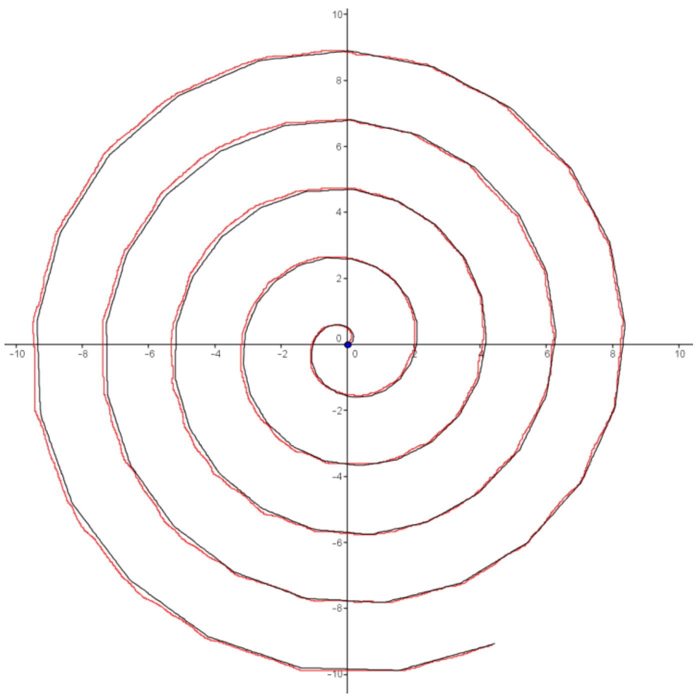


Figure 3.21 Digitally created spiral in black and manual trace line shown in red (to scale).

Calibration of the digitising tablet within the analysis software environment yielded an error margin of 0.02mm which is the maximum recording resolution of the software. The digitising tablet was therefore not taken to contribute to the margin of error of the analysis. Not including photographic distortion, which would have to be calculated separately for each spiral based on its diameter, the total error margin of the measurements was deemed to be ±0.4mm for the high resolution tracings rising to ±0.5mm for low resolution tracings and to ±1.1mm for form measurements.

In general, quantification of variables should operate at a level which accords with the limit of human perception as discrimination beyond this point may introduce spurious differentiation (Wu & Dalal 2005). Size discrimination is a relative judgement which has been found to be equivalent to two percent of the dimension being compared (Stuart, Bossomaier & Johnson 1993) but with many contextual factors affecting perceptions of difference (Smith 1982) and with variation between cultures in relative size judgement (Doherty, Tsuji & Phillips 2008). Because of this it is not possible to make a general statement that this margin of error is not perceptually important. However, it was felt likely that such a difference would only be noticed under close scrutiny and direct comparison and that this behaviour would not be likely to represent the typical use even of meaningful decoration so the margin of error was perceptually acceptable.

3.2 Identification of form

Analysis of form was based on sampling points on the primary path – a calculated line running along the centre of the traced spiral. Working from the primary path, the centre of each spiral was identified and the scale and orientation of the spiral were normalised for comparison.

3.2.1 Creation of the primary path

The primary path was used to remove from consideration the decorative aspects of the spiral, described as style variables, leaving only its basic shape. Tests were used in the perceptual survey to establish the effect of tracing of the inside, outside or middle line for the assessment of form. Seven motifs tested in the perceptual survey had lines wide enough to assess whether participants were calculating from the inside, outside or centre line when placing end points (Figures 3.8b-d p.82 and 3.12a-d p.86). These tests showed no strong trend in outline preference. Outside was the numerically dominant placing in four tests, middle line twice (once tied with outside) and inside twice.

Without clear differentiation, the primary path was deemed to run from the innermost end, through the midpoints between the sampling points of the inner trace line and the closest point on the outer trace line, to the outermost end (Figure 3.22).

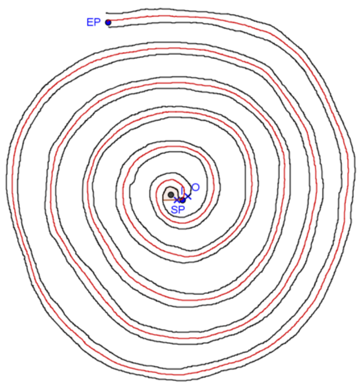


Figure 3.22 Specimen spiral with the primary path marked in red.

For spirals with central eyes, the primary path was extrapolated around the inside of the eye measuring from the outline half the distance between the two first points of the spiral line (Figure 3.23). This approach did not allow for an increasing or decreasing trend in path width to be reflected in the course of the primary path around the eye. An attempt to extend a statistical interpolation tool – Klasson splines (Klasson 2008; Klasson 2011) - to extrapolation resulted, as with regression based interpolation, in a rapid diminution of prediction quality. Any attempt at statistical extrapolation is liable to be hampered by the irregularity of decorative spirals.

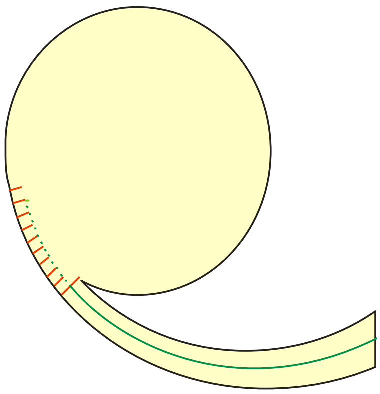


Figure 3.23 Calculation of the primary path around the eye of a spiral.

3.2.2 Normalisation

Spiral tracing data were normalised prior to analysis. The spirals were aligned along their maximum diameter with the innermost end of the spiral lying on the right of the maximum axis. Where spirals had an identical maximum diameter at more than one location, the diameter which placed the start point closest to the top of the spiral was used. The spirals were reflected, where necessary, to run anticlockwise from the centre. All measurements of dimensions were proportional to the maximum diameter of the spiral.

3.2.3 Quantification of form

An advantage of the quantitative recording of decoration is the potential to carry the descriptions obtained across more than one study and to augment a bank of descriptions in future work. To achieve this, an absolute description of those attributes which had been analysed is needed. Pattern matching techniques which provide a measure of relative difference within the current data sample were therefore not appropriate as a means of comparing spiral form.

The chosen method of description of spiral form was derived from the ψ-s curve which represents an irregular curve or closed shape as a sequence of tangent angles (ψ) measured at points of known distance along the path (s) (McConnell, Kwok, Curlander, Kober & Pang 1991).

The method used in this research differs from that of McConnell *et al.* (1991) in that a constant path length between tangent angle measurements was assumed. This change was made to accommodate the production of spectral density plots (discussed in section 3.4.1, p.101) as a means of summarising the form data prior to the creation of class groups. Actual rotational distance between measurements showed a standard deviation of 0.009 radians so no substantial inaccuracy was introduced by this assumption of constancy.

Since the spiral path segments are plotted as straight lines within the analysis applet, the tangent at the generating points of the primary path was deemed to be a line perpendicular to the bisector of the angle made by the two segments meeting at each point.

3.3 Quantification of style

Style variables were measured as interval variables to make them compatible with the summarised form data. Orientation, rotational length, curvilinearity and irregularity were all described by a single variable each. Spacing and path width were described with four variables each.

3.3.1 Orientation

In choosing the basis for measuring orientation, the most strikingly ‘orientated’ aspect was felt to be the axis of the maximum diameter (Figure 3.24).

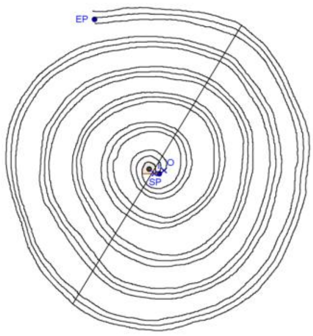


Figure 3.24 Maximum diameter of the specimen spiral marked, orientation 1.03 radians from the positive x axis.

There were instances where the orientation could not be determined if a single ‘correct’ orientation for the artefact could not be identified, for example, when the spiral was in the centre of a circular dish. Cluster analysis (see section 3.4.3, p.105) requires a measurement to be present for every variable. Accommodating missing values by making orientation a categorical field would limit the types of statistical classification system which could be used. To avoid losing analytical power, two analyses were run for each test which included spirals with missing orientation data. The first excluded the orientation variable. From this, the median orientation value of the classes to which the spirals with missing data had been assigned were taken. These were used as estimated values in the second analysis which included the orientation variable. The estimated values are highlighted in the case study data tables (Appendix 2, Tables A2.2-A2.5).

3.3.2 Rotational length

The maximum diameter of the spiral, where available, provides the most appropriate sense of the overall size of the spiral. Calculation of the length of the spiral path is also likely to reflect the size of the spiral so it is more relevant as a perceptual variable to measure rotational length as an angle. Rotational length was measured from the primary path in radians.

3.3.3 Curvilinearity

Perceptions of curvilinearity may vary according to viewing distance. For example embroidered spirals which, seen at a likely viewing distance for the garments or furnishing fabrics in use, appeared curvilinear may, when viewed close up, appear angular due to the way in which they are stitched. For consistency and accuracy the spiral was assessed according to its actual shape rather than approximating to a curve since the natural viewing distance is subjective and variable between different types of object. Extrapolating a curve, rather than closely tracing the edges of the spiral path, would introduce error. In assessing the effect of medium or technique on spiral appearance, recording of actual, rather than perceived, curvilinearity would also be important.

Curvilinearity was quantified as the proportional length of straight (s) to curved (c) segments given by $s/(s+c)$ using the average values of the inside and outside tracings of the spiral. A sequence of tracing points was deemed to form a single straight segment if the angle between the first pair of points and at least eight subsequent points was less than 0.035 radians (Figure 3.25).

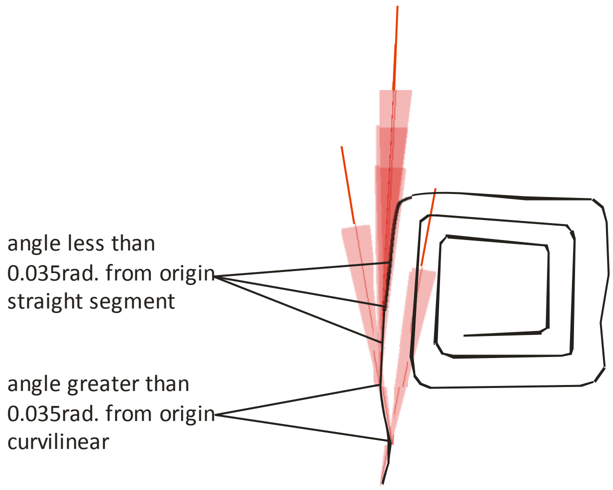


Figure 3.25 Calculation of curvilinearity.

3.3.4 Irregularity

Irregularity covered minor variation in the path of the spiral which did not have significant impact on the spiral form. Irregularity was determined by measuring the chirality of inflections in the traced spiral outline. Chirality was calculated using Hel-

Or, Peleg and Avnir's (1991) measure which divided the spiral path into segments and measured whether each segment, taken separately, would gather or deflect particles when rotated about the centre by subtracting *r*1 (the distance from the proposed centre to the start of the segment) from *r*2 (the distance from centre to the segment end) (Figure 3.26). The count of negative distances was subtracted from the count of positive distances and divided by the total count giving a chirality score. A chirality of one indicated a regular spiral and deviation towards zero indicated increasing irregularity. The average score was found from the tracings of both sides of the spiral path. Interpolated sections of the traced spiral were excluded from assessment of irregularity.

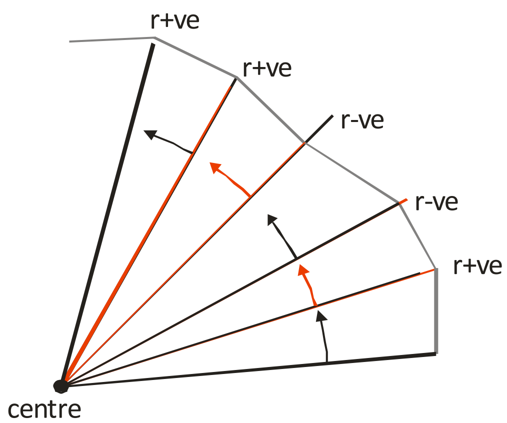


Figure 3.26 Calculation of irregularity.

Minor damage which does not obscure form may still have a substantial effect on assessment of irregularity. It is therefore necessary to consider if local irregularity was present at the time of making due to decorative intent; or the technology employed; or if it is a consequence of subsequent wear and tear. Areas of obvious minor damage (Figure 3.27) which was not significant enough to require the spiral path to be interpolated were discounted in tracing and represented as far as possible as a smooth curve.

Figure 3.27 Areas of the specimen spiral with irregularity detail lost due to corrosion.

This means that irregularity which was present in the original curve will have been lost in these sections. There are probably also some decorative spirals where damage is not identified or artefacts of the manufacturing process are wrongly identified as damage. Analysing only perfect examples of decoration would greatly reduce the sample size so these flaws in the assessment of irregularity are difficult to avoid and the significance of the effect is difficult to quantify.

Comparison of the automated mathematical traces, which should be free from irregularity error, with manual traces of the same spirals showed that the process of tracing decreased the irregularity score by an average of 0.34.

3.3.5 Width of paths and spacing between paths

Path width and spacing (the distance between the outer edge of one rotation and the nearest inner edge point of the next rotation) were quantified using two criteria – median and trend, derived from normalised measurement of path and spacing distances taken from each tracing point of the inside curve line to the nearest point on the next curve line (Figure 3.28).

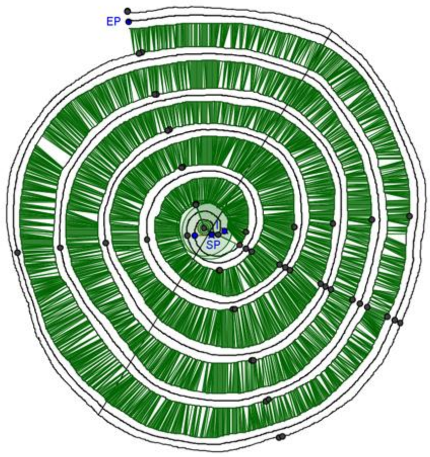


Figure 3.28 Measurement lines used for calculation of spacing on the specimen spiral marked in green. The same principle was used for calculation of the primary path.

If two or more consecutive rotations of an irregular spiral overlapped, by less than fifty per cent of narrowest path width in the overlapping section, the spacing was regarded as zero and the full path width was measured including the overlapping section. Dividing the path width up would otherwise have disproportionately reduced the average path width. If the paths overlapped by more than fifty per cent of the width, the definition of a spiral was deemed not to have been fulfilled and the curve was excluded from analysis or the end points determined accordingly.

The median path and spacing widths gave a sense of the values of path width and spacing as a proportion of spiral size whereas trend indicated change over the course of the spiral. The trend in path width and spacing (i.e. unchanging, increasing or decreasing) was assessed by fitting a third degree polynomial curve to the path width or spacing measurements plotted against the rotational length of the spiral (Figure 3.29). A third degree polynomial was chosen as it accommodated the three most common types of path width or spacing trend – a constant value along the full length of the path; a gradual increase or decrease along the spiral path; and a sudden increase at the end of the spiral path following constant values or gradual change.

a.

b.

Figure 3.29 Specimen spiral - a. Path width measurements (red) and trendline. b. Spacing measurements and trendline. The specimen spiral had path width trend parameters of 0,0,0 and spacing trend parameters of 0,0,0.01.

Due to the need to have a value for each variable, median spacing for spiraloids was calculated as the distance between the start and end points of the spiraloid. Trend parameters for spiraloids were recorded as zero.

3.4 Methods of comparison

The raw data obtained from the analysis applet were exported into Microsoft Excel, collated and down-sampled for form quantification. Statistical tests were carried out using PASW Statistics 20 (SPSS). Cluster analysis was used to test for significant type groupings within cultures and the results of these analyses used to highlight significant variables and groupings for cross-cultural comparisons.

3.4.1 Summarisation of spiral form data

For best comparability, the spirals should be the same rotational length with the same number of sampling points. It was felt better to reduce the longer spirals (down-sampling) rather than to interpolate points into the shorter spirals to raise the number of sampling points closer to that of the longer spirals. Up-sampling (interpolating sampling points into) the shortest spirals sufficiently to match the longer ones would have required that most of the sampling points were interpolated. Down-sampling was achieved by substituting in a single mean value for equal consecutive groups of points to bring the number of sampling points to the nearest integer below 256. The significance of the smoothing effect of down-sampling the longer spirals was offset by calculating irregularity separately using the full tracing data.

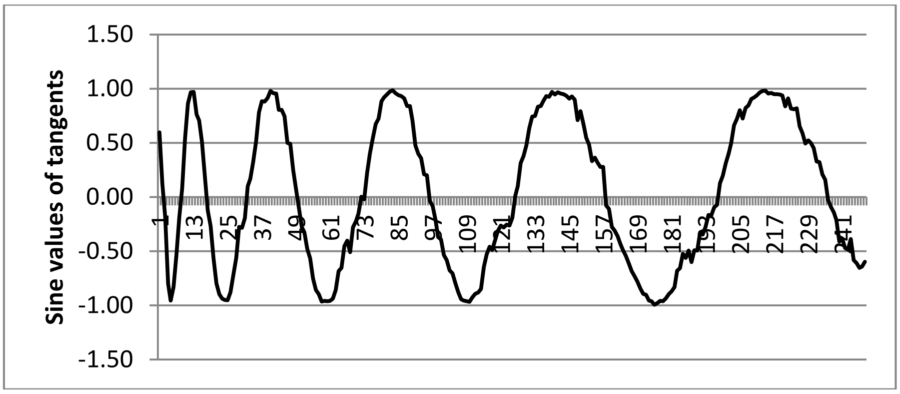


Figure 3.30 Down-sampled sine wave of the specimen spiral.

The sine of the tangent angle was used in the analysis of the form data to correct for 360˚ modulation (Figure 3.30). To compare waves directly it needed to be established that waves relating to equivalent sections of the curve, in terms of rotational distance from the centre of the spiral, were being compared. Extrapolation of an irregular decorative curve to its centre would rapidly become highly inaccurate due to the irregularity of the curve. To avoid the need to attempt this, spectral density plots were used in comparison. This analysis technique decomposes the wave into periodic sine and cosine waves (Pennsylvania State University 2013). The spectral density plot shows the component wave frequencies present in the spiral wave and the amplitudes of the waves at each frequency (Figure 3.31) (Pennsylvania State University 2013).

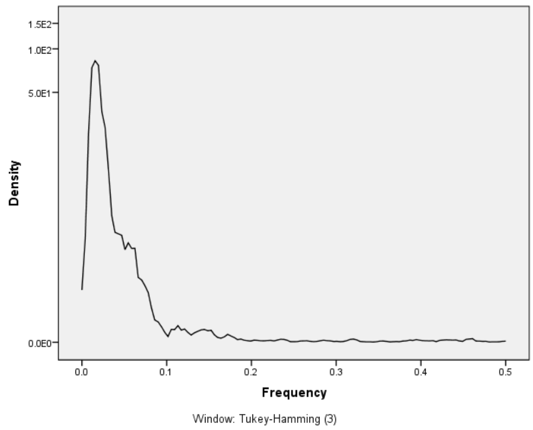
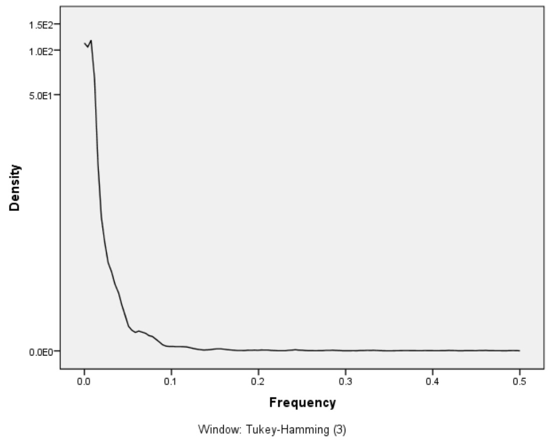
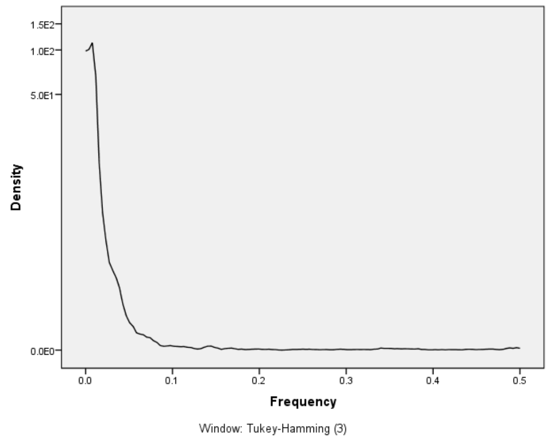


Figure 3.31 Spectral density plot of the specimen spiral.

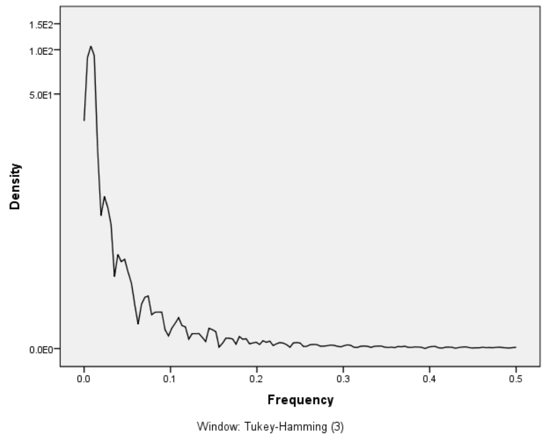
A moving average transformation (using a Tukey-Hamming window with a span of three) has been applied to the calculated frequency values in Figure 3.31 creating a smooth density plot and removing high variance which makes the identification of significant frequency peaks difficult (Meko 2013). The window model and span were chosen to allow the frequency of the highest density peak to be precisely defined which was necessary to characterise the expansion rate effectively (Figure 3.32). The decomposition of the wave form allows the frequency of the highest amplitude signals which best represent the gross form of the spiral to be identified.



a.



b.



c.

Figure 3.32 Spectral density plots. a. The automatically traced hyperbolic spiral at a span of five. b. Manually traced hyperbolic spiral at span of seven for noise minimisation. c. A quadrilateral spiral at a span of seven with higher frequency variance retained.

Comparison of the form of the spirals was carried out using the Pearson correlation coefficient. The spectral density plot of each spiral was correlated with every other spiral in the analysis group and these sets of correlation values for each spiral were fed into a cluster analysis to create class groups along with the style data.

3.4.2 Variable weighting

It is apparent from studies comparing the influence of pairs of grouping principles that some provide a more powerful grouping stimulus than others (e.g. Ben-Av & Sagi 1995; Palmer & Rock 1994). This evidence suggests that the variables used within the analysis should be weighted according to their influence on the creation of groups. The limited results of the perceptual survey suggest that form is the strongest differentiating factor followed by orientation with the other variables used all having the same modal value (Appendix 1, Table A1.2). However, all significant similarity scores obtained from the survey were high so do not provide a strong basis for segregation. Perceptual studies have also shown that the importance of variables as differentiators depends on the combinations of differing variables; the nature of the motif; and the expression of the variable (e.g. Quinlan & Wilton 1998; Beck 1966a). A further problem in assigning weights to variables is the difference between cultures in the perceived importance of variables. As discussed in Appendix 1, the results of the perceptual survey did not allow cultural differentiation and the majority of identified studies measuring similarity have drawn from North American or European populations with a sufficiently undifferentiated visual culture that they cannot be taken as indicative of any universal norms that might be applied to the weighting of variables. Because it is neither possible to determine the relative perceptual values of the cultures being studied nor to assume that there was commonality between cultures in this respect, it was decided that weighting would not be imposed on the variables. To minimise the effect of differing magnitudes of variation in different measurements, the Z-scores of the variables (representation of the values as a proportion of the standard deviation from the mean (Shennan 1988, p.75)) were used in the creation of cluster groups.

3.4.3 Clustering

Hierarchical clustering was used to create class groups of spirals. This is an agglomerative clustering method which merges the spirals into groups until they are all contained within a single group. Of the three types of clustering available in SPSS, this method had advantages over two-step clustering of not needing the number of clusters to be specified in advance and of indicating the amount of difference between clusters in different levels. Also, it does not assume that all classes contain a similar number of members as is the case with k-means clustering (Cleophas 2012). Testing on the Shang-Zhou case study determined the choice of furthest neighbour (CLINK) clustering using squared Euclidean distance as a measure. These methods yielded classes which accorded best with subjective assessment of difference.

Hierarchical clustering is dependent on the order in which the cases are arranged. To allow for this, each test was run four times with the spirals arranged in a different random order each time. Clusters which were robust for each run were accepted as valid. Where comparisons were being made, for example between cultures or media, the clustering was carried out with the whole sample randomised and with samples randomised within separate sub-groups. The reordering of the sample rarely changed the resulting classes.

Hierarchical clustering imposes a grouping structure on datasets when it may not be appropriate to do so. For this reason subjective judgement of the aesthetic properties of the spirals and consideration of the distance values between groups need to be used to assess whether the clustering is appropriate and to determine the appropriate number of meaningful clusters. Hierarchical clustering is a descriptive method which does not indicate the factors which cause the clusters to be created or necessarily imply that clusters arise from the same underlying cause. Within identified spiral classes discriminant analysis was used to identify which variables were important in creating the group.

3.5 Summary

The method proposed in this chapter for classification and analysis of spiral motifs has been designed to cope with the wide variety of spiral shapes encountered in decorative contexts. In attempting to encompass this variation, reference has been made to studies of human perception of form as well as to existing quantitative methods of analysing spirals. Raw data, in the form of images, collected from a range of source types were assessed according to three classes of measurement variable – form, style and interrelationship. The results of multivariate statistical tests applied to these data to identify groupings of types of spiral motif were set alongside contextual information to offer a quantitative means of studying change and diffusion in spiral motifs within and between the two case study regions. The results of these case studies are the focus of Chapter 5.

4 Background to the case studies

This chapter discusses the choice of case studies and provides context for the studies looking at the structure of the society, the religious practises, known connections with surrounding cultures and the range of techniques and media associated with decorative spirals. Evidence for the existence of representational or symbolic meanings for spirals within the culture is considered and existing typologies of decoration and means of classifying spirals within the decorative canon of the cultures in question are discussed.

4.1 Choice of case studies

A problem in the analysis of a specific geometric motif in cross-cultural comparative studies is that it is required to be present in more than one culture whereas the underlying structure of decoration is always measurable. In assessing the movement of decorative elements between cultures, Grabar (2006) highlights the need to consider how significant the foreign influence is and how it is identified – either by consistencies with known external types or by inconsistencies with the internal type. He states that to establish whether outside influence is, firstly, present and, secondly, of more than one-off significance it is necessary to have good typologies for artefacts or designs from the cultures being studied. A similar principle of identifying typing significance would ideally need to be applied in considering the evolution of a motif within a single culture – evolution requires a frequently used motif.

The final choice of case studies was driven by several essential requirements for inclusion in the research:

- spirals must be a commonly used motif in at least one area of the decorative arts of the culture. Serpell (1979) found that cross-cultural comparisons could be distorted by a difference in skill and familiarity with materials and techniques in reproducing designs and the same might be said for motifs - that valid comparison can only be made between cultures where there is a common view that a spiral constitutes a valid and defined decorative motif rather than an occasional and incidental extension of a non-spiral curve. This does not necessarily require an understanding of a spiral as a geometric construct;

- there must be sufficient data available to make a valid comparison (this requires the artefacts used to have a date and place of origin sufficiently precise to make a comparison of change over time and between cultures at the same time);
- and a sufficient available sample size must be available for study.

Within these constraints, the aim was to cover a range of geographical areas and media and to choose case studies which were independent of each other.

The chosen studies are of East Asia focussing on:
Japan during the Early-Late Jōmon periods (c.3000-1000[1]),
the Shang to Western Zhou Dynasties (c.1800 to 771),
and the Eastern Mediterranean and Egyptian area represented by examples centred on:
the Dynastic Egyptian Middle Kingdom and First and Second Intermediate Periods (c.2181-1550),
Bronze Age Cyprus (c.1600-600).

Peregrine (2001) emphasises the need for random sampling from the population of potentially appropriate cultures. The primary limiting factors in not taking a random sampling approach to the choice of case study were the failure with some potential study areas to access a sufficiently large sample of provenanced material e.g. Maori wood carving, Chavin (Peruvian) textiles and the painted pottery of a number of Balkan Neolithic cultures. The inclusion of a greater range of case study areas would improve the geographical and temporal scope of this study and it is hoped that the range may be expanded with future work.

4.2 Culturally dependent interpretation of decorative spirals

In some ways, this study harks back to early approaches of taking objects and, specifically, particular elements of their decoration out of their cultural context. There is a considerable body of literature that argues against the study of individual design elements in isolation from their context. Washburn (1983a, p.3) states that to isolate a motif from its cultural context is to cause it to lose meaning. Such an approach may

[1] All dates relating to the case studies are BCE unless otherwise stated.

also cause potentially irrelevant meanings to be imposed by an outside observer (Casrnir 1999). Indeed, there is no way of knowing if the motif identified by the analyst was perceived as a valid decorative unit in isolation by its creator (Jernigan 1986) and this problem may be especially significant in the consideration of geometric constructs found within representational contexts (e.g. Figure 4.1) or where possible symbolic meanings are unknown.

Figure 4.1 Spirals in representational context in the eyes and tail of a frog on a 1st century bell from Yunnan province, China, British Museum, acc. no. 1948.1013.15.

Both O'Sullivan (1986) and Bradley (1997, p.5), in their discussions of North Atlantic rock art, note that the composition of the decoration can be equally or more important than the motifs represented. O'Sullivan (1986) expands on the problems of considering motifs in isolation in observing that this approach can cause discrete motifs which are readily describable to be favoured over apparently nebulous background decoration. A risk inherent in all classification systems which focus on a single construct or element of a design is giving the aspect under consideration undue prominence to motifs which may only be a minor element of the design aesthetic under consideration. This risk applies particularly to motifs as the single motif may only be a small element of a larger design. It must also be remembered that even apparently objective classification techniques may still be subject to cultural variation in their application. In discussing the appliqué textiles of the Cuna, Hirschfeld (1977) noted that most of the grossly symmetrical designs had some minor elements of asymmetry. Having identified a preference for complex asymmetrical designs within the culture, Hirschfeld believed that these asymmetries should be regarded as the conscious production of complex noise rather than errors so to assess only the gross symmetrical structure of the design may be to miss relevant detail.

In spite of the problems, raised above, in considering motifs in isolation, the decision was made to asses an isolated motif in this research because the focus was on developing a method of analysis and a system of classification to test if and what useful information could be extracted from a single motif type, not to suggest that this should be considered in isolation from all other available information in practical application.

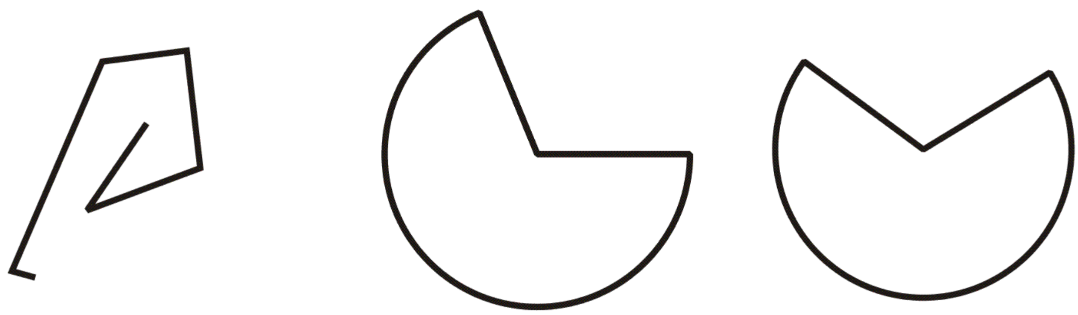
The classification approach used in this research is put forward as an alternative to the externally structured classification system commonly applied to decorative spiral motifs. It is suggested that more appropriate groups can be built from the properties of the decoration itself but not that meaning can be assigned by this method. The variables used in analysis are, in themselves, external constructs which may or may not have guided the production of the motif and the relevance of which may vary from culture to culture. Variables for testing were sought that have been shown to be valid perceptual differentiators to attempt to mitigate this risk but the limited temporal and geographical approach to this validation has not eliminated it.

Within the scope of this research, the limitations raised above in isolating a single motif type for analysis will vary for the different research questions. In making comparison with EVP or naturally occurring spiral forms, the potential overvaluing of spiral motifs and their isolation from a decorative context does not pose a significant problem since it is the spiral in isolation which is being considered. However, attempts to create meaningful type classes based solely on spiral motifs may be hampered by analysing only a single component of a design scheme and it would be remarkable if they created a typology which reflected classifications drawn up by analysing the object and its decoration as a whole. The question raised by Jernigan of the validity of the motif as a decorative unit is addressed by requiring its presence as a common element of the decorative scheme of the cultures in question although this does limit the scope of applicability of any single motif.

An advantage of breaking down the description of a motif is that it is possible to identify aspects which are consistently similar within a culture or between cultures. If the expression of a measured variable of geometric decoration can be shown to be associated with patterning consistent with another social or cultural aspect of a society, this can be used as a basis for broader suppositions that individual perceptual values which guide the decoration production are associated with the social or cultural concept which is the focus of study provided that this commonality can be demonstrated across a sufficient range of societies.

It had initially been intended that this study should focus only on spirals in non-representational decorative contexts. It has, however, become apparent that assumptions of the presence or absence of pictorial or symbolic meaning in decoration (particularly for prehistoric cultures lacking additional sources of interpretive information) placed arbitrary and potentially biased limits on the inclusion or exclusion of data.

The strength of representational response to the survey motifs was striking. Even though the focus of the survey was on motifs as geometric rather than representational constructs, only two of the 22 motifs which participants were asked to describe did not attract at least one representational interpretation. This shows a strong inclination amongst survey participants to assign representational meaning even to highly distorted and abstracted shapes. Test motif 97 (Figure 4.2a), for example was described as a kite/broken kite (three times), sleeping penguin (once), suit (once), coffin/broken coffin (twice) and a destroyed paperclip (once). The assigned meanings included some culturally nuanced responses such as the description of test motifs 100b and 100c as Pac-Man (by six participants) or 100b as the Utility Clothing Scheme mark by one participant (Figure 4.2b and c).



a. b. c.

Figure 4.2 Perceptual survey test motifs 97, 100b and 100c.

The inclusion of representative motifs is also appropriate in searching for the presence of EVP-inspired decoration since this may have been interpreted in a representational manner in explaining the visual effects.

Representational decoration may introduce non-aesthetic, factors into the estimation of similarity and the creation of groups (Goldstone 1995). Vessel and Rubin (2010) found that aesthetic preferences varied less between individuals when they were asked to judge representational imagery than with abstract images and hypothesised that this was an effect of common experiential and emotional associations overriding a purely aesthetic reaction.

All spiral decoration found within the cultures and periods in question was included in the sample group with the exception of spirals which appeared in the context of a known pictogram or writing system. There is potential for overlap in interpretation between writing and decorative symbols. In giving a free response to describing the shape of a motif in the perceptual survey (Appendix 1, Table A1.3), eight participants identified abstract motifs as letters, numbers or musical notation. No other symbolic meanings were attributed to motifs. However, the inclusion of writing within the study introduces such a an large additional field that writing or equivalent notation was excluded from the scope of this research. The identification of writing raises potential problems of bias but the risk of ambiguity was felt to be less than that between abstract and representational imagery.

Emotional responses also vary between cultures; Pittard Ewing and Jevons (2007) commented that angular shapes could be viewed as hostile or aggressive forms societies whereas Fischer (1961) assigned a male and female symbolism to angular and curvilinear shapes and therefore associated them with the expression of sexuality. When asked to provide free description of test motifs in the perceptual survey (Appendix 1, Table A1.4), four participants used emotive language relating to the perceived attractiveness of the objects. The clearly emotionally charged terms were all positive 'beautiful', 'pleasing', 'elegant' and 'lovely'. All four participants gave positive responses to Figure 4.3a and one also to Figure 4.3b.

a.  b. 

Figure 4.3a. Test motif 157 - ironwork scroll in railings. b. Test motif 157b - modern ceramic plate from Morocco with spiraloids.

It is not clear why the two motifs above were described using emotive language. They were the only two of the five free description motifs to attract descriptions relating them to flower or plant forms but one of the participants who found Figure 4.3a attractive described it as a wave rather than a plant form and Figure 4.3b received most responses describing it as plant or flower. There is no indication whether cultural familiarity affected the nature of emotional responses. The ironwork spiral might be expected to be more familiar to the, participants (three of whom were British, the fourth did not state their nationality) than the spiraloid whorl with a Moroccan origin. An emotive response in description of the motifs had not been expected and would be an interesting area to explore further.

An additional consideration raised in the analysis of geometric motifs in isolation is that the cultural significance placed on a geometric motif may be highly variable. In some cases the spiral may represent a key symbolic element of a design whereas in other instances it may be no more than a decorative means of ending a trailing line with no special significance placed on it. To compare both within the same classification system cannot, in any culturally meaningful way, be considered a comparison of like with like. This difference could lead to spurious comparisons being drawn and care would need to be taken in choosing comparative studies to subjectively assess context and judge equivalence. For other questions the potential to assess the ornamental and the meaningful might be turned to an advantage by allowing consideration of the differences between the two forms. One might hypothesise that decoration would be executed with less care and therefore greater variation than meaningful symbols or alternatively that meaningful symbols would occur more often and therefore be subject to greater elaboration and variation. A common quantification system could test this or consider whether movement of motifs between cultures affected their presentation when in one instance the motif had meaning and in the other a purely ornamental function.

The inclusion of spirals identified in any context almost certainly incurs the problem of identifying as spirals a greater range of spiral types than the artisans may be aware of producing or intending to produce but it was felt less likely to introduce distortions into the sample to treat the spirals as meaningless for the purposes of sampling than to attempt to edit the sample on the basis of incomplete or absent interpretive information.

It must therefore be remembered that the application of geometric classification methods cannot necessarily be taken as an insight into the mind of the designer but this does not make the application of geometric criteria in analysis necessarily invalid. The producers of the decoration may still conform to a consistent set of characteristics in creating a symbol which is coincidentally spiral so still allow consistent type classes to be created from spirals and in the abstraction of a symbol or natural form to represent it in decoration it is still as probable that the same perceptual values which guide the creation of a pleasing decoration will apply as when creating decoration with no meaning attached.

4.3 Background to the case studies

For each group of case studies, the social and political structure of the societies and major changes in these within the period of study have been briefly summarised. Known external trade and cultural contacts are also noted. The focus of these case study introductions is on the contexts in which spiral decoration occurs within the culture looking at the range of media; the use of spirals in representational contexts; and the techniques used to produce spiral motifs. Where appropriate, existing typologies which make reference to spirals are recorded.

4.3.1 East Asia

This group of case studies analyses spiral decoration on pottery vessels from Neolithic Japan and on Shang Dynasty bronze vessels. These studies are rather more disparate in location and in temporal continuity than is ideal. Habu (2004 pp.34-35) draws cultural links, predating the period of this research from South China to the Amur River Valley to Japan which do not encompass the more inland regions of China included in this study so not directly linking Jōmon culture to the Chinese study areas. However, given the proximity of Japan to the Chinese coast it would be extremely surprising if there were not some form of contact between the Chinese east coast and Japan within the case study period and cowrie shells have been found in large numbers as grave goods in the Shang capital of Anyang (Chang 1980, p.88). These indicate that contact and the movement of desirable goods across the full geographical area of the case studies would have been possible.

4.3.1.1 Ceramic vessels and figurines of Jōmon Japan

The Jōmon period of Japan is the earliest period studied in this thesis. The earliest identified evidence of Jōmon culture dates back to 12500BCE (Table 4.1), having developed from an indigenous Palaeolithic culture (Habu 2004, p.3). This study focusses on the Early to Late Jōmon periods from 5000-1000BCE.

Period	**Date**	**Spirals sampled**
Incipient Jōmon	12500-8000	no spiral decoration found
Initial Jōmon	8000-5000	no spiral decoration found
Early Jōmon	5000-2500	3 spirals
Middle Jōmon	2500-1500	80 spirals
Late Jōmon	1500-1000	11 spirals
Final Jōmon	1000-300	no spiral decoration analysed

Table 4.1 Jōmon Period divisions (Kaner 2009, p.169) and numbers of spirals sampled from each period.

The Jōmon employed Neolithic technology in pottery and reached population densities typically associated with agricultural communities. However, foraging retained significant economic importance and sedentism was not generally established (Kaner 2009, p.15; Habu 2004, pp.132-3). Marine resources were important in the Jōmon economy and a number of the known Jōmon sites are represented by shell middens which appear to have begun as specialist processing sites in temporary seasonal occupation but later grew into permanent settlements (Matsui 2001, p.120; Habu 2004, p.58). The Early and Middle Jōmon periods appear to have coincided with a period of relative warming with a subsequent period of cooling into the Late Jōmon (Habu 2004, pp.42-43). The warmer climatic period allowed the exploitation of an increased range of wild food plants, nuts being of greatest importance (Habu 2004, p.45). Sika deer and boar were the most commonly hunted mammals (Habu 2004, pp.45, 59). Poorer climatic conditions at the start of the Late Jōmon period were associated with a reduction in population and a move of settlement to higher ground (Kaner 2009, p.44). From the Early Jōmon period, there is evidence of some plant cultivation including gourd, beans, millet, buckwheat, burdock and rice (Habu 2004, p.59). However, the adoption of agriculture as the main substitute method did not occur until the start of the subsequent Yayoi period when both bronze and iron working were introduced from Korea (Habu 2004, p.50).

Ceramics were the main medium for decoration in the Jōmon culture although carved bone, horn and stone have been found in small quantities (Kidder 1964, p.14). This case study analysed spirals found on vessels and on dogū – ceramic figurines. Jōmon ceramic decoration is entirely textural with no evidence of painting having been found. The earliest decorated Jōmon pottery had clay applied in strips or beads (Habu 2004, p.28; Kidder & Esaka 1968, p.150). This technique continued to be employed on vessels throughout the Jōmon period with the addition of decoration created by finger-working (Kidder & Esaka 1968, p.154); deep ridging; or point marks created with a bamboo tools (Kidder & Esaka 1968, p.190); twisted cord impressions in closely packed parallel lines (the decorative technique after which the Jōmon culture is named); and the use of sculptural elements (see Kaner 2009, cat.no.41 for sculpted example). Dogū decorative styles followed those found on pottery and some overlap between the two object types is found in the representation of human figures on vessels (Kaner 2009). During the Middle Jōmon period, dogū became more technologically complex. They developed from flat slabs forms designed to be held up with props or strings to being self-supporting. Some of the more complex figures were constructed with hollow heads (Kaner 2009, pp.41-44). The disruption to the settled way of life at the end of the Middle Jōmon period arising from climatic change coincided with a reduction in the production of dogū with new designs being introduced at the end of the Late Jōmon and into the Final Jōmon (Kaner 2009, p.44).

Vessels developed into highly elaborate forms with an emphasis on decoration over function by the Middle Jōmon period possibly reflecting a change from functional cooking vessels to ritual objects (Foster McCarter 2007, p.104). In this context, it is suggested that much of the decoration on the pots is of representational or symbolic significance and possibly relates to ritual celebrating the transformation of food from raw to cooked, although the meanings of the representations can only be speculated on (British Museum 2013). Ritual dancing is believed to be depicted on some vessels and a possible interpretation of a bulbous vessel of the Middle Jōmon period is as a drum with pierced holes around the top for attaching a skin and a dancer depicted on the side (Takashi 2009, pp.136, 140). Kaner (2009, p.32) cites ceramic models of mushrooms as possible evidence for the consumption of psychoactive drugs in rituals. The primary use of Dogū was in ritual. The majority of dogū are female and may represent an earth mother figure (Kaner 2009, p.52). Ritual practise involving dogū appears to have involved breaking and scattering the figures, depositing concentrated broken fragments in a cemetery or pit burial of dogū accompanying a body or in isolation (Kaner 2009, pp.50-51).

Both vessels and dogū show considerable regional variation; Habu (2004, pp.39, 210-11) provides a chart indicating some of the regional and temporal variation in Jōmon pottery styles. The internal regional variation is not indicative of cultural isolation. Movement of jade and obsidian provides evidence of extensive trade networks having been established across the Japanese archipelago by the Middle Jōmon period transporting raw materials and finished goods (Habu, 2004, pp.3, 223-225). Contacts outside the Japanese archipelago from a very early period have also been proposed. Early lithic assemblages in northern Japan resemble those found in the Amur River Valley Basin in south-eastern Russia along with pottery which may predate Jōmon examples and it is argued that ceramic technology may have come from this region into the north of Japan (Habu 2004, pp.32-34).

South-eastern Russian contact has been proposed at the start of the Jōmon period and the change at the end of the Jōmon period to the Yayoi culture appears to have been stimulated by the arrival of Korean migrants (Noma 1966, p.20). However, there appears to be little evidence of foreign influence during the Jōmon period (Noma 1966, p.286). Most Early and Middle Jōmon pottery has been found in central Japan in the mountainous region of Honshū (Noma 1966, p.11). Noma suggests that this would have created cultural isolation away from possible foreign contacts. A study of the diet of Honshū communities indicated little input of marine resources (Habu 2004, p.75).

During the Late Jōmon and, more noticeably, during the Final Jōmon, a Korean influence seems to have returned and can be seen in pottery styles with a resulting simplification of decoration (Habu 2004, p.208). Given the long distance contact at either end of the Jōmon period, the isolation from contact outside the archipelago for much of the Jōmon period seems surprising but does seem indicated by the cultural record.

Spirals in Jōmon decorative culture

Spirals appear on both dogū and vessels at the end of the Early Jōmon period. On dogū, spiral motifs continue to be found on Final Jōmon figurines which are outside the scope of this study. On pottery spiral decoration is dominant in the Middle Jōmon period although it must be noted in this regard that the vessels analysed in the study were less precisely dated than the dogū. The spiral decoration found on vessels and dogū is markedly different. On dogū, spirals tend to be densely coiled with a narrow path width and to have greater rotational length than the large spirals of high expansion rate which dominate on pottery vessels. Only one spiral motif seems to overlap both object types, a spiral of low rotational length seen on the head of dogū and, around the very top of vessels.

On pottery vessels, snakes are thought to be an early motif and it has been suggested that many early curvilinear forms represent snakes (Figure 4.4a) (Kidder & Esaka 1968, p.94). Some examples of spiral motifs have snake heads and there also appears to be a split tail form characteristic of snake representations but many similar forms are highly abstracted with no apparent representational features. These snake forms were later transformed into other representational motifs including highly abstracted birds with spirals present at the tips of the wings and forming the head or eye (Figure 4.4b) (Kidder & Esaka 1968, p.150) and, as mentioned above, dancing humans with linked hands. One example of a pottery drum is particularly interesting as a possible link between trance states and EVP in that it depicts a discrete spiral alongside a dancing figure (Takashi 2009, p.140).


a.


b.

Figure 4.4a. Possible snake motif (indicated by arrow) on a Middle Jōmon pot, Tsunan Town Board of Education. b. Bird motif drawn from a Middle Jōmon pot.

Spirals on dogū have been used in several representational contexts. A recurring example is in the depiction of a spiral as hair or a headpiece. An alternative interpretation of these spirals is, again, as a snake (Kaner 2009, p.55). It has been conjectured that the snake figure represents an earth mother and that this motif was associated with the nurturing of food explaining its occurrence on vessels (Kaner 2009, p.55), although that would make their placement on the heads of humanoid representations of a goddess figure incongruous. Besides placement on the forehead of figures, spirals on dogū are particularly placed in the centre or the back of the figure usually as a single motif (e.g. Kaner 2009 cat. nos. 7, 21) but, in one instance, as a running line of spirals (Kaner 2009, cat. no. 61). A number of spiral motifs are depicted over limb joints possibly as a depiction of decorated clothing (Kaner 2009, p.30).

The objects included in this case study were well provenanced with only two lacking a place of origin and all having dates assigned within a cultural period (Appendix 2, Table A2.2). Final Jōmon Period spiral decoration was not included within this research. This did not affect the decoration analysed on pots which was concentrated in the Middle Jōmon period but did exclude some dogū with spiral decoration.

The spirals sampled in this case study were drawn from 48 vessels, one lamp and 13 dogū. Most analysed spirals were in a good state of preservation with little chipping or degradation of the edges; 24 spirals had interpolated sections up to a maximum of 28% of the total length. Some large coiled snake motifs were the only, notable, exclusion from analysis; since they often consisted of multiple curves running in parallel from a single centre (Figure 4.4a), they only inconsistently fulfil the minimum rotation criterion of spirals/spiraloids so some examples were excluded that could be seen to form part of an aesthetic continuum with the analysed examples.

4.3.1.2 The Shang Dynasty and Western Zhou Period

The main body of data for this case study was drawn from Shang Dynasty (c.1766-1027) bronze vessels, running on into the subsequent Western Zhou Dynasty (1046-771).

The Shang Dynasty was centred on the lower Yellow River Valley. The dynasty is divided into three political periods – Erligang, Late Erligang and Anyang (Chang 1980, p.322). In this region, millet and rice were the principal crops with dogs, cattle, sheep, pigs, water buffalo, Pere David's deer and (imported) horses being the main economically valuable animals (Lu 2005, p.51; Chang 1980 Ch.2). The settled agricultural economy of the Yellow River Valley allowed the development from segregated villages into clustered village groups and later the development of a state system with the rise of the Xia Dynasty (Zhimin 1988, Chang 1980, pp.287,361). The Shang Dynasty represents a continuation of a ruling line, the Tzu clan, from the predynastic period in a hierarchical structure with a capital and local rulers in walled towns (Chang 1980, pp.1-5, 158-162).

Mutual influence between contemporaneous Yellow River Valley cultures can be seen in the similar forms of some bronze vessels (Zhimin 1988). Potential copper ore sources and war raids to Kung Fang in northern Shaanxi suggest contact within a c.200 mile radius was viable and high status cowrie shells must have been brought inland at least a similar distance (Chang 1980, pp.151-5). Salt was also traded outside the Shang area (Chang 1980, p.258). By this period there is evidence of the exchange from Central Asia to China along the jade route (Wood 2002, p.26). Shang cultural influence can be identified as far north as Beijing to border the Lower Xiajiadian culture during the Erligang period (Chang 1980, p.294). Allan (2007) argues that Erlitou pottery motifs may have influenced Lower Xiajiadian painted pottery decoration. To the south, the early Shang settlement area was bounded by the Yangtze River with evidence of cultural contacts again being present in the bordering Jiangxi Culture. Some Shang vessel forms spread southwards and glazed, stamped geometric pottery entered Shang areas from cultures to the south (Chang 1980, pp.305-6). Stamped geometric pottery included spirals amongst its characteristic motifs in later phases (Chui-Mei 1984) which very strongly resemble some of the *leiwen* spirals seen on Shang bronze vessels.

The Western Zhou Dynasty began with the conquest of Shang around 1122. The temporal overlap and evidence of cultural contact between the Shang and Zhou permitted significant continuity of bronze vessel styles between the Shang and Western Zhou cultures and late Shang and early Western Zhou bronzes can be difficult to differentiate stylistically (Chang 1980, p.21). The Zhou state structure developed from that of the Shang but was made more systematic during the Zhou Dynasty. A system of local administration was formalised with rulers being given recorded mandates to rule by the central authority (Allan 2007).

Bronze working was known in eastern China by the end of the third millennium (Allan 2007). Bronze was used in the construction of weaponry, harness and vehicle fittings and vessels. The earliest evidence for the production of bronze ritual vessels comes from the Erlitou period, which immediately preceded the Shang Dynasty (Allan 2007). The Shang Dynasty shows an increase in the amount and detail of decoration on bronze vessels (Chang 1980, p.233) and an expansion in the range of types of vessel from wine vessels in the Erlitou period to the inclusion of food and water vessels by the Late Shang (Allan 2007). Bronze casting centres have been found at Hsiao-t'un and in the region of Miao-p'u-pei-ti/Hsüeh-chia-chuang. It is suggested that these centres developed contrasting styles (Chang 1980, pp.28, 233). Shang and Western Zhou bronzes were cast in clay piece moulds decorated by carving an initial stage of decoration into a model of the vessel then creating an impression of the model in a mould and finishing the decoration by carving into the inside of the mould (Chang 1980, p.233; White & Otsuka 1993, p.15).

Pottery of the Shang Dynasty continued the wheel technology developed in the earlier Longshan Culture (Chang 1980, pp.234-5, 340-1). New developments in the Shang period, found on high-status White Pottery, were the introduction of glaze and of finely engraved decoration. Cord marked and stamped decoration continued in use from earlier cultures on lower-status pottery (Chang 1980, pp.234-5, 340-1).

Shang Dynasty bronze vessels are accepted to be associated with ritual practises (e.g. Allan 2007) so the decoration on them might be expected to reflect religious beliefs and practises. Keightley (1978) stresses the ordered nature of Shang religion and suggests that a similar desire for order guides the highly geometric and abstracted decorative style. The structure of Shang religion placed worship of the god Ti at the highest level, through the intercession by royal ancestors and the living king who took on a magician or shaman role in reading oracles (Keightley 1978, Tong 2002). Evidence for Shang Dynasty religious practises from historical and archaeological sources shows the use of divination and oracle bones, a practice involving the heating of bone and studying cracking patterns and of requests for divine intervention made by animal sacrifice (Keightley 1978; Tong 2002). The *Guo yu* text (compiled in the 4th century BCE) refers to individuals performing religious rites for themselves but the Shang Dynasty provides the first written evidence of magicians or shamans and suggests that people assuming these roles would have to be susceptible to being possessed by a divinity (Tong 2002). Similarly, Keightley (1978) describes *Pin* ceremonies in which the king received an ancestral spirit 'as a guest'. The Shang/Zhou case study offers the strongest evidence of all the cultures considered in this research of the possible use of psychoactive drugs capable of inducing hallucinations. Hemp is frequently referred to as a textile and food crop in the *Shih Ching,* written in the Zhou Dynasty (Li 1974). References to cannabis as a psychoactive drug or medicine post-date the period of this case study. An Eastern Zhou period text refers to hemp in a negative context which is attributed to its depressant properties and the *Shen-nung pen-ts'ao ching,* a 5th-7th century CE herbal compiled from earlier sources, states that cannabis "if taken in excess will produce hallucinations. If taken over a long term, it makes one communicate with spirits and lightens one's body." (Li 1974, pp.445-446; Prioreschi 1995, p.154). Texts relating to the Zhou Dynasty (the *Tongdian* compiled in 735-812 and the *Zhou li,* 4th-3rd centuries BCE) describe ritual dancing and drumming as a continuation of older practises which retained religious significance in that period (Tong 2002).

Spirals in Shang Dynasty and Western Zhou Period decorative culture

Spiral decoration in this period shows continuity from Erlitou period woodcarving and lacquer work through Erligang cast bronze vessels. Spirals are found on a wide range of types of object and in multiple media including bone plaques, ceramic vessels of the White Pottery style, stone figures, wood (surviving as impressions in clay) and on bronze goods (Loehr 1953; Chang 1980, pp.114-117). White Pottery has been found in storage pits at Hsiao-t'un (Chang 1980, p.98) implying day-to-day usage whereas bronze vessels, in the large majority of cases, have been found as grave goods from high status sites (Chang 1980, pp.132, 205, Allan 2007). Loehr (1953) suggests a direct link through White Pottery between decorative motifs of Machang painted vessels and Shang bronzes. However, Zhimin (1988) suggests that the origins of the Shang cultural tradition were more localised and ran back through the Longshan, Yangshao and Peiligang Cultures within the middle Yellow River Valley area. Chang (1980, p.284) also proposes a local cultural succession through the Yangshao, Longshan, Xia and Shang cultures.

Typical Shang Dynasty decoration is an animal style which, by the Late Shang, showed a limited range of regional variation but a consistent set of motif types across the Shang cultural area, prominently featuring *taotie*, dragons and birds (Figures 4.5 and 4.6) (Allan, 2007).

a. 

b. 

Figure 4.5 Shang/Western Zhou Dynasty animalistic decoration. a. A *taotie* mask detail from a late Shang Dynasty *jia,* British Museum, acc.no. 1945,1017.191. b. A *long*, one of several types of dragon depicted in the period, British Museum, acc.no. 1952,1216.1.

Spirals motifs are used in a small group of roles in representational depictions – as horns, ears, tails, joints (at the tops of legs and wings), and as surface patterning across the bodies of the animals. Depending on its use, the spiral form appears remarkably consistent in each type of use even when the overall decorative style of vessels differs and when transferring across different media (Figure 4.6). The ground 'thunder cloud' (*leiwen*) spiral (Fig 4.7) which is characteristic of Late Shang (Yinxi Period) bronze decoration is found on Erligang vessels as a border motif and, earlier, as a pottery motif during the Erlitou I period (Allan 2007, Loehr 1953).

a. 

b. 

Figure 4.6 Consistency in use of spirals in depictions of birds' wings in different materials: a. Late Shang jade goose, British Museum, acc.no.1945,1017.40. b. On a Shang bronze vessel, British Museum, acc.no. 1936,1118.4

Figure 4.7 Background *leiwen* patterning on a Shang Dynasty vessel, British Museum acc. no. 1957,0221.1.

A typology by Max Loehr of the decoration of bronze vessels which is based on the shape of the vessels and the type and arrangement of the decoration in an evolutionary type series identifies identifies spiral shape as an important differentiator, particularly between the final three styles III, IV and V. In style III, patterns of flattened spirals on a plane with the rest of the decoration begin to emerge (Loehr 1953). In style IV *leiwen* appear for the first time and spirals are separated from other motifs as a background pattern (Loehr 1953). In style V, non-spiral motifs are raised in relief above the spiral ground which is sometimes omitted (Loehr 1968 cited in Chang 1980 pp.28-30). Chang (1980, pp.81, 264-267) proposed that Loehr's styles IV and V developed around the time of the establishment of the Shang capital near Anyang and that earlier styles may have been pre-dynastic in origin; as they are already present in the earliest phase Shang site at Erligang. Karlgren also identified spirals as amongst the motifs characterising different decorative styles on Shang bronzes (Chang 1980, p.27).

This case study used only vessels as examples. The spirals sampled in this case study were drawn from 51 vessels (Appendix 2, Table A2.3). 41 dated to the Shang Dynasty, seven to the Western Zhou and two were undetermined. 18 types of vessels were sampled (Table 4.2).

vessel type	**number sampled**
pou (wine vessel) one example described as pou/weng	2
gu (goblet)	3
jue (spouted wine vessel)	4
li ding (tripod vessel)	1
li (3-lobed tripod vessel)	3
zun (wine jar)	5
ding (food/cooking vessel)	10
fangzun (wine vessel, rectangular cross section with flared lip)	1
grain vessel unspecified type	1
jia (tripod wine vessel with round mouth)	2
fang yi (wine vessel with rectangular cross section and pointed lid)	2
he (3-lobed tripod wine vessel)	2
gui (food vessel)	6
hu (wine vessel)	2
you (wine vessel)	4
pan (shallow water basin with a foot)	1
jiao (wine vessel)	1
zhi (wine vessel)	1

Table 4.2 Types of Shang Dynasty vessel from which spirals were sampled.

Although corrosion had damaged some decoration, the spirals sampled were generally in a good state of preservation. There were very few vessels from which no spirals could be analysed. 23 of the analysed spirals included some degree of interpolation of the path up to a maximum of 26% of the length. The provenance of the vessels studied was very poorly resolved in terms both of date and place of origin with only five having an, even approximate, place of origin and only 21 having a time resolution less than the extent of a full dynasty. Three vessels in the sample came from Anyang. Yinxu, the final Shang Dynasty capital and the site of the royal mausoleums is located in the Anyang region (Chang 1980, p.70; Tang, Jing & Rapp 2000). It is not clear if the vessels were found in the excavation of the city itself or the broader Anyang region which includes other major urban sites and is possibly the location of some earlier Shang capital cities (Tang *et al.* 2000). This lack of provenance poses a considerable restriction on the study, creating type clusters and in the conclusions that can be drawn from the results. Regional style differences cannot be segregated.

4.3.2 The Eastern Mediterranean and Egyptian area

From the Neolithic into the Classical Greek period, spirals were a frequently occurring motif in a large area centred on the Eastern Mediterranean and Egypt. A further link has been suggested to the spiral decoration of Danubian Neolithic pottery (Crowley 1989, p.105) through the Cyclades and from there throughout the Aegean/Eastern Mediterranean (Shaw 1970). The number of cultures within this area with spirals as a notable element of their decorative arts creates a difficulty in determining the origins of spiral motifs and a number of theories have been put forward in this extensively studied area (e.g. Crowley 1989; Tufnell & Ward 1966; Ward 1902). Although the Cypriot sample in this study is of a later period than the Egyptian case study, both cultures have had a common source for spiral decoration suggested in transmission of textiles and pottery from Crete and mainland Egypt (Barber 1998; Steel 2004, pp.17, 154; David 2002, p.153). Shaw (1970) noted links in spirals as pottery decoration between the Minoan ivy leaf motif, which first appears in the Early Minoan III period, and Egyptian heart-shaped spiral pairs. Shaw (1970) argues that this spread from Crete to Egypt in or slightly before the Middle Minoan I period in woven patterning of cloth. Along with Marinatos (1951), Shaw suggests that the later naturalisation of the heart-shaped spiral motif to a more leaf-like form combined with a central flower shoot in Aegean decoration towards the end of the Middle Minoan period reflects an Egyptian influence from lotus or papyrus representations. By the Egyptian Middle Kingdom and Cypriot Middle Bronze Age, Cyprus was well established as a trading post for contacts between the Near East, the Western Aegean and Egypt (Steel 2004, p.170). These close links over a long period suggest that a commonality in spiral forms might be expected between the two case studies providing a contrast with the Shang/Western Zhou and Jōmon case studies.

4.3.2.1 Egyptian scarabs and scaraboids

The Middle Kingdom (Table 4.3) represented a time of reunification of Egypt under a single king following the fragmentation of the First Intermediate Period into autonomous regions under a purely notional monarch (Grajetzki 2006, pp.3, 7). The new ruling group arose from Thebes whose rulers gradually assumed control of the whole country during the Eleventh Dynasty (Grajetzki 2006, p.10) although regional rulers remained powerful outside parts of southern Egypt in the early Middle Kingdom (Grajetzki 2006, pp.97-99). Social stratification is shown in both formal divisions of ranks amongst the ruling group and evidence from settlements of the organisation of towns into areas of small (manual labourers') and large (officials') houses and there is little evidence for social mobility (Grajetzki 2006, pp. 139-142). However, social divisions between professions in the mass of the population are less clear (Grajetzki 2006, p.143). The Middle Kingdom ended with fragmentation of central rule at the end of the thirteenth dynasty giving rise to the Second Intermediate Period (Grajetzki 2006, p.63). Thirteenth Dynasty kings appear to have only had strong control over Upper Egypt with Lower Egypt coming under the control of an incoming population from southern Palestine (Grajetzki 2006, pp.64, 73). An advance of the Nubian state from the south further reduced the kings' control (Murnane 1997, p.30). Over the following century the eastern invaders became established in the Delta settlement of Avaris as the Hyksos rulers and gained functional rule over Upper Egypt until the renewed advance of the Upper Kingdom vassal states established the first New Kingdom dynasty (Murnane 1997, p.31).

Date	Period	Dynasty	no. of analysed spirals
2181	First Intermediate Period	VII	2
		VIII	
		IX	3
		X	
2160-2025		XI	1
2025-1995	Middle Kingdom		33
1976-1794		XII	2 4
		XIII	1
1700-1550	Second Intermediate Period		1
1550-1292	New Kingdom	XVIII	5
1292-1185		IXX	
1186-1069		XX	

Table 4.3 Timeline of Egyptian kingdoms and dynasties (adapted from http://www.digitalegypt.ucl.ac.uk/chronology/index.html) and numbers of spirals sampled in each period

The Middle Kingdom population was organised into urban settlements with temples and administrative buildings with facilities for defence and food storage (Grajetzki 2006, pp.81-83). This was supported by a large rural population underlying an economy based on agriculture and, in some parts of the country, cattle farming (Grajetzki 2006, p.78). Evidence exists for both free trade in private sales at markets and for centralised collection and distribution of resources for state employees (Grajetzki 2006, p.84).

Contacts outside Egypt had been limited in the Old Kingdom although there were steady military assaults on Nubia (Redford 1997, p.40). During the Middle Kingdom, there is evidence of trade with Nubia and of the construction of fortresses at Egyptian land borders to the south and northeast. Continued military forays from the Eleventh Dynasty led to the conquest of Nubia in the Twelfth Dynasty and a resident Egyptian population there in the Thirteenth Dynasty (Grajetzki 2006, p.134; Murnane 1997, p.28). Nubia and sub-Saharan Africa, reached through Nubia, had important luxury raw materials such as gold and ivory (Redford 1997, p.40). Archives at Uronarati on the southern Egyptian border record trade with Nubians and edicts controlling the movement of Nubian merchants into Egypt (Smith 1990). The Kerma Culture of southern Nubia became powerful during the Second Intermediate Period and conquered most of northern Nubia as well as venturing into Upper Egypt (Grajetzki 2006, p.135). Initial trade contact with Palestine was to obtain access to Syrian and Mesopotamian raw materials – turquoise and copper from the Sinai Peninsula and cedar wood from Lebanon through Byblos; excavations at both Byblos and Ugarit to the north have revealed large numbers of Egyptian finds (Grajetzki 2006, p.146; Redford 1997, p.43). A resident Palestinian population became established in the Egyptian Delta some of whom occupied high administrative posts (Grajetzki 2006, p.136). Minoan pottery first occurs in Egypt during the Middle Kingdom and it is suggested that the presence of this material is the source for the rise in popularity of the spiral in Egyptian decoration (Grajetzki 2006, p.136). There is, however, little evidence of direct trade with Crete. Minoan material may have been traded via Lebanon during the Middle Kingdom and direct contact established only during the New Kingdom (Grajetzki 2006, p.136; Redford 1997, p.44).

The original use of scarabs reflects the administration of trade, communications and storage of supplies. They derived from stamp seals, used to seal documents, containers or doors, which developed from cylinder seals during the First Dynasty, initially as button seals mounted on rings (Reisner & Wheeler 1930). The oval seal form with an amulet carving on the reverse generally in the form of a scarab beetle developed into its final form between the Sixth and Ninth Dynasties (Reisner & Wheeler 1930). Different scarab types are identified with ‘royal name’, ‘personal name’ and ‘decorative’ scarabs being stylistically distinct (Reisner and Wheeler 1930). Of the analysed sample for this case study 44 of the scarabs had pattern inscriptions, seven had name inscriptions, four were uncertain and one of the spirals in the sample was from a carving on the reverse of the scarab.

A study of Middle Kingdom and Hyksos scarabs and seal impressions from Semna and Uronarti from the first half of the Thirteenth Dynasty identified two main types of seal – the first to develop bore the name of the king, an official or an administrative department as the primary inscription (Reisner & Wheeler 1930; Smith 1990). Later, private seals of individual officials with either a name or an all-over geometric pattern were used as a secondary seal alongside official administrative seals (Reisner & Wheeler 1930; Smith 1990). Administrative name seals have little decoration but often include spirals or spiraloids as border decoration (Reisner & Wheeler 1930). Pattern seals have spiral, concentric circle or knot decoration as the main imagery sometimes combined with auspicious symbols (Reisner & Wheeler 1930); Petrie (1920, p.25) suggests that these developed in simple form around the Eighth Dynasty. Smith (1990) suggests that the private seals with names belonged to more senior officials than those with only pattern or pattern and symbol decoration. Reisner and Wheeler (1930) distinguish between high quality carving which, they suggest, was carried out by carvers employed by the royal court and cruder carving techniques which they suggest were locally made; they link the quality and detail of the carving to the status of its owner. This study has focussed on scarabs rather than seal impressions. Alongside their use as administrative seals, scarabs appear to have served a decorative and auspicious function as amulets, particularly associated with regeneration as well as being a declaration of status possibly passed down several generations of a family before being deposited in a tomb (Grajetzki 2006, pp.103, 143; David 2002, p.175).

In Middle Kingdom Egypt, a change in the focus of religion occurred, transferring away from the leader as an absolute divine authority to a belief in the control and authority of the gods over the whole population (David 2002, p.150). The practise of religion focussed on purification, recitation and offerings of food to icons of a deity (Teeter 1997, pp.148-151). Texts from Dynastic Egypt mention requests to ancestors to appear in the dreams of the supplicant "*Become an akh for me before my eyes so that I can see you in a dream fighting on my behalf*" and the ritual of the early New Kingdom cult of Amenhotep I includes drum beating and chanting (Teeter 1997, p.153) which has, in some ethnographic examples, been associated with trance states (Neher 1962). However, there is no strong evidence in either the written record or archaeological finds to suggest that psychotropic drugs or trance states which might have induced EVP were a part of Middle Kingdom religious practise.

Petrie (1920) identified four categories of Egyptian decoration: geometric, representational, structural and symbolic. Geometric decoration included angular forms – arrangements of zig-zags, triangles, hexagons and squares, which Petrie associates with origins in woven structures (Nelson 1936; Petrie 1920, p.14), particularly in earlier periods but by the Middle Kingdom appears to have been dominated by more curvilinear forms, predominantly arrangements of knots and spirals.

Spirals in Middle Kingdom decorative culture

Spirals on scarabs were uncommon before the Middle Kingdom, but were more frequently found on button seals (Figure 4.8) in a different character from that seen later on scarabs – the number of rotations tends to be greater and sharply angular forms are found which are not seen on later scarabs. The origins of spiral decoration on Old Kingdom and Middle Kingdom seals and scarabs is unresolved. Throughout the period spiral decoration was used in Crete, the Cyclades and the Near East and, by the Middle Kingdom also on Mycenaean pottery (Ward 1970). Reisner and Wheeler (1930) and Ben-Tor (2007, p.12) suggested a development of Middle Kingdom spirals from earlier Egyptian motifs – either from Naqada II pottery or Old Kingdom motifs or gold wire jewellery. Alternatively, both Ward (1964) and Reisner and Wheeler (1930) raise the possibility of multiple sites of independent evolution for relatively simple geometric motifs.

Figure 4.8 Ninth Dynasty button seal from Qaw, (©Petrie Museum of Egyptology, University College London acc. no.UC20752).

The first occurrence found of spirals on scarabs dates to the Fifth Dynasty (Petrie 1920, p.19). These earliest designs tend more towards hooks than spirals and tend not to be linked in complex interrelationships (Petrie 1920, p.21). Nevertheless true spirals are found in small numbers on Old Kingdom and First Intermediate Period scarabs. Spirals only became a common motif on scarabs from the start of the Middle Kingdom, possibly through transference of spiral decoration from Minoan or Cycladic decoration to Eleventh Dynasty Egypt via Syria (Crowley 1989, pp.182-183, 194). By the Twelfth to

Thirteenth Dynasties, the use of linked spiral or concentric circle motifs became a characteristic feature of Egyptian scarabs (Ben-Tor 1997). Spiral decoration on scarabs declines in the late Middle Kingdom. In the Second Intermediate Period and New Kingdom scarabs with spirals are found but are less frequent and designs which prioritise spirals over inscriptions in terms of surface area also reduce in number. Whereas, on Middle Kingdom scarabs, the area of the scarab available for inscription often seemed compressed by the desire to render a smoothly curving border of spirals (Fig 4.9a), in the Second Intermediate Period, there seems to be a tendency, as in early examples, to relegate spiral decoration to a compressed hook forms (many of which were excluded from this research since they did not have sufficient rotation length) and are longitudinally compressed to allow a larger area for inscription (Fig 4.9b). The beginning of this trend to reduction appears to be visible in the late Middle Kingdom scarabs from Lahun although examples with fuller spirals are not precisely dated within the Middle Kingdom period so the point at which they begin to decline cannot be determined.

a. 

b. 

Figure 4.9a. Middle Kingdom spiral border, (©Petrie Museum of Egyptology, University College London, acc.no.UC29073). b. New Kingdom spiral border, (©Petrie Museum of Egyptology, University College London, acc.no.UC11897).

Only one spiral decorative style on scarabs appears to have become more common in the New Kingdom – crossed spirals (Figure 4.10). They are found on Middle Kingdom scarabs but make up a much greater proportion of the spiral decoration found on New Kingdom examples. These may be two dimensionally symmetrical abstractions of plant representations.

Figure 4.10 Crossed spiral decoration on a New Kingom scarab, (©Petrie Museum of Egyptology, University College London, acc. no.UC60391).

Spirals were also found as architectural decoration; examples of painted spiral tomb decoration were found in the Middle Kingdom, for example, in the tomb of Hepzefa at Assiut (completed between 1971 and 1928) (Shaw 1970) but reached a peak later than the spiral decoration on scarabs with most examples dating to the New Kingdom (Petrie 1920. p.31). Petrie (1920, p.28) differentiates the spiral decoration on scarabs from spirals on architecture by the nature of the space they were intended to fill with large wall or ceiling surfaces allowing regular designs expanding in all directions rather than spirals on scarabs which he suggests were initially distorted to fit around name inscriptions.

In representational contexts, spirals on scarabs have mainly been associated with plant forms identified by a broadening of the outer end of the coil to represent a lotus seed pod or a reed head (Figure 4.11). On pre-Middle Kingdom scarabs, the large majority of spirals seem to have formed part of representational depictions of plants. This is a curious abstraction since the plants with which they are most commonly identified – papyrus (a symbol of the Lower Egyptian kingdom) and lotus (Ward 1902, p.102; Petrie 1920, p.42; Marinatos 1951) do not naturally assume any planar spiral growth forms of the types depicted; the use of spirals seems more likely to be an imposition of the spiral motif onto the traditional three stemmed depiction of water plants than a derivation of spiral decoration from a plant source.

Figure 4.11 Spiral representing a lotus or reed, (©Petrie Museum of Egyptology, University College London, acc.no.UC18125).

In the majority of cases, spirals cannot be identified as representational although there is consistent representation of the horns of Hathor as spirals (Figure 4.12a) and a single instance on a scarab of an udjat-eye including a spiral (Figure 4.12b). Representations of an udjat-eye in other contexts not infrequently include spirals and this usage continued into the later Dynastic period (Figure 4.12c).

a.

b.

c.

Figure 4.12a. Hathor horns, British Museum, acc.no.1930,0711.202. b. An udjat-eye on the top of a scarab, Oriental Museum, University of Durham (Wellcome Collection), acc.no.101585/17. c. An udjat-eye on a 26th Dynasty amulet, British Museum, acc. no. EA63381.

On the scarabs used in the study, there is a single instance in which a snake's head has been added to spiral decoration (Figure 4.13a). Although this explicit representation as a snake appears to be unusual, there may be a case for arguing that a number of the spiral structures on Middle Kingdom scarabs relate to snakes. The basic structure of the running spiral border seen in Figure 4.13a is common on many scarabs of this period so it is possible that less readily identifiable snakes are represented in other examples. In other examples where spirals form the main decoration of the scarab, similarities of layout can be seen between linked spirals (Figure 4.10) and endless knot patterns (e.g. Figure 4.13b) which have also been used to represent snakes (Figure 4.13c).

a. b. c.

Figure 4.13a. Snake as border decoration on a Middle Kingdom scarab, British Museum, acc. no. 1960,0514.53. b. Endless knot design on a Middle Kingdom scarab, (©Petrie Museum of Egyptology, University College London, acc. no. UC60359). c. Snake in an endless knot form on an animal mummy case, (©Petrie Museum of Egyptology, University College London, acc. no. UC8220).

Scarabs have long been used to make categorical distinctions in typology of scarab decoration. The majority of the classification systems use the arrangement and interrelationship of spirals as the basis for type classes rather than the shape of the spirals themselves e.g. Petrie (1920, pp.20-21). Petrie (1920, p.23) also noted variation over time in the way these features occurred in the placement of spirals on the scarab – initially around the sides of a name inscription but later sometimes fully encircling it and also in the nature of linkages with long links being more typical of pattern scarabs than name scarabs. Both Shaw (1970) and Grenfell (1915) segregate the different interrelationships of spirals as being important in identifying different origins and meanings for motifs which include spirals as a main component with Shaw, on the basis of brush strokes in tomb paintings, separating pairs of spirals joined to form a heart-shape as leaf forms from S spiral links although she suggests that the two forms may have merged in copying.

Although the focus of this study was on Middle Kingdom scarabs when spiral decoration was at its height, a small sample of earlier and later scarab spiral decoration was included since, as discussed above, some types of spiral decoration appeared to show change over time. The Old Kingdom and First Intermediate Period sample was too small to draw any conclusions but more examples were available from the Second Intermediate Period and New Kingdom.

The majority of scarabs sampled in this study (Appendix 2, Table A2.4) are made of faience or steatite. Only two examples were carved in a hard stone (obsidian and jasper) and one incised into gold sheet. A number of the scarabs had spirals which were too damaged to analyse. Some which could be analysed had minor damage and chipping. 15 of the spirals sampled had interpolated sections to a maximum of 30% of the length. Provenance of the scarabs was poor, only 36 of the 53 scarabs in the study were identified to an excavation site.

The scarabs and scaraboids in this study of known provenance were found at nine sites from both Upper and Lower Egypt. The earliest scarabs in the sample from the 9th Dynasty came from tombs at Qaw, (Brunton 1927, p.40). The main evidence for the 9th Dynasty comes from chamber tombs representing a moderately well off population (Brunton 1927, p.74). At the time of excavation, scarabs from Qaw represented the earliest examples of scarabs used as amulets rather than seals (Brunton 1927, p.74). The majority of scarabs in this sample were from Lahun which began as a workers' village associated with the construction of the pyramid of Senusret II but became an important, planned, settlement in the late Twelfth Dynasty with a population of around 3000 (Grajetzki 2006, pp. 57,92,116-8,141; Shaw 1997, p.71). There is evidence of tombs and houses of officials as well as a large number of smaller houses (Grajetzki 2006, pp.57, 92, 116-8, 141). The Upper Egyptian sites from which scarabs have been sampled were placed on important trade or communication routes. Tell el Yehudijeh a settlement founded in the Middle Kingdom or Second Intermediate Period (David 1998, p.80) operated as a control point for the land route from the Sinai Peninsula to Egypt; there is evidence of a Hyksos fortress at this site (Bietak 1999, pp.791-2). Nubt was an major settlement centre, a religious site for the worship of Seth (Grajetzki 2006 p.93) and an important communication point with access to navigable stretches of the river from which gold from nearby mines could be transported (Grajetzki 2006 pp.92-93; David 2002, p.40). Koptos, likewise, was associated with the start of the shortest access route to the Red Sea and an access route to silt stone quarries and gold mines (Grajetzki 2006 pp.92-93).

A greater range of sites from Lower and Middle Egypt was sampled, although sample size from each site was small, in several cases only a single scarab. Meydum was an important royal burial ground in the Old Kingdom with a pyramid built by Snefru and substantial surrounding tombs.(David 2002, pp.79-80, 100-1). The scarab analysed in this case study was from a deposit dating from the New Kingdom reuse of some of the tombs as Meydum although the scarab itself dated from the Hyksos period (Petrie, Mackay & Wainwright 1910, pp.36-7). A single scarab was analysed from Hawara, a long-standing cemetery site, established in the 12th Dynasty around the pyramid of the deified Amenhat III and continuing into the Roman period (Uytterhoeven & Blom-Böer 2002). One scarab from Sedment, a cemetery site near the town of Herakleopolis, and an important First Intermediate Period settlement was included in the sample. Tombs in the Sedment cemeteries do not reflect a very wealthy population and may have been those of local village populations (UCL 2001). The Mostagedda cemetery was, similarly, probably used by smaller settlements in the area and does not include burials of members of the ruling group or of officials (Grajetzki 2006, pp.103, 144)).

4.3.2.2 Cyprus

The period of the Eastern Mediterranean case study covers prehistoric Chalcolithic society to the end of the, protohistoric, Bronze Age on Cyprus (Steel 2004, p.1). However spirals only appear as a common motif in the Late Cypriot period (Table 4.4).

Period		Date	No. sampled spirals (gold-work spirals in brackets)			
Late Cypriot	IA	1650-1550				
	IB	1550-1450	(26)			
	IIA	1450-1375	(2)		5, (2)	(1)
	IIB	1375-1300				
	IIC	1340/1315-1200		3		
	IIIA	1200-1100				
	IIIB	1100-1050				
Cypro-Geometric	IA	1050-1000	1	2		
	IB	1050-950				
	II	950-900	1		1	
	III	900-750		2	1	
Cypro-Archaic	I	750-600	10	(1)		
	II	600-475				

Table 4.4 Timeline of Cypriot periods (adapted from Kiely n.d.) and the spirals sampled from each.

Two major population movements to Cyprus have been posited within the time period of this study, from Anatolia in the third millennium and from the Aegean in the second millennium, both associated with times of significant cultural change on Cyprus (Steel 2004, p.20).

The Bronze Age on Cyprus represented a period of major population increase, a settled economy and increased arable production with wheat and barley forming the staple crops (Steel 2004, pp.128, 131). By the Late Cypriot period the three cornerstones of the Cypriot economy were agriculture (sheep, goats and cattle predominating), copper production and international trade (Steel 2004, p.158).

By the thirteenth century, a hierarchical social structure was well established with the development from entirely village settlements to larger fort settlements (as possible centres for internal agricultural distribution (Steel 2004, p.152)) and satellite villages and settlement structure; by the Late Cypriot period there was a tendency for settlement sites to move towards the coast and major urban settlements had developed (Steel 2004, pp.129, 149-50, 152, 156). Three lower tiers of settlement developed inland - secondary administrative settlements tertiary settlements and sites showing evidence of craft specialisation (Steel 2004, p.156). The provenanced material used in this case study came from twelve sites summarised in Table 4.5.

Table 4.5 Places of origin of the Cypriot vessels and gold-work from which spirals were sampled.

Site	Type	Period[2]	Economy	External influence	Objects analysed	References
Enkomi	urban walled settlement with wealthy cemetery and religious sanctuaries (one of the earliest urban sites on Cyprus)	settled Middle-Late Cypriot transition	Commercial centre and trading port; secondary copper processing – dominated the copper industry before 1300	mainly Mycenaean imports and local copies of high status pottery often with representational scenes	7 pottery vessels, 29 gold diadems or mouthpieces	Steel (2004, pp.152,156); Collard (2011 p.289); *passim*; SCE website (n.d.); Muhly (1989)
Kouris Valley	encompasses major coastal trading ports including Kourion and Episkopi-Bamboula	settled Middle-Late Cypriot transition (LCIIIB)	Commercial centres and trading ports, secondary copper processing	Direct access to imported goods; settled Mycenaean population producing pottery in local styles but with Mycenaean decoration	1 pottery vessel	Steel (2004, p.156); Karageorgis (1969); Reyes (1994); Muhly (1989); Iacovou (1989)
Idalion	fortified settlement, religious sanctuaries, cemeteries	Settled beginning C16th occupied through to the end of the case study period	copper and later ironworking	indirect probable contact with Enkomi though Hadjicosti suggests possibly a Mycenaean settlement following 13th-12th century migrations	3 pottery vessels	SCE website (n.d.); Hadjicosti (1997)
Ayios Iakovos	religious sanctuaries (BA-IA) and cemeteries (MBA-LBA)	BA-IA, LC	?copper extraction	indirect probable contact with Enkomi	1 pottery vessel	Steel 2004, p.157); Collard (2011, p.217); SCE website (n.d.)

[2] Abbreviations used in this table: LC – Late Cypriot, BA – (Early/Middle/Late)Bronze Age, IA – Iron Age

Site	Type	Period	Economy	External influence	Objects analysed	References
Palaepaphos and Palaepaphos-Skales	Palaepahos urban settlement by 14th-13th century, Palaepaphos-Skales wealthy cemetery	LC/LBA; occupied in C11th; extant by LCIIA continued in occupation throughout the study period	trading port, most important Cypriot trading port by the Cypro-Geometric period	Near Eastern imported pottery, notably little Aegean imported pottery	2 pottery vessels	Steel (2004, p.157); Karageorghis (1983 cited in Popham 1985); Coldstream (1989); Iacovou (1989)
Maroni	Wealthy urban settlement and cemetery by 14th-13th century. Influence diminished due to centralisation of power to coastal cities in LCIII	Occupied by C14th; LCII	Regional centre controlling food production Secondary copper processing. Control of Kalavassos copper mine from LCIIC-LCIII	Staging post for traders from Euboia travelling to the Near East; imports of Aegean and Near Eastern pottery	2 gold mouthpieces	Steel (2004, p.157); Muhly (1989); Reyes (1994); Cadogan (1989)
Aradhippou	Tomb near Klavdia village	Tomb CAI, Klavdia settlement Late Cypriot, continued in occupation throughout study period	Klavdia trading port and access route from coast to centre of island	Egyptian and Aegean imports found from MBA	1 pottery vessel	Kiely (n.d.); Bailey (1969)

Site	Type	Period	Economy	External influence	Objects analysed	References
Episkopi-Bamboula (within Kouris valley)	Settlement site	Late Cypriot (occupation ended in LCIIIA)	Possibly on the transport route for copper from inland mines to the coastal cities		1 pottery vessel	Hadjisavvas (1989); Iacovou (1989); Collard (2011, p.289 *passim*)
Amathus	necropolis	C13th. IA, Cypro Archaic	Trading port	imports of Proto-Geometric and Geometric pottery; Staging post for traders from Euboia travelling to the Near East; possible Assyrian imports in C13th; later Egyptian and Phoenician trade contact	4 pottery vessels	Childs (1997); SCE website (n.d.); Reyes (1994)
Marion	settlement and cemetery, some wealthy tombs	established by Chalcolithic, most archaeological remains date to 7th-4th centuries	Trading port	minimal within period of study but Attic and Cycladic imports in significant quantities in late IA; Mycenaean type tombs	2 pottery vessels	Childs (1997); Coldstream (1989)
Stylli	cemetery	Geometric and Archaic periods	n/a	Phoenician influence	1 pottery vessel	SCE website (n.d.); Winbladh (2007)
Lapithos	wealthy cemetery	cemetery EBA-IA; also Neolithic remains	Copper extraction and trade in region	Mycenaean type tombs; possible Phoenician influence at end of case study period	2 pottery vessels	SCE website (n.d.); Coldstream (1989); Karageorgis (1969); Reyes (1994); Kiely (n.d.)

Although at a key interface between the Near East and Mediterranean Europe, Cyprus remained considerably isolated until the Bronze Age when contacts were initially made with Crete, then Syria, Palestine and southern Anatolia during the Early Cypriot period (Tatton-Brown 1987, p.26). It was only in the early second millennium BCE that Cyprus came to be significantly influenced by contacts with the Near East and Egypt with a variety of prestige goods including pottery imported and exported but the main trade interest is believed to have been in the copper sources on Cyprus which were traded for silver and finished luxury goods (Steel 2004, pp.2, 143-144; Tatton-Brown 1987, p.19). At the end of the Middle Cypriot period, trade in pottery indicates that important contacts with Lower Egypt and the Levant had been established (Steel 2004, pp.17, 154). Trade continued with Egypt and the Levant into the Late Cypriot period and, by the fourteenth to thirteenth centuries Cyprus had established a significant role in Aegean trade networks and was importing and imitating Mycenaean pottery styles (Steel 2004, p.170).

Collard (2011) suggests use of psychoactive drugs in Late Cypriot ritual in the form of opiates also the consumption of alcohol with the intention of inducing hallucinatory experiences for ritual or social purposes. On the basis of vessel shape representing its contents, Collard (p.156) also speculates on the use of mandragora root although this cannot yet be supported by evidence of organic residues. Opium residues have been found in Base Ring ware pottery (Collard 2011, p.137) and the shape of some vessels has been conjectured to resemble poppy heads (Collard 2011, p.138). The typical decoration on Base Ring ware of spirals, wavy lines and concentric arcs (Collard 2011, p.133) could accord with typical EVP forms. Although both alcohol and opiates, consumed in large enough quantities, are hallucinogens, it is not clear, from descriptions by those experiencing the hallucinations, that they induce the type of EVP which are the focus of this research (Collard 2011, p.161; Manford & Andermann 1998). As well as possible hallucinatory effects, as a religious stimulus for the representation of spirals, there is evidence of the worship of horned gods and sacrifice of horned animals. However representation of horns on figurines of gods are not presented as spirals (Steel 2004, p. 175).

Pottery production was introduced in Cyprus in the late Neolithic. Early decorative styles on vessels consisted of incised or painted geometric linear patterning (Tatton-

Brown 1987, p.24). Although floral and representational decoration of vessels was briefly introduced around 1600 in imitation of Near Eastern styles, geometric decoration created using combs or multi-headed brushes remained the most common decorative style on Cypriot pottery until the reintroduction of representational decoration on pottery vessels in the Iron Age (c.1050) again under Near Eastern influence (Tatton-Brown 1987, pp.26, 29).

Production of pottery on Cyprus changed over the period of study from a domestic base in the Middle Cypriot period with regional variation identifiable across the island to specialist centres in the Late Cypriot period which allowed the development of more technically skilled forms of hand-made pottery such as thin-walled Base Ring ware in the Late Cypriot period (Steel 2004, p.163; Tatton-Brown 1987, p.26). Wheel-made pottery was introduced by 1600 and until about 1250 was used to produce imitations of Near Eastern styles which co-existed with local hand-made pottery styles (Tatton-Brown 1987, p.26). In the late thirteenth and early twelfth centuries, refugees or attacking parties from mainland Greece settled in Cyprus following the collapse of the Mycenaean civilization and caused substantial disruption to the previous way of life on Cyprus (Collard 2011, p.32). Following the collapse of Mycenaean production centres, regional demand for Mycenaean pottery styles persisted (Collard 2011, p.33). In response to this, a change to greater mass production occurred around the Late Cypriot IIC period along with the disappearance of traditional styles such as Base Ring ware and of elaborate vessel shapes; standardisation of sizes; poorer quality surface decoration and the gradual dominance of fast-wheel made pottery, particularly White Painted Wheelmade III (Steel 2004, pp.163-165; Collard 2011, p.33; Tatton-Brown 1987, p.27).

Spirals in Ancient Cypriot decorative culture

Imported goods were used as a means of asserting status and foreign motifs copied in locally produced goods (Steel 2004, p.169). The earliest examples of Cypriot spiral decoration found in this study are, however, on Base Ring pottery (Figure 4.14), a style developed locally at the start of the Late Cypriot period which continued into the Late Cypriot IIIA (Steel 2004, p.150, Kling 1991, p.182).

Figure 4.14 Base Ring ware juglet, British Museum, acc. no. 1897,0401.1282.

Although initially relatively uncommon, spiral motifs rapidly became more frequent reflecting the introduction or development of different pottery styles. The appearance of spirals as a common motif may relate to the increasing import of Mycenaean pottery and the status value placed on Aegean iconography around this time (Steel 2004, p.165) although the highest status and most controlled imported pottery types were those featuring pictorial rather than geometric decoration (Steel 2004, p.170-1). A particularly common Mycenaean import was the stirrup jar (Steel 2004, p.170). Locally produced examples of these frequently included spiral motifs. Aegean influence cannot be said to explain fully the use of spiral decoration. Between approximately the fifteenth and ninth centuries most spiral decoration is found on White Painted Wheelmade III pottery (Figure 4.15). This style group of locally-made pottery is based on the technical structure of the vessels rather that the cultural influences on them. Its creation acknowledged the difficulties in Cyprus of creating type groups in the face of merging local, Aegean and Near Eastern influences in both vessel shape and decoration (Kling 1991, p.182).

Figure 4.15 White Painted Wheelmade III bowl, British Museum acc. no. 1896,0201.3.

The majority of analysed examples of spiral decoration on pottery were from the Cypro-Geometric and early Cypro-Archaic period appeared on Black-on-red ware (Figure 4.16a) with a few examples also found on Bichrome ware (Figure 4.16b), which had a Syro-Palestinian origin (Tatton-Brown 1987, p.29) (Appendix 2, Table A2.5). Black-on-red ware was constructed using a technique of Phoenician origin although Phoenician vessels tended to use only concentric circle decoration (Coldstream 2003, p.44).


a.


b.

Figure 4.16a. Black-on-red ware jug, Medelhavsmuseet, acc.no. MM1997:003. b. Bichrome ware amphora, Medelhavsmuseet, acc.no. MM acc 0699.

The Cypro-Geometric decorative style provides prime examples of the ambiguous concentric circle/spiral motifs discussed in Chapter 2 and the occurrence of spirals on pottery decoration from this period may reflect a mechanically convenient means of creating decoration which was meant to be interpreted as the, more common, concentric circle motif. It is possible that the multi-headed compass which is believed to have been used in the creation of smaller concentric circle decoration (Eiteljorg 1980) slipped during the drawing of lines and that their spiral nature is coincidental. Without surviving compasses having been discovered it is not possible to tell whether slipping in this manner would have been possible or likely. None of the instances of Cypro-Geometric spiral decoration seen in this research show signs of a break in curve or sudden change in curvature which might indicate a slip or a painter making the best of a mistake. From this period, spirals are most common as large motifs on opposite sides of stirrup jugs or around the centre of dishes and bowls. Multi-headed compasses would be difficult to operate on the highly curved sides of some jugs and flasks (Figure 4.17). If spirals were created whilst the vessel was turned on a wheel, as concentric circle motifs were on Greek Geometric vessels (Murray 1978, p.83), a spiral form would be easier to create using the natural tendency for the brush to drift down the curved side. Similarly, pottery decoration in the centre of dishes and bowls might have been created more easily on a wheel by moving the brush radially outwards as the wheel turned than by holding steady a multi-headed compass which would have required a high number of brush heads and a relatively large diameter.

Figure 4.17 End and profile view of a base ring ware jug with spiral decoration over a highly curved surface, British Museum acc.no.1876,0909.72.

A second set of data used in this case study was drawn from gold diadems and mouthpieces from tombs at Enkomi and Maroni. In the Late Bronze Age, a reliable source of gold was established through trade with Syria and Egypt (Tatton-Brown 1987, p.42). Gold was worked into rolled strip wire or with repoussé or stamped decoration on gold sheet (Tatton-Brown 1987, p.43). The spirals on Cypriot goldwork show great uniformity. The large majority are dense coils linked in pairs most of which were created as stamped motifs. The similarity between motifs suggests that each single punch head depicted a pair of spirals (Figure 4.18a). Only two examples show sufficient variability in motifs to suggest that they may have been created freehand (Figure 4.18b and c).

a.


b.

c.

Figure 4.18a. Stamped motifs on a diadem 1897,0401.272. b and c. Possible freehand motifs on a mouthpiece and a diadem 1897,0401.517 and 1897,0401.269. All from Enkomi. British Museum.

The majority of spiral decoration on the Cypriot pottery vessels has no identified representational or symbolic significance. The few exceptions of known representational function depicted a lotus flower (Figure 4.19b), and an unidentified, presumed land plant (Figure 4.19a). Only one item of goldwork had an apparently representational meaning (Figure 4.18b) showing a probable land plant.

a. 

b. 

Figure 4.19 Detail from vessels showing spiral plant representations, Medelhavsmuseet, acc. nos. E.003:261 and NM Ant 1719.

An upper date limit of 600BCE was imposed on the collection of data because the inclusion of a larger geographical range of case studies had initially been envisaged and, in most cases this date made a convenient cultural break. Within the Cypriot case study, this choice of date was less appropriate as it cut across the Cypro-Archaic period and the style of regular spiral decoration on pottery continued in use to a significant extent after this point.

The spiral motifs on pottery sampled in this case study were drawn from 12 types of vessels with distributions given below.

krater	4
plate/dish	3
bowl	11
kylix	1
barrel jug	2
amphora	2
jug	3
flask	1
cup	1
carinated cup	1
bottle	1
pyxis	1

Table 4.6 Cypriot vessel types from which spirals were sampled.

The spirals sampled from pottery were generally in a good state of preservation although the earlier material dating to Late Cypriot I and II tended to be in poorer condition; 13 spirals included sections of interpolation with a maximum interpolation length for a single spiral being 19%. Of the sampled pottery vessels, six lacked a precise place of origin and two could only be broadly dated to within the study period. The distortion caused by curvature of vessel walls prevented the analysis of spirals on 21 pottery vessels and particularly affected the earlier examples of spiral decoration from the Late Cypriot II period. The diadems and mouthpieces showed generally poorer preservation, with 37 of the sampled spirals having some degree of interpolation to a maximum of 31%. The mouthpieces and diadems sampled in this case study show a lack of diversity in sampling, with all but one example having been excavated at Enkomi. This lack of diversity reflects the data available from the museum collections surveyed. Of the sampled mouthpieces and diadems, one had no precise provenance and a second example lacked a defined place of origin.

4.4 Summary

The case studies chosen for this research were selected as examples of regions which showed a sequence of cultures with high prevalence of spirals running from the Neolithic into the Bronze Age in the eastern Mediterranean and East Asia. This allowed for some assessment of internal continuity and potential cultural transmission within each of the case study clusters. The eastern Mediterranean and East Asian study areas, appear to have had, at most, minimal and indirect contact. Comparisons were made between the two groups to assess whether cultural distinctions can be drawn and whether similarities can be found supporting the idea of a common response to a common natural stimulus when the cultural input to the development of decorative styles might be expected to be quite different.

5 Testing and evaluation of the classification method

The first stage in considering the results of this research compared the proposed method with an existing classification system based on mathematical spiral forms, assessing the principles which underlie the creation of the class groups and the visual coherence of the class groups created by correlation to mathematical spirals and cluster analysis of the form and style variables used in the newly proposed method.

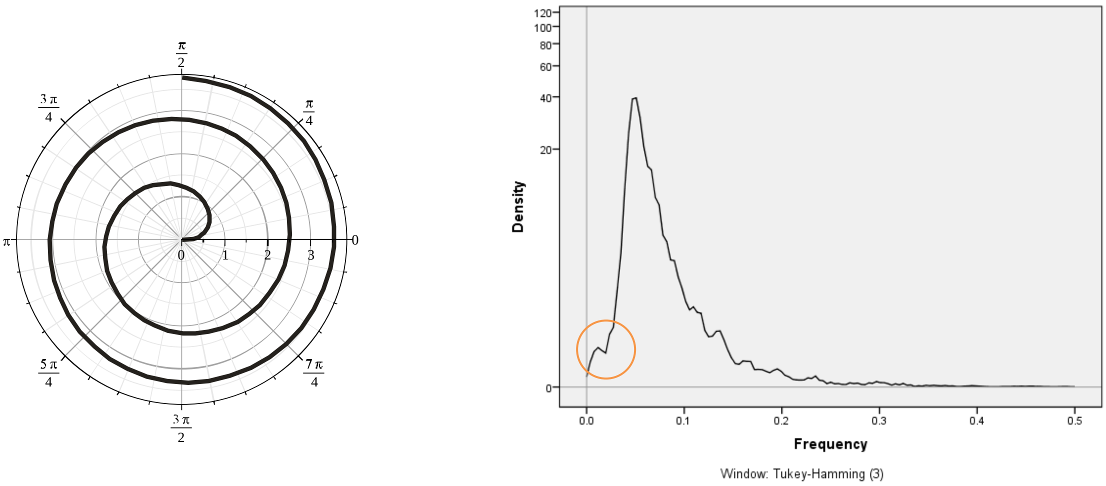
The effectiveness of the method in application is considered in addressing the final three research questions. Application to case study data tested whether it is possible to use this method to distinguish between the spiral decoration of different cultures. The case study data were then turned to address the opposite questions of whether commonalities could be identified which crossed cultural boundaries and which might be attributed to a known natural origin in either substantive forms or disturbances of the visual system.

As a final stage, in assessing the results of this research, an evaluation of the proposed analysis method is required; whether it is effective in discriminating between spiral motifs; whether there are systematic problems in the current implementation of the method which may have affected its application to the test case studies; and how precision and accuracy might be improved. Beyond the basic working of the method, it needs to be shown that such a method is of practical use and is reliable and could be used to classify the full breadth of variation seen in decorative spiral motifs.

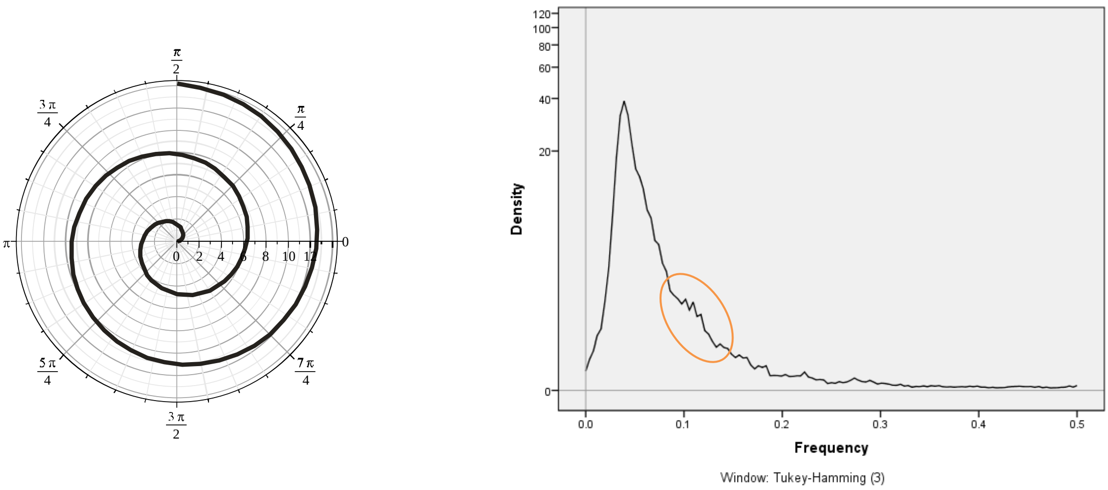
5.1 Comparison of method with fitting to mathematical spirals as a classification technique

As an initial test of the viability of the established approach of making reference to mathematical spiral types in classifying decorative spirals, the spectrum density plots of the five template spirals (Figure 5.1) were correlated with each other, using two-tailed Pearson correlation, to test whether there was sufficient difference between the types to make the distinction of separate decorative classes viable given that the majority of decorative spirals do not match perfectly any mathematical spiral curve. Two pairs of template spirals showed significant positive cross correlations – parabolic and Archimedes' spirals had a correlation of 0.912 and logarithmic and hyperbolic spirals had a correlation of 0.997. The high values of both these correlations suggest that in the case studies used in this research, and probably in the majority of historic or prehistoric cases, many decorative spirals will share a high correlation with both spirals in these pairs. Division of parabolic from Archimedes' spiral and, particularly of logarithmic and hyperbolic spirals may not be appropriate. For comparison tests, the five spiral types were retained as separate divisions since that has been the norm in previous studies using mathematical spirals as classification groups.

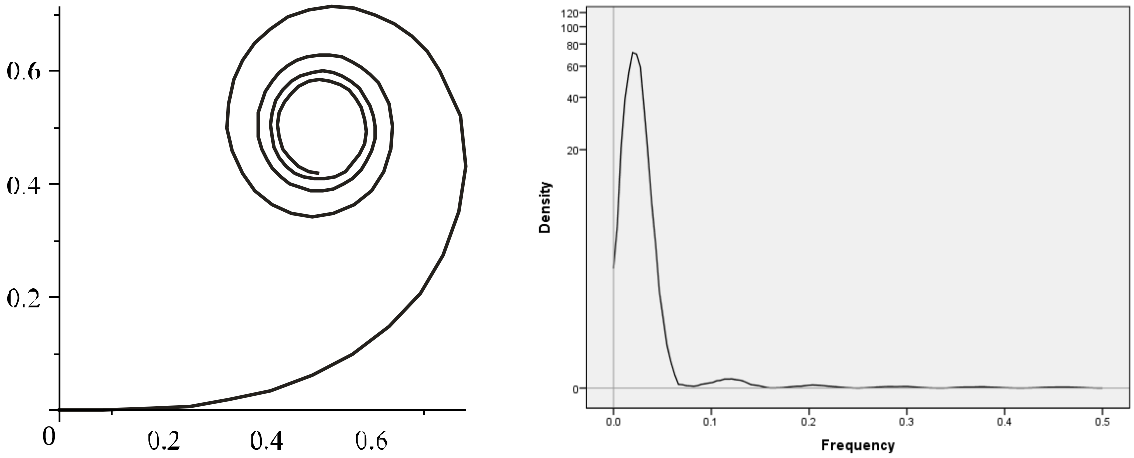
Figure 5.1 Mathematical template spirals and their spectral density plots: a. parabolic b. Archimedes'. c. Euler. d. logarithmic. e. hyperbolic. Orange circles indicate the characteristic secondary signal peaks characteristic of the mathematical spiral forms (see section 5.5.6). (Figure runs over two pages.)



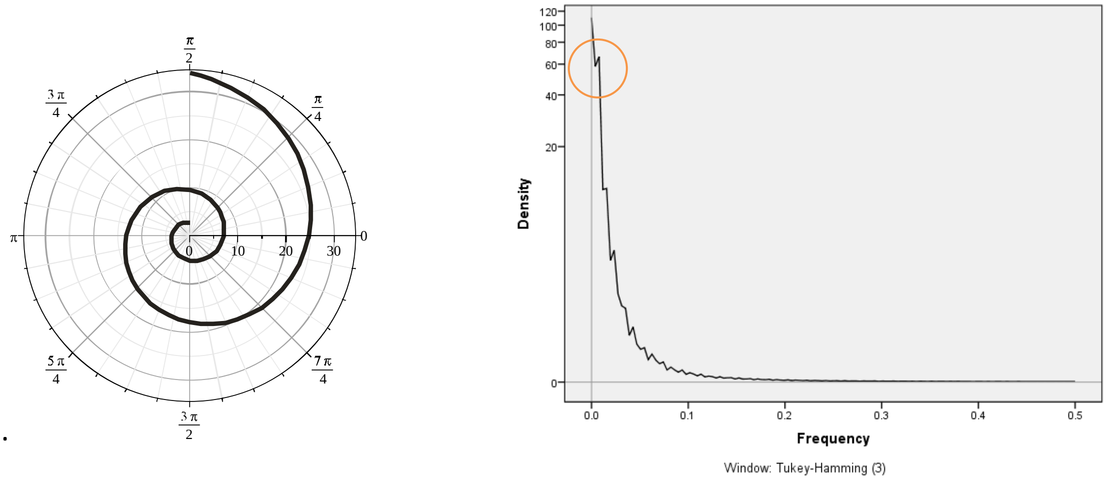
a.



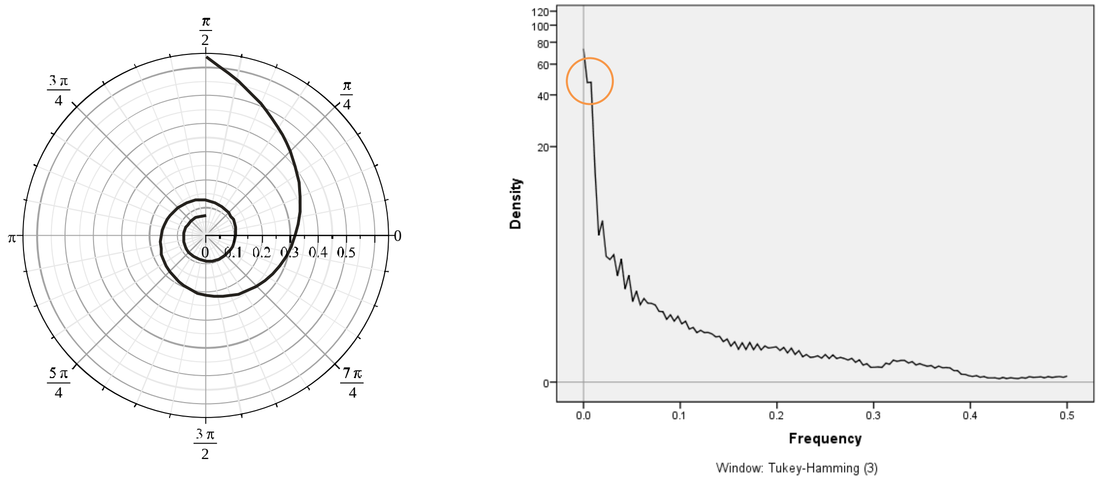
b.



c.



d.



e.

All decorative spirals had a significant correlation of at least 0.5 with at least one of the mathematical template spirals. Spirals which showed the lowest correlations tended to register similar correlations with two template spirals suggesting that they include characteristics of more than one mathematical form. Spirals were placed into mathematical classes according to the template type with which they showed the highest correlation (Appendix 2, Tables A2.7-10).

Although the logarithmic and hyperbolic type groups could not be reliably separated, it is interesting that a significant majority ($p<0.00$ for each case study) of the spirals in this group tended to resemble most strongly the hyperbolic examples. This may reflect a genuine tendency to intentionally reproduce hyperbolic forms but it may, alternatively, reflect a difficulty in drawing a regular logarithmic spiral. The idea that the spirals in the hyperbolic/logarithmic group may have been intended to replicate logarithmic rather than a hyperbolic form is supported by the presence of all the known representational plant, horn and reptile tail depictions which, in real examples, all approximate logarithmic forms. In attempting to draw a logarithmic spiral, there is a tendency to use the previous rotation as a guide to drawing the next. This creates a spiral with a relatively low expansion rate in the centre, then a relatively sudden increase to resemble a logarithmic form, but in a mathematical sense, more closely fitting a hyperbolic form. All of the decorative spirals known to depict logarithmic forms fell into the logarithmic/hyperbolic group, so this classification can be said to be valid. However, the size of the hyperbolic/logarithmic group raises difficulties with using this type as a decorative class. Among the set classified as hyperbolic, those with a lower correlation end would not be assessed visually as hyperbolic, so assigning decorative groups on this basis would only be effective if a minimum correlation value were applied. This approach would leave some spirals unclassified.

Decorative spirals which visually resemble Archimedes' spirals mostly fell into the mathematical spiral class of Euler spirals. None of the Shang/Western Zhou Dynasty spirals which appear to resemble an Archimedes' form were classified as such. The only examples which were classified as Archimedes' types were those from the Cypriot case study with greatest rotational length. The gradual decline in spectrum density frequency peaks of some of the angular Shang/Western Zhou spirals more resembled Archimedes' than Euler forms. However, the failure to match the position of the maximum peak, which is raised with an increasing number of rotations, exerted a strong countering influence and caused the spirals to be classified as Euler. The Cypriot Archimedes' spiral-resembling motifs assigned to both the Euler and Archimedes' type groups were similarly defined by the frequency of the maximum peak rather than the shape of the subsequent signal. Spirals in the Cypriot study which were linked to other spirals in S or C-coils also fell into the Euler group. This does match the visual impression of these spirals relatively accurately.

A problem in the use of mathematical definitions is highlighted in the correlation of the triangular spiral CSBM15.2 (Figure 5.2) to mathematical spiral forms in that the aspects of spiral form which are mathematically important do not necessarily accord with those that are visually important. The property emphasised in the classification of a regular expansion rate caused the spiral to have a correlation to an Euler spiral of 0.645 setting aside the more perceptually important property of its triangular shape which causes it to bear little visual resemblance to any mathematical spiral.

Figure 5.2 Concave triangular spiral CSBM15.2.

No spirals from any of the case studies correlated most strongly with parabolic spirals. This agrees with the visual impression of the spirals, none of which showed a consistently decreasing trend in expansion rate.

Within each case study culture, both grouping based on mathematical spirals and by cluster analysis were effective at bringing together the spirals known to be of representational origin. The cluster based method missed more representational spirals from the classes in which representational spirals dominated but the mathematical grouping drew more non-representational spirals into the same group with the representational spirals. The same tendency of over-separating or over-grouping is found with visual distinctions of spirals. For example, the separation in clustering of the, visually similar, classes 4 and 5 of the Shang/Western Zhou Dynasty spirals (Appendix 2 Table A2.12). The grouping based on mathematical spirals links these but places the majority of angular spirals used as background decoration on vessels in the same class as the representational motifs whereas clustering separates most of these into class 1. For most case studies there is a high degree of homogeneity and variation is continuous so it is difficult to make class divisions. This raises the question of whether is appropriate to attempt to assign groups at all. Zhushchikhovskaya and Danilova (2008) who use mathematical spirals as a means of grouping note that some spirals fall between groups and it may be more appropriate to regard many of the motifs as being on a continuum of change. Although clustering and discriminant analysis rely on the creation of separated classes, they are better suited to the assessment of continuous variation than the use of mathematical spiral classes since they assign a rank order of similarity which runs across the class divisions but still also allow spiral shape classes which are truly separated to be identified.

Across cultures where no clear link or contact can be established, high numbers of spirals correlate with a hyperbolic/logarithmic form. The common natural occurrence of logarithmic forms (Kappraff 1992) suggests that reference to spirals found in the natural environment may have guided these cultures and that abstraction of these falls within limited form boundaries. To establish clearly the consistent link between known representational spirals and a form resembling a logarithmic or hyperbolic spiral, measurement of resemblance to the mathematical spiral type by correlation of spectral densities or by another method which provides a quantified indicator is preferable to assigning spirals to mathematical classes based on visual impression. A quantified similarity strengthens the argument for an objective link between representational forms and logarithmic spirals and makes identifying a common underlying principle between cultures easier.

The objection in this thesis to the use of mathematical spirals as classification groups is largely methodological. Such classifications assume absolute boundaries rather than a continuum of variation and, as such, will be compelled to include forms that bear little or no visual resemblance to the mathematical spiral form or an arbitrary cut off of correlation must be imposed so that these mathematical classes do not encompass all the spirals present in the culture and would have to be combined with non-mathematically based class groups. Also mathematical spiral definitions do not necessarily reflect visually important properties of spirals. When visual assessment of the mathematical type of spirals is inaccurate, as it is bound to be, given the close correlation of some spiral forms, the use of mathematical terminology misrepresents the form of the spiral. In contemporary culture where digital arts allow much more precise construction of decorative spirals or where a mechanical, or a ruler and compass based means of laying out a decorative spiral were frequently used in the decorative scheme of a culture a closer accord might be found to a mathematical curve and the use of mathematical terminology might provide a relevant description of spiral form. Without clear evidence of a mathematical basis having been employed in the construction of decorative spirals it is argued that mathematical classes are inappropriate.

5.2 Results of the application of the method to test case studies

For each case study, the spirals were clustered based on their visual properties to identify whether significantly differentiated type classes of spiral motif could be identified within each culture. Discriminant analysis was carried out on the clusters to identify the variables which were important in dividing them, taking a minimum factor loading of magnitude 0.3 to identify significant variables. Finally, the data from all four case studies were pooled and a differentiation analysis carried out to see if the individual cultures could be distinguished from each other. The relevance to grouping of the contextual attributes across the entire sample was also tested.

5.2.1 Jōmon Period case study

The Jōmon spirals were clustered into five classes (Appendix 2, Table A2.11). The fifth class only contained a single spiral which was clustered with the remaining spirals at the highest level of differentiation and was shown to be highly separated from the other groups in discrimination analysis. This spiral had the highest rotational length of any in the sample and it was probably this that caused its strong separation because of the effect of rotational length on the form variables. For this reason, the spiral was treated as an outlier and excluded from discrimination analysis although it was included in the assessment of the distribution of individual style variables.

Discriminant analysis identified the form correlation with four spirals, JKAN13.1[1] and JKAN2.1 (Figure 5.3) as required variables for separating the classes although the eigenvalues of both factors were relatively low (9.485 on function 1 and 3.485 on function 2) so these correlations did not fully explain variation.

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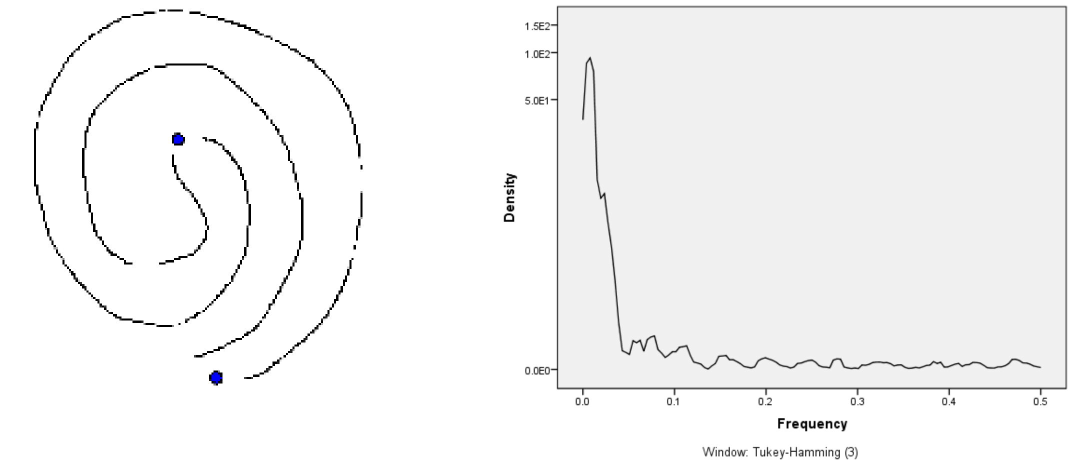
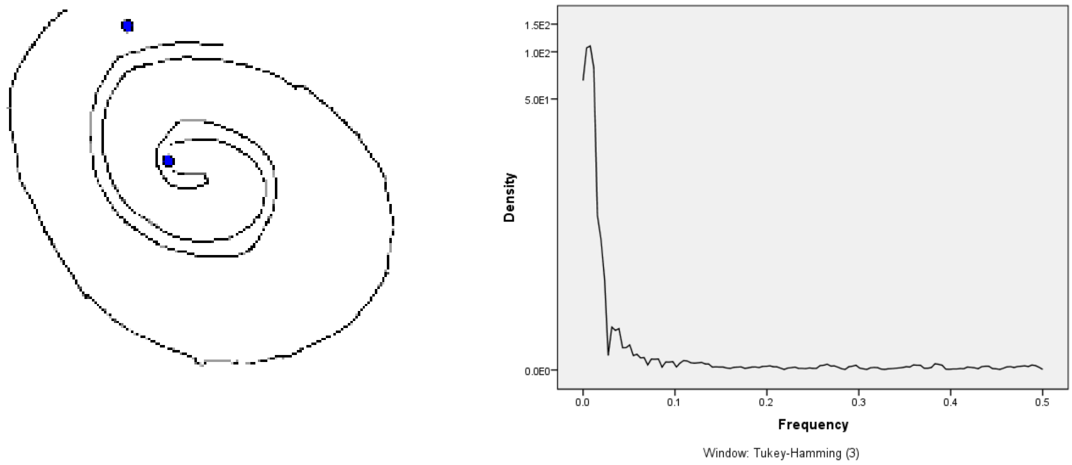
[1] Spirals from the four case studies were assigned codes with the prefix J for the Jōmon study, CS for the Shang/Western Zhou study, EG for the Egyptian study and CY for the Cypriot study.

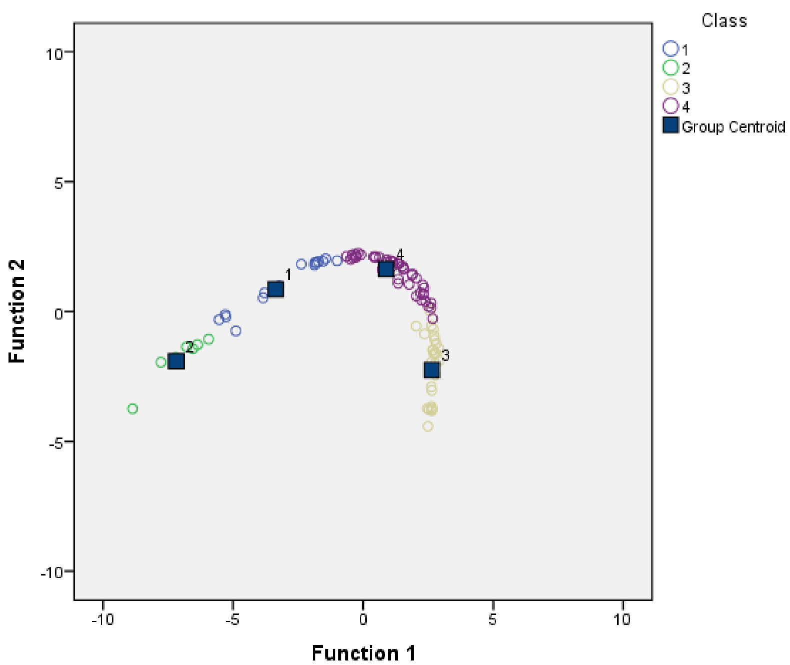


a.



b.

Figure 5.3 Form correlation spirals and spectra. a. JKAN13.1. b. JKAN2.1.



	Function 1	Function 2
JKAN13.1	0.445	0.896
JKAN2.1	0.74	0.997

Figure 5.4 Distribution of clustering classes and variable loadings on the first two discriminant functions for the Jōmon case study.

Discrimination showed poor separation of the classes identified (Figure 5.4). Function one is most strongly identified by positive correlation with JKAN2.1 with JKAN13.1 operating more weakly. The two spiral form spectra are similar, JKAN13.1 has a more pronounced secondary peak associated with an increasing expansion rate at the outermost end whereas JKAN2.1 shows a gradual decline in signal peaks more associated with a constant expansion rate. Visually, the strongest division is between the pair of classes 3 with 4, and 1 with 2 (see Table A2.5). Classes 3 and 4 are visually dissimilar from the spirals used in discrimination and show a negative value on function one. These classes consisted of spirals of very low rotation or those with a very high increase in expansion rate. All spirals of known representational form from vessels are included in these two classes. These were all representations of snakes. However, the headdress spirals on dogū, which have also been suggested to represent snake forms, more frequently fell into the first two classes. On the strength of this, discriminant analysis was used to test whether spiral motifs on vessels differed as a group from those on dogū. This did not yield a significantly different mean on any variable.

Most of the spirals in the first two classes were of relatively high rotational length with a low spacing and constant path width and expansion rate. This group tends to encompass small decorative motifs on the vessels and the majority of the dogū motifs. Function two (Figure 5.4) separates spirals in classes 1 and 4 from classes 2 and 3. The spirals with a high positive value on the second function in classes 1 and 4 showed the sudden drop in density signal to almost zero, which is characteristic of rotational lengths below two full rotations. Given the lack of separation amongst the spiral groups it seems more appropriate to view these spirals as being on a continuum of variation across the four classes. The order of the classes in the discriminant analysis was changed from that in clustering with the low rotation spirals in classes 1 and 4 drawn together at the centre of the continuum; short smooth spirals of low expansion rate at one end of the range; and the shortest spirals with a very high expansion rate, at the other. On the basis of this continuum, the single class 5 spiral was placed as an outlier beyond the class 1 spirals.

Discriminant analysis based on the separation of the motifs into Early, Middle and Late Jōmon periods operated on the form correlations of spiral JKAE19.1 (Figure 5.5) and the first coefficient of spacing trend. With only three objects, the Early Jōmon sample was too small to draw any effective conclusions about grouping. Eigenvalues of both discriminant functions were very low 0.564 for function one and 0.040 for function two. On neither function were any of the periods separated effectively (Figure 5.6).

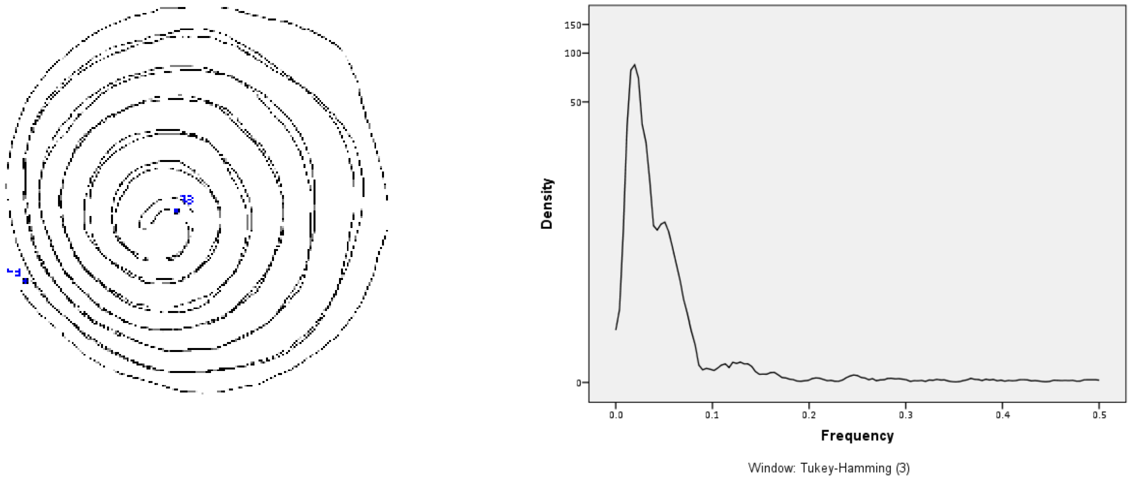
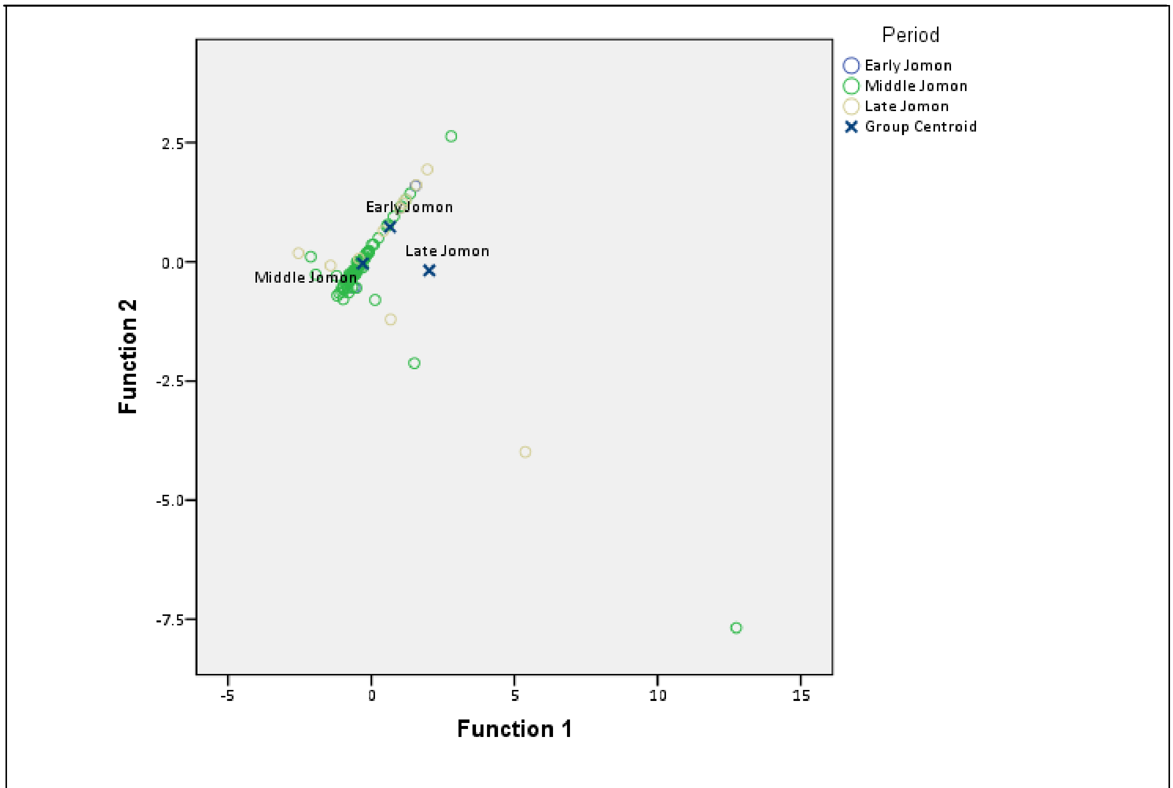


Figure 5.5 Spiral JKAE19.1 and its density spectrum.



	Function 1	Function 2
JKAE19.1	0.474	0.881
Spacing trend 1	0.643	-.766

Figure 5.6 Jōmon chronological period discrimination and loading on the discriminant functions.

Discriminant analysis applied to spirals to distinguish between modelled and incised decoration did not yield a significantly different mean value on any variable. Both Middle and Late Jōmon clusters showed similar variance on both functions and Early Jōmon spirals fell within the range covered by both groups. Both Middle and Late Jōmon groups included outliers on function two. Differences are marked between the Jōmon chronological periods in pottery decorative styles and techniques (Kaner 2009, p.18; Kidder & Esaka 1968) but there is no indication that it is possible to separate the spirals according to cultural period. Zhushchikhovskaya and Danilova (2008) analysed Jōmon pottery. Using visual assessment they identified both logarithmic and Archimedes' spirals amongst the Middle Jōmon examples the opposing loadings on the spacing variable would not contradict this indicating the presence of spirals with high and low expansion rates. Zhushchikhovskaya and Danilova found organised orientation in Middle Jōmon vessels with horizontal banded decoration. This characteristic could not be identified in the Middle Jōmon sample used in this case study either taking the sample as a whole or assessing only those vessels with horizontal banded decoration. Sample size was very small, only eight spirals from vessels with horizontal banded decoration were included in this case study. The Late Jōmon sample were not compared with the findings of Zhushchikhovskaya and Danilova because no vessels were sampled from that period in this study so like with like comparison could not be made.

5.2.2 Shang Dynasty and Western Zhou Period case study

Of the four case studies, the Shang/Western Zhou study had the greatest number of spirals with known representational meaning. This was the only study in which the classes generated in clustering could be seen to differentiate between representational forms. The spirals were clustered into five classes (Appendix 2, Table A2.12). Classes 2 and 3 contained 22 of the 30 representations associated with mythical creatures in the form of tails, horns, whiskers, ears, nostrils and decoration on the face of *taotie*; the remainder fell into class 1. Classes 4 and 5 separated out all but one of the snake representations; the exception, CSBM15.1 (Figure 5.7) fell into class 3. Curiously, this exception resembled the Jōmon snake depictions in having a divided tail, a feature not present in any of the other Shang/Western Zhou snake depictions. Clustering of this spiral with the other snake representations put it with the Jōmon and Egyptian snakes separately from the two Western Zhou Period snakes but, as is discussed below, these two snakes are outliers from the whole case study sample.

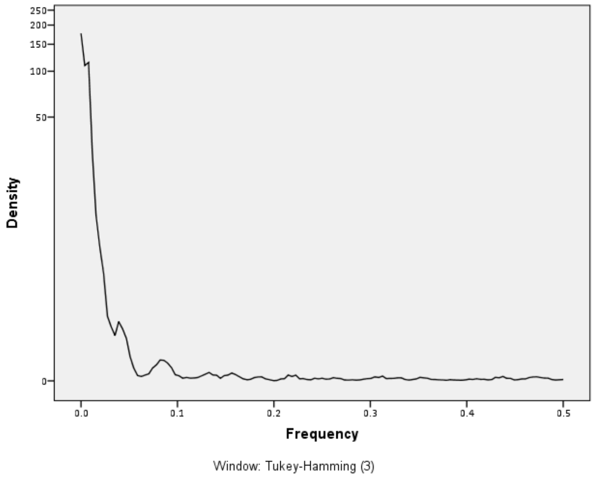
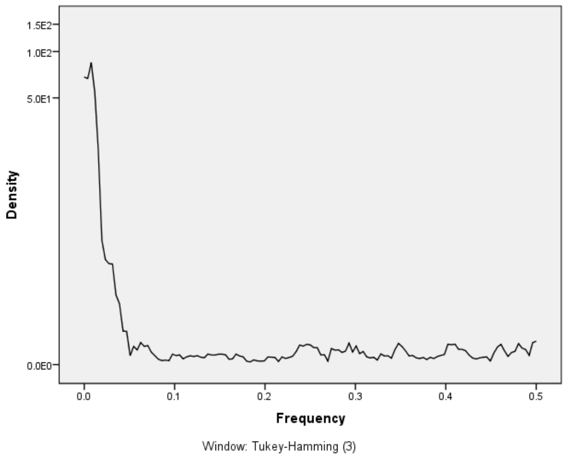


Figure 5.7 Spiral CSBM15.1 and its spectrum density plot.

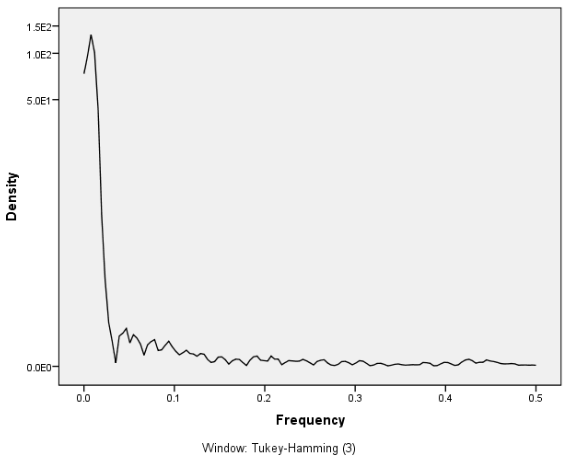
Discriminant analysis identified the form correlations of three spirals as being suitable to separate the clusters – CSVAM8.1, CSBM12.84 and CSVAM3.1 (Figure 5.8).

Figure 5.8 Below. Differentiating spirals and their density spectra. a. CSVAM8.1. b. CSBM12.84. c. CSVAM3.1

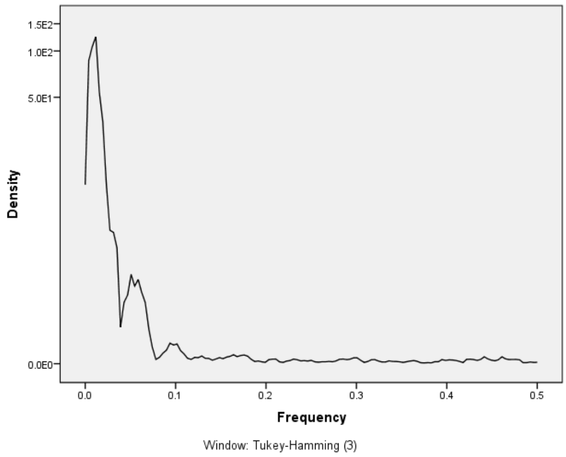
a. 



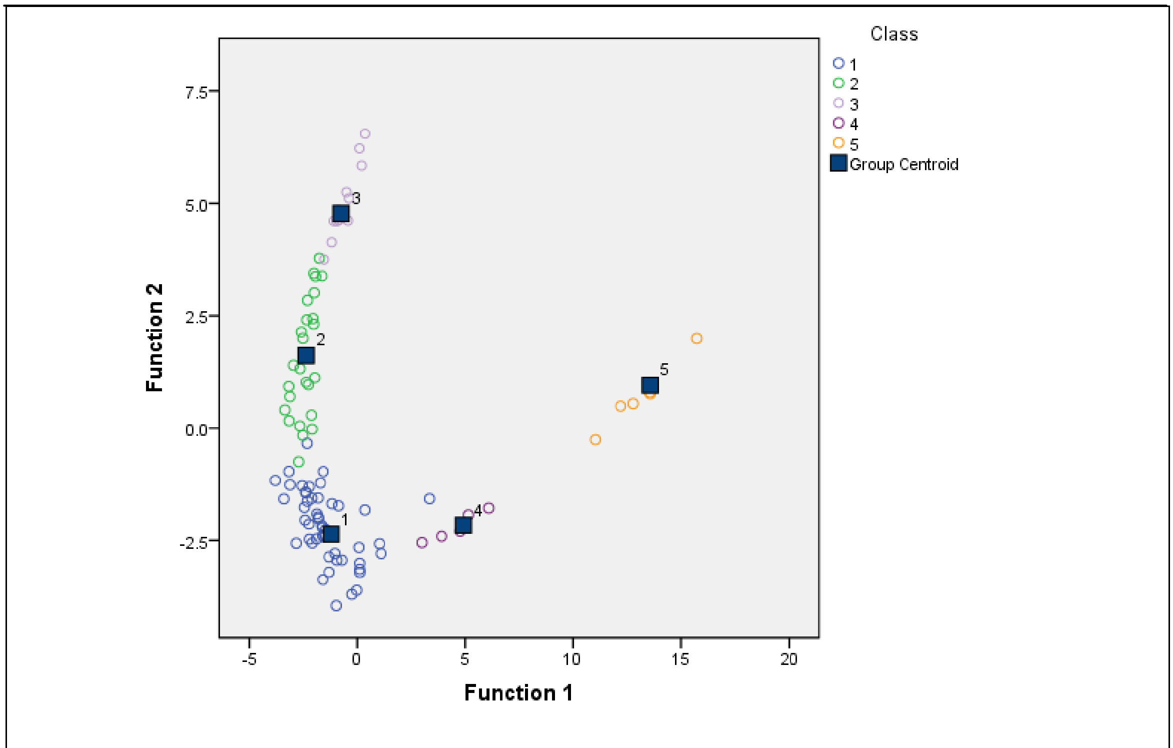
b. 



c. 



The first two discriminant functions encompassed 87.6% of variance. The spirals of class 1 clustered with classes 2 and 3 on function one (eigenvalue 20.307) (Figure 5.9).



	Function 1	Function 2
CSVAM8.1	-0.846	0.232
CSBM12.84	-0.819	-0.263
CSVAM3.1	-0.200	-0.912

Figure 5.9 Distribution of the clustering classes and variable loadings on the first two discriminant functions, Shang Dynasty and Western Zhou Period.

This function was characterised by two representational spirals, depicting a horn and a tail. Both spirals showed an increasing expansion rate and represent the two types of expansion typically found in depictions of objective natural forms – dense low expansion curvature followed by a sudden expansion in CSBM12.84 and a more constant increase in CSVAM8.1. These are the typical form patterns of the class 2 and 3 spirals. The similarity of class 1 to classes 2 and 3 on this function is more difficult to explain given the constant and low expansion rate of most of the spirals in this class, it may be a result of a common frequency peak around 0.02 arising from the angular nature of CSVAM8.1 and the angular spirals in the class. This effect also explains the inclusion of especially oblong or rhombic angular spirals which do not have a representational interpretation in class 3. Classes 4 and 5, consisting of spirals with a constant expansion rate and high rotational length, are the most strongly segregated by function one. Most of the spirals they contain are Late Shang Dynasty or Western Zhou Period. This clustering result may have been skewed by the inclusion of the Western Zhou Period vessel CSBM17, which represents an unusual regional style variation (Rawson 1987, cat. no.27). Cluster formation may have drawn spirals into this group which would otherwise fit relatively well into the main groups.

Class 1 is best characterised visually as containing angular spirals, most of which have a constant expansion rate although some spirals of increasing expansion rate explain the wide spread of values over function two (eigenvalue of 6.297). Class 4 overlaps with class 1 on this function. Spirals in this class match the quadrilateral shape of CSVAM3.1 and have a relatively lower rotational length than those in class 5, explaining the distinction on this function. Classes 2 and 5, which overlap, and class 3 are increasingly distinct from CSVAM3.1 according to their increasing expansion rate and decreasing rotational length.

Examination of individual variables of style showed that orientation had a significantly non-random ($p<.000$), bimodal distribution (Figure 5.10). It is likely that this arises from the higher number of triangular and quadrilateral spirals in the Shang Dynasty sample. These tend to be aligned parallel to the top of the vessel but to have a slight rhombic skew causing the two peaks in the maximum diameter depending on whether they are skewed to the right or left. Loehr (1953) noted that the *leiwen* ground-covering spirals which make up the majority of the angular spiral sample were an important feature of his style types four and five. The high numbers of these spirals on vessels means that they are likely to be strongly represented in a random sample.

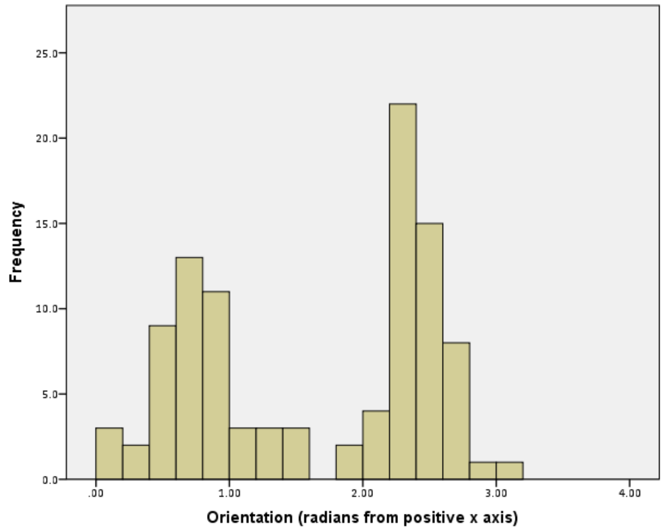


Figure 5.10 Shang Dynasty/Western Zhou Period orientation bimodality.

The Western Zhou Period sample group did not form a significant separation from the Shang Dynasty vessels sampled on the mean value of any variable. There is considerable stylistic continuity between the two periods (Chang 1980, p.21) and the spirals from each period cannot be visually separated.

5.2.3 Middle Kingdom Egyptian case study

This case study was separated by clustering into five classes (Appendix 2, Table A2.13) but the spiral decoration does not show strong separation into class groups. Only classes 4 and 5 appear visually distinct in containing more rounded spiral forms with a greater rotational length than those in the other classes. The same lack of separation was reflected in discriminant analysis. The spirals were divided according to form correlations with spirals EGBM3.3 and EGPET1.5 (Figure 5.11) on the first two functions which cover 91% of the variance. Function one, with an eigenvalue of 18.604, was strongly loaded by positive correlations to the spiral forms (Figure 5.12). Function two with an eigenvalue of 7.392 much less so.

a.

b.

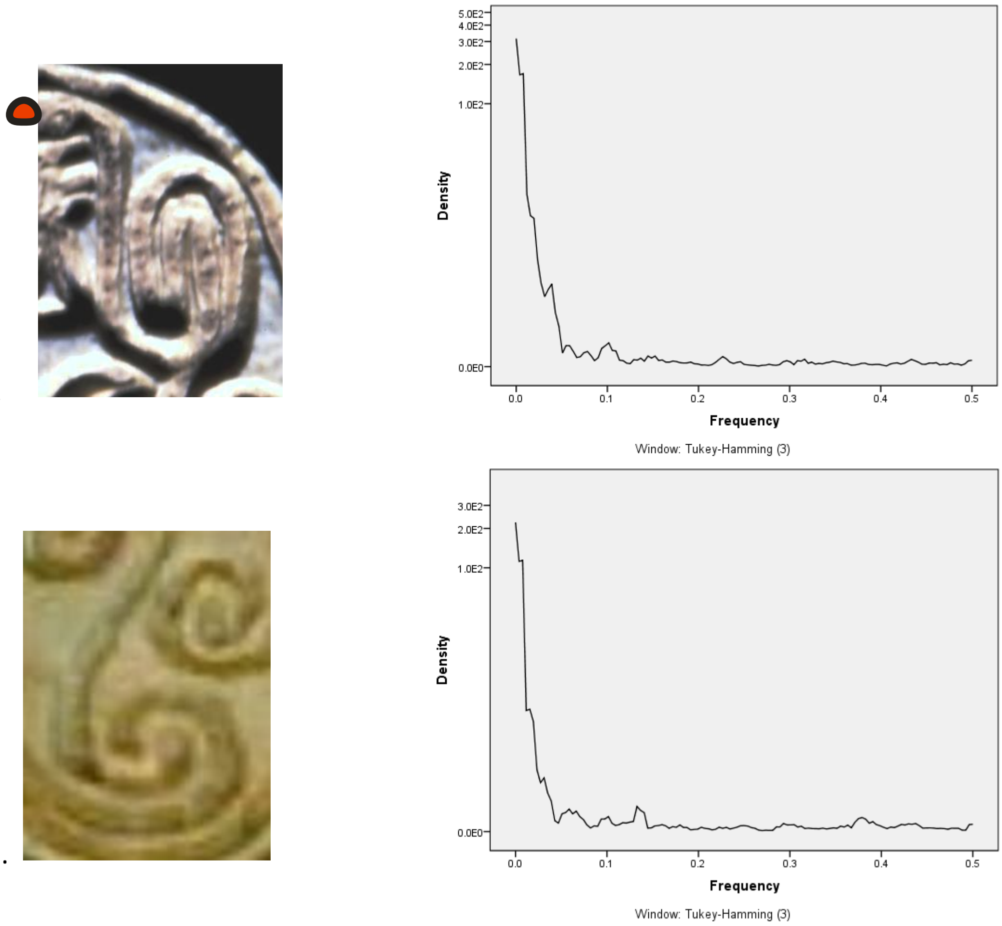
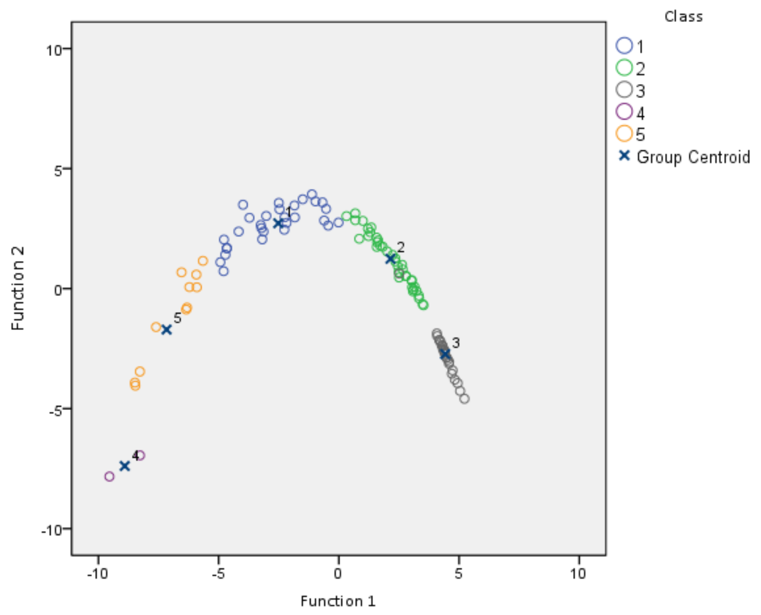


Figure 5.11 Differentiating spirals with their density spectra. a. EGBM3.3 (marked with a red dot) British Museum acc.no. 1960, 0514.53. b.EGPET1.5 ©Petrie Museum of Egyptology University College London, acc.no. UC11131.

The third variable, median path width, is characterised by the third function (eigenvalue 0.228) and separates class 3 spirals from the other groups which show little variation on the median path width. All five clusters show separation on the first function, the second differentiates the spirals into three clusters made up of class 4; classes 5 and 3 together; and classes 1 and 2 together.



	Function 1	Function 2
EGBM3.3	0.928	0.373
EGPET1.5	0.939	0.343
path width median	0.058	-0.080

Figure 5.12 Scatter plot of spiral classes and variable loadings on the first two discriminating functions, Middle Kingdom Egypt.

One extreme of difference on the first function is represented by class 2 which is made up of spiraloid or barely spiral hooks. Most of these have a relatively high expansion rate and spacing because they form a centrally linked interrelationship with another spiral so the expansion needs to accommodate a second coil. At the opposite extreme classes 4 and 5 are those with the strongest visual difference from the other classes. Classes 4 and 5 include spirals from representational depictions of plants and those which form final motifs in running lines of spirals decorating the entire scarab face. Since these fall at the end of the chain they do not link with any other spiral. They are mostly single spirals with a longer rotation and a low expansion rate.

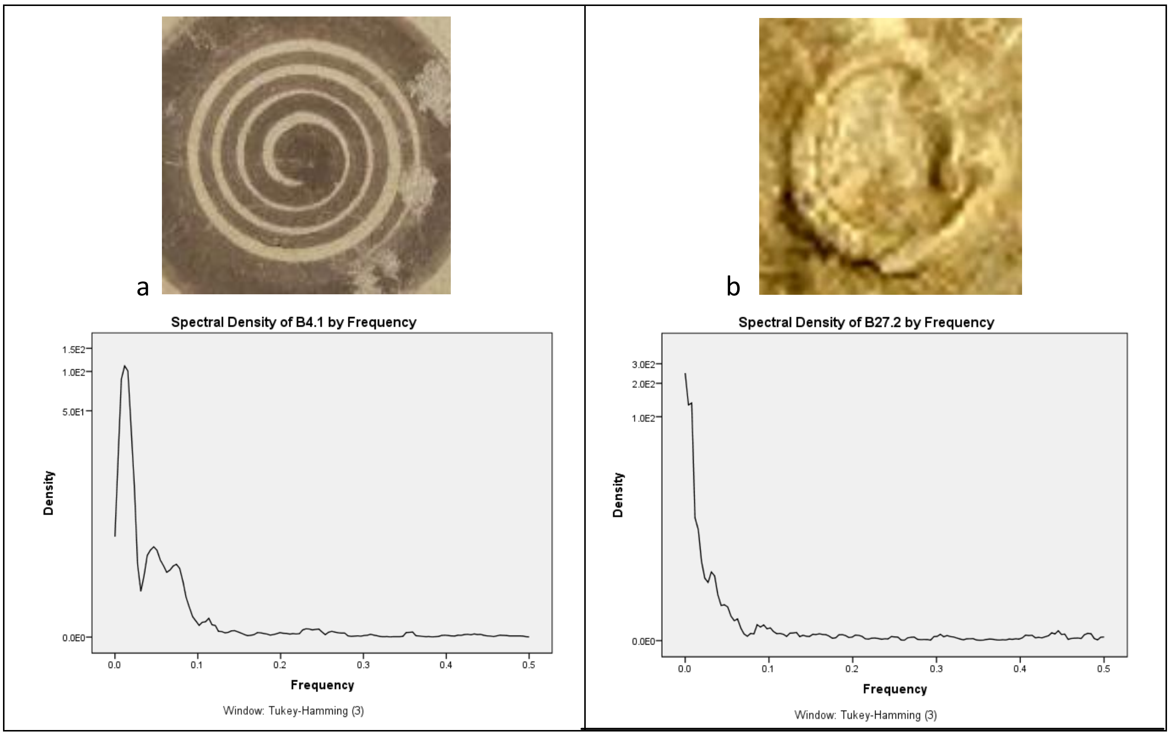
Representational spirals are spread across the class groups. The spectrum density frequency which represents an elliptical tendency in spirals is closely merged into the main density peak of elliptical spirals. Because of this, the visual difference between the elliptical spirals which form running borders and the more circular spirals or spiraloids which are more commonly part of all over linked spiral decorative patterns on scarabs is not identified in the form correlations.

Most scarabs in the sample were made of steatite or faience. 12 scarabs were excluded from the sample as their material, and therefore construction technique, was unknown. Gemstones were represented in too small quantities in the sample to assess whether the hardness of the stone affected the nature of the carving. Faience scarabs could not be assessed on difference in technique since both moulding and engraving techniques were used in the working of faience (Nicholson & Peltenburg 2000, p.188) and the techniques could not be securely identified in the sample. Assessment according to material type did not show significant difference between the groups on the mean values of the discriminating variables.

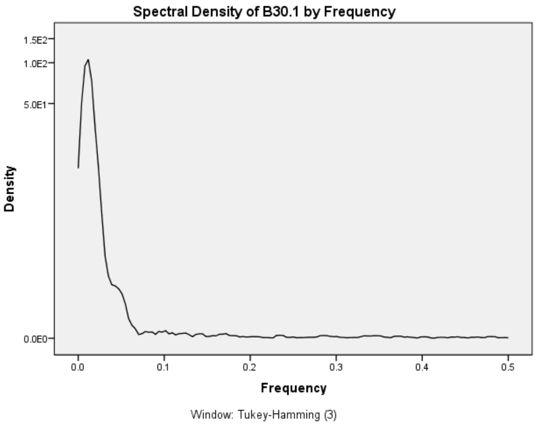
5.2.4 Bronze Age Cypriot case study

Spirals in this case study were divided into three classes over nine levels of clustering (Appendix 2, Table A2.14). Stepwise discriminant analysis revealed that the key dividing variables were the form correlations to spirals CYBM4.1 and CYBM27.2 (Figure 5.13) which operated on function one which had an eigenvalue of 15.127 and CYBM30.1 which operated mainly on function 2 which had an eigenvalue of 4.087. A fourth form correlation to CYBM15.2 acted negatively on both functions, slightly more strongly on function 1 (Figure 5.14).

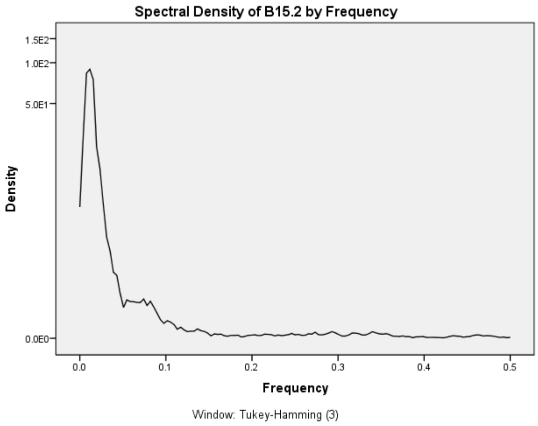
Figure 5.13 Below. Discriminating spirals with their corresponding density spectra underneath. a. CYBM4.1. b. CYBM27.2. c. CYBM30.1. d.CYBM15.2

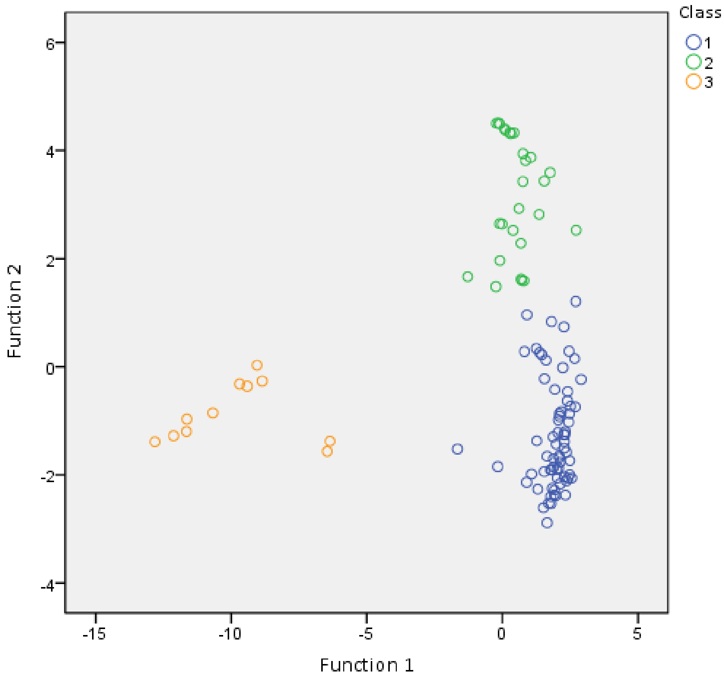


c



d





	Function 1	Function 2
CYBM4.1	0.561	-0.576
CYBM27.2	0.258	0.845
CYBM30.1	0.567	-0.315
CYBM15.2	0.554	-0.446

Figure 5.14 Scatterplot of Cypriot spirals on the first two discriminant functions and variable loading on the functions

Class 1 was the largest group encompassing three quarters of the goldwork spirals and half the pottery motifs. On the second function, correlation with CYBM27.2 loaded most strongly as a factor of both the low rotational length and the low frequency of the maximum density peak, indicative of a rapidly increasing expansion rate, of the spirals in class 2. Class 2 was most clearly characterised by representational function – all of the identified plant representations fell into this cluster. Only one pottery spiral featured in this group which was not a plant representation. A number of goldwork spirals in this group resembled the style of spirals depicting plants with a constant, narrow path width suggesting that there may be a broadly plant inspired source for some of the goldwork decoration as well.

Class 1 predominantly consisted of spirals with a tight central core and a sudden decrease in curvature to a straight line. In most cases, this arose from the motif being a component of a linked pair of spirals. The cluster divisions for classes 1 and 3 were not entirely satisfactory from a visual perspective. One visually coherent group of tightly coiled, regular spirals with a constant expansion rate was split between classes 1 and 3. Since these groups were most strongly divided on form variables, it is likely that the visually inappropriate split of this group of spirals arises from the problem of the maximum spectrum density peak being affected by rotational length.

Class 3 spirals, the most strongly segregated of the classes, show a negative relationship to the forms of all the characterising spirals. With spirals CYBM30.1 and CYBM15.2 this can be related to the increase in expansion rate at the end of the spiral. With CYBM4.1 the negative relationship seems obscure and arises from the impact of rotational length on form description. Visual differentiation can be made on the presence of a large open centre of the spirals in class 3. All the class 3 spirals are those presumed to have been painted whilst the vessel was being turned on a wheel. This class is the most strongly differentiated in form and rotational length and is typical of the stark contrast between the Late Bronze Age/Early Iron Age Geometric decorative style in the Aegean which appears to have had an origin in Athens (Murray 1978, p. 83) and earlier more flowing and less regular decorative styles.

Discrimination of spirals according to their construction technique initially identified irregularity as a key distinguishing variable. This may be attributed to digitisation error (see section 5.5.1) in the case of guided painted spirals, and damage in the case of stamped spirals, so was excluded from subsequent analysis. Without this variable, discrimination operated on two form correlations with one spiral, CYBM39.4, and six variables of style – the first coefficient of path width, median path width, the first and second coefficients of spacing, median spacing and irregularity (Figures 5.15 and 5.16). Of these, no individual variable loaded strongly on function one and only the path width variables had a loading above 0.3 on function two. Eigenvalues for both functions were also low 4.436 on one and 1.352 on two.

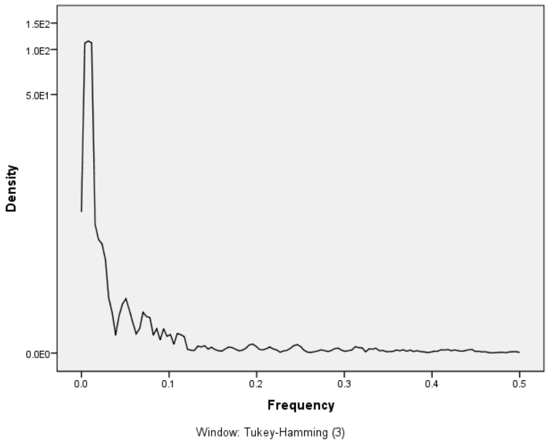
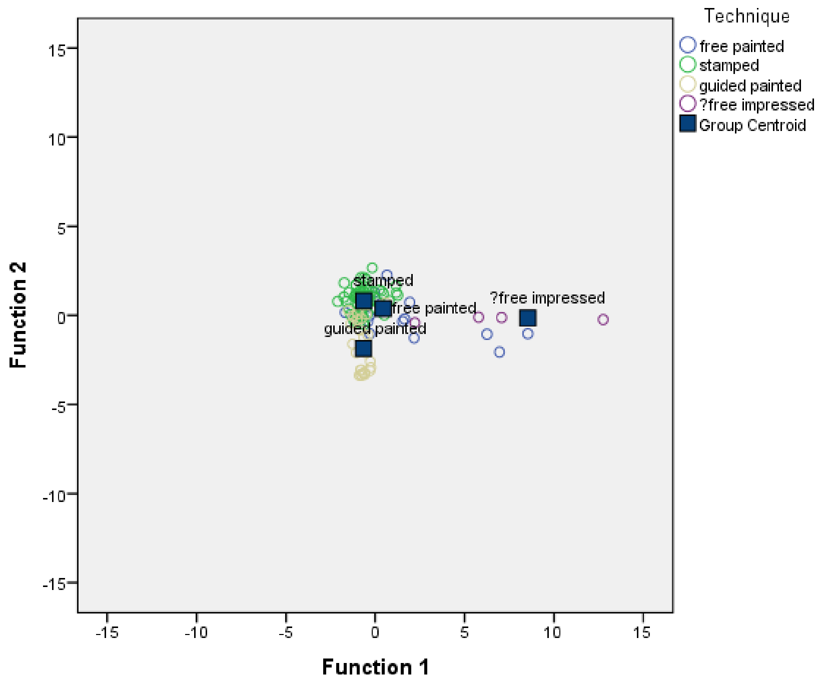


Figure 5.15 Spiral CYBM39.4 and its spectral density plot.

Four technique classes were assigned – freehand painted decoration; 'guided painted' decoration, presumed to have been carried out on a wheel; stamped decoration on metal; and decoration where a recurring stamp shape could not be identified which was presumed to be freely incised into the gold sheet. Segregation of technique groups was poor (Figure 5.16).



	Function 1	Function 2
Spacing trend 2	0.229	-0.41
CYBM39.4	0.16	-0.53
Median path width	0.120	0.477
Path width trend 1	-0.024	0.787
Median spacing	0.245	0.208
Spacing trend 1	0.085	0.145

Figure 5.16 Distribution of Cypriot spirals according to manufacturing technique and loadings on the first two discriminant functions.

The separation on function one of the freely painted and impressed spirals from stamped and guided examples is most strongly affected by spacing. Painted spirals are likely to have a higher spacing than the stamped spirals for which three-dimensionality can distinguish the coils with little or no spacing needed. The low spacing values of the guided spirals support the supposition that they were meant to resemble concentric circles. A large spacing value and in particular variation in spacing would make this illusion less effective as the eye would be able to follow the line better and non-parallel lines arising from curvature variation would appear incongruous. Function two reflects the regularity of the guided spirals. Median path width is lower and tends to be constant. This is reflected in the loading of the first path width trend coefficient indicating a tapering towards the centre of the stamped and free impressed spirals.

There is a broad homogeneity across the spirals in the Cypriot study. The segregation of classes 2 and 3 appears to have arisen from representational significance and from variation in technique respectively although neither of these divisions was absolute. There was no clear distinction between spirals on the goldwork and on pottery vessels except for the tight, regular spirals of group 3 which were exclusively found on pottery. The inclusion of the maximum diameter variable would certainly have allowed a distinction to be made but this is most likely to be a function of the size of the decorated object so is not a perceptually significant difference.

5.2.5 Cross-cultural comparison

The scope of decoration covered in this analysis is too narrow to be likely to reflect fully the variety of decoration in a culture. The second research question asked whether spiral motifs considered in isolation from context showed characteristic differences or whether homogeneity and limits on variation could be identified across cultural boundaries.

The results obtained from discriminant analysis carried out on the full set of spirals from all four cultural case studies differentiated the cultures on form correlation with spiral EGPET8.2 (Figure 5.17) and with the median spacing variable.

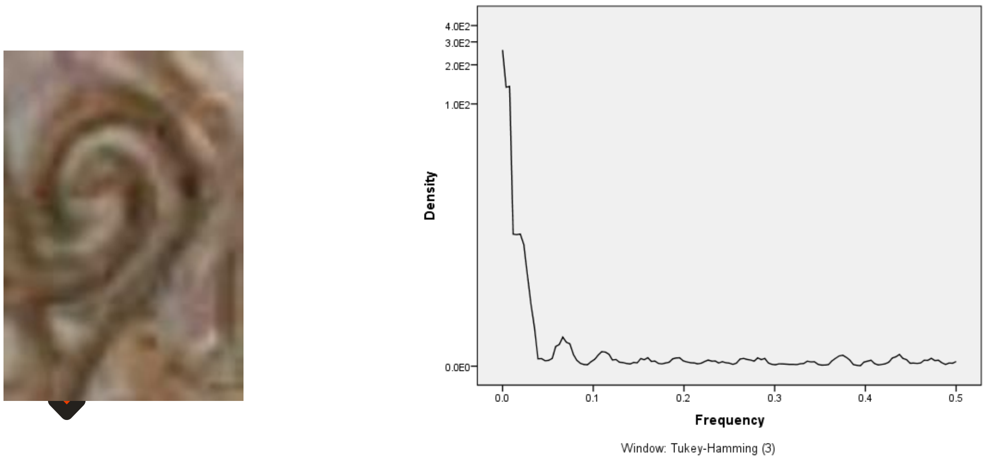
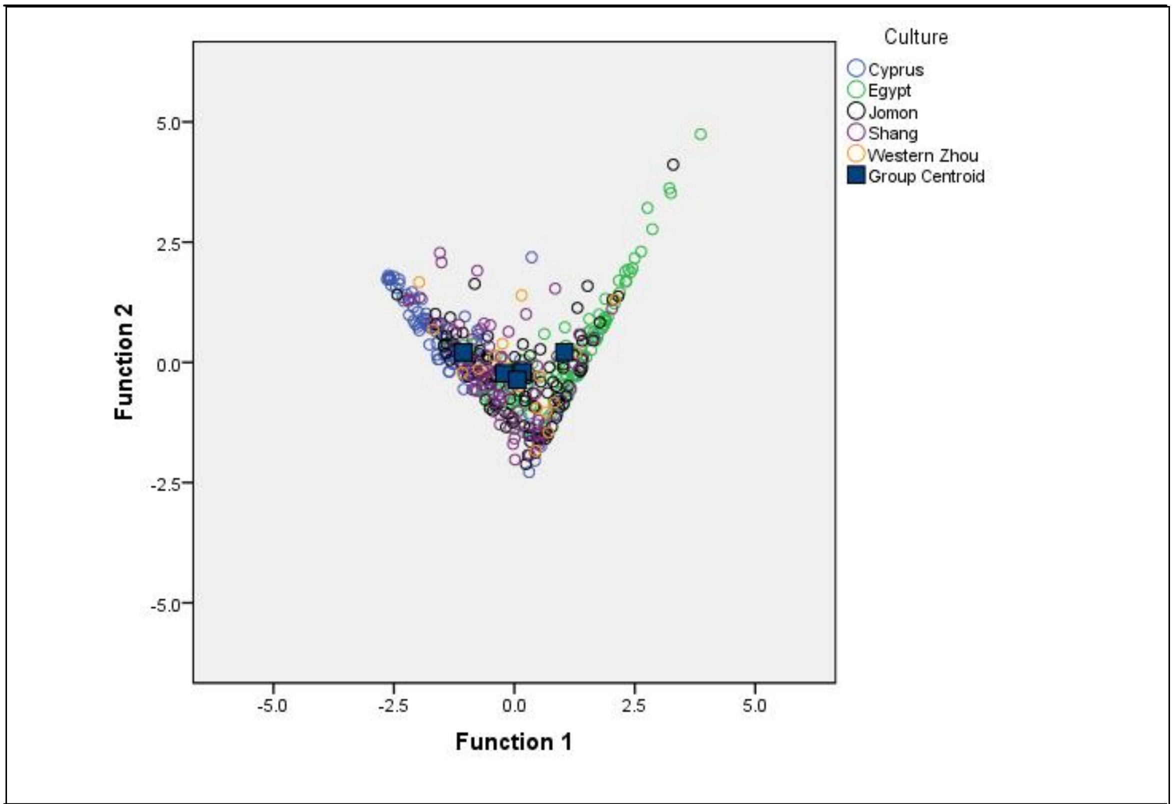


Figure 5.17 Spiral EGPET8.2 (triangle marking the relevant spiral, detail from UC29073, ©Petrie Museum of Egyptology University College London) and its density spectrum.



	Function 1	Function 2
EGPET8.2	0.892	-0.452
Spacing median	0.827	0.561

Figure 5.18 Cross-cultural spiral distributions on the first two discriminant functions and loadings of variables on the two discriminant functions.

Although Cypriot and Egyptian spirals are slightly differentiated on both functions in their extreme values (Figure 5.18), the scale of difference is too low to identify a clear distinction between these cultures. The extremes seen in the Cypriot and Egyptian examples reflect rotational length most strongly; with the long Cypro-Geometric spirals which are assumed to have been produced with some form of mechanical aid contrasting with the spiraloid or barely spiral motifs on scarabs which make up interlinked running spiral patterns so have a low rotational length to accommodate two or more spiral paths wrapping around each other in a small space. The median spacing value is similarly affected. Both the Cypro-Geometric painted spirals and the spirals punched into gold sheet have an exceptionally low median spacing value. In the case of the pottery, this may be to create the impression of concentric circles. The low spacing of the goldwork may be a purely aesthetic choice or may imitate coiled wire. Proportionally to their overall diameter, the running spirals on scarabs have a particularly high spacing, again to accommodate the linking of several spirals. The Jōmon , Shang and Western Zhou distributions overlap each other and the

Mediterranean case studies. Assessment of the distribution of individual style variables in isolation also showed no significant cultural differentiation with the exception of curvilinearity discussed below (p.177). The two regionally paired case studies were chosen to study whether commonalites could be identified within the pairs that might suggest contact and a regional style which contrasted with the other case study pair. In no instance could a significant difference be identified on the basis of this pairing either taking the discrimination results or the distributions of individual style variables.

The most striking aspect of the cross-cultural comparisons was the apparent similarity between cultures and lack of detectable variation in the expression of individual variables. The distribution of spirals shown in Figure 5.18 is most influenced by form variance. Both this distribution and the division of spirals according to their mathematical form resemblance show that data are skewed to a relatively small range of form expressions.

As discriminatory measures, style variables were largely redundant with only variables relating to path width and spacing registering as relevant variables for discrimination. Scatter plots of the distribution of individual variables by culture show why the style variables did not register in discrimination – there is a great homogeneity between cultures on all variable expressions. The distribution of the style variables was not, however, always random suggesting that there are some constraints on the typical shapes of spirals which cross cultural boundaries.

The Cypriot case study included some spirals of exceptionally high rotational length and similarly long spiral paths are typical of other cultures such as painted motifs on pre-Dynastic Egyptian Naqada II period pottery vessels. However, the large majority of spirals in each case study were of no more than 3.6 rotations length and, with the exception of the Cypriot study, the mean value was around 2.5 rotations (Figure 5.19).

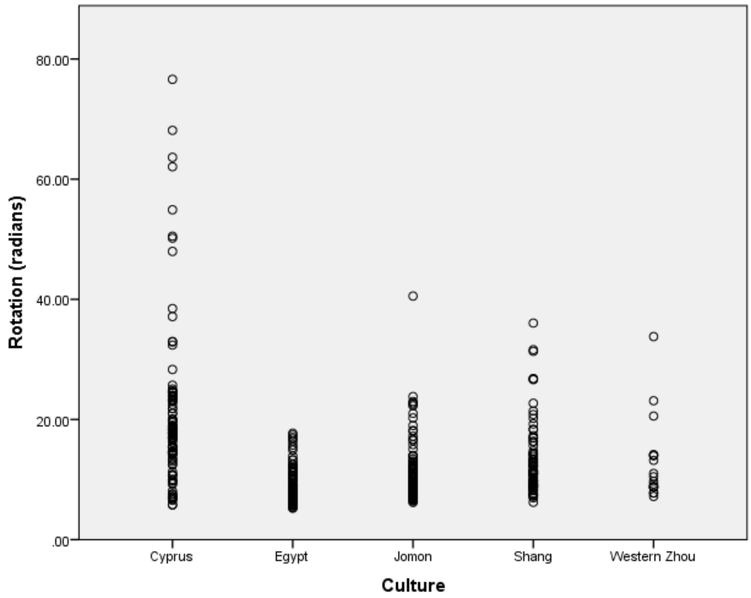
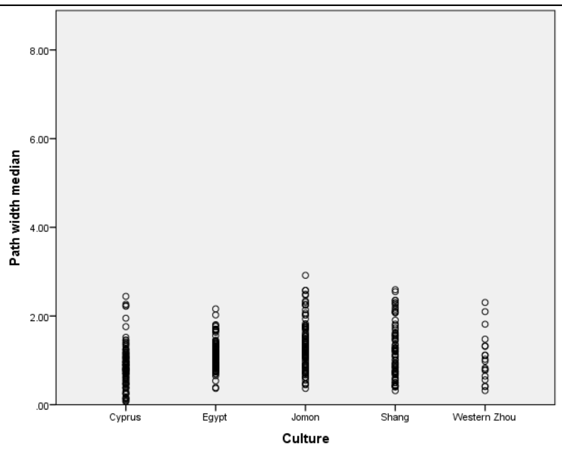


Figure 5.19 Distribution of rotational lengths by case study.

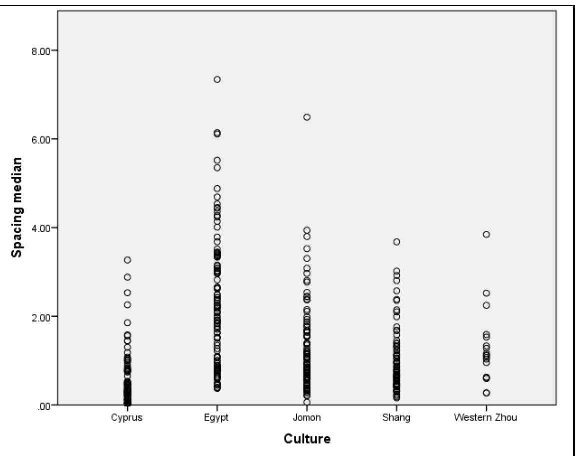
There are a number of possible explanations for this cross-cultural consistency. An aesthetically acceptable cut off point for maximal length may be implied across cultures, possibly where the motif can be readily perceived as a spiral and further rotations are redundant and possibly confuse the interpretation of the form by encouraging the eye to skip between consecutive rotations. It may also be relevant to consider the finding during the digitisation of spirals for this research that, in tracing spirals of high rotational length fatigue and therefore error increased (section 5.5.1, p.194). Depending on the tightness of the spacing and the desire for regularity, it may be that at a physiological level, around 3.6 rotations represents a suitable maximum length for avoiding the onset of increased irregularity particularly in mass production where the time available for the production of each motif will be limited. The form of the spirals will also impact on maximum rotational length; spirals with a constantly increasing expansion rate grow very rapidly in size over a few rotations so spirals approximating natural forms with logarithmic characteristics will be limited in the number of rotations by the available space. It is likely that expansion rate and spacing are reflected in the rotational length of the Egyptian sample which has the lowest range of all the cultures. Spirals which link together at a central point, as most of the scarab spirals do, require a relatively high expansion rate and have little room for a high rotational length before the paths merge into each other.

Irregularity could not be shown to be non-random in any of the case studies except the Cypriot spirals where the non-random indicating high irregularity distribution may be attributable to tracing error (see section 5.5.2, p.195).

Trends in path width and spacing along the course of the spiral path show undesirably high regression error from a third order polynomial curve from a methodological point of view (see section 5.5.5, p.196). However, from a cultural comparative regard, they show remarkably high agreement with a trend line which accommodates only two changes in magnitude of curvature along the length of the spiral. Median path width and spacing values (Figure 5.20), which were proportional to a spiral maximum diameter of 10, showed significant differences amongst the four case studies although all within a limited range of variation which suggests a consistent preference for a balance of equal path width and spacing though with greater variance in spacing.



a.



b.

median path width	Cyprus	Egypt	Jōmon	Shang/ Western Zhou
Cyprus	-	<0.001	<0.001	<0.001
Egypt	<0.001	-	0.004	ns
Jōmon	<0.001	0.004	-	ns
Shang/Western Zhou	<0.001	ns	ns	-

median spacing	Cyprus	Egypt	Jōmon	Shang/ Western Zhou
Cyprus	-	<0.001	<0.001	<0.001
Egypt	<0.001	-	<0.001	<0.001
Jōmon	<0.001	<0.001	-	ns
Shang/Western Zhou	<0.001	<0.001	ns	-

Figure 5.20 Median path width (a) and spacing (b) and significant differences in distributions between cultures.

The clearest differences which can be seen between cultures are in the tendency towards high spacing in the Egyptian spirals reflecting the interlinking of spirals at the centre and the higher number of spiraloids in this study than the others generating a relatively higher spacing and lower path width. The Cypriot spirals have the lowest range, accounted for by the guided spirals with a particularly high rotational length so low proportional path width and spacing values.

With the exception of the Shang/Western Zhou data discussed in section 5.2.2 (p.163), the distribution of orientation was not significant in any of the case studies. The quadrilateral spirals of the Shang were also represented on the curvilinearity variable (Figure 5.21). All case studies showed a significant distribution ($p=.012$) for the combined Shang/Western Zhou data, $p<.000$ for the other three). In each case though, the trend was towards curvilinearity and the Egyptian, Cypriot and Jōmon cultures did not show significant differences in distribution but all three differed significantly from the Shang/Western Zhou study ($p<0.01$). This agrees with Bar and Neta's (2006) finding of a preference for curvilinearity in a laboratory study of preference for curvilinearity in abstract shapes and real objects. They attribute this to an aversion to angular objects as potentially injurious. The unusually high occurrence of angular spirals in the Shang/Western Zhou study may be a particular attribute of that culture or it may reflect the context in which the spirals are used. In none of the other case studies are spirals used as a two-dimensional background pattern (Figure 4.7, p.124) (the two-dimensional spiral patterning on the Cypriot goldwork is the only decoration so should be considered a foreground pattern) and in this context, angular spirals allow complete coverage of the ground whereas highly curvilinear spirals would only provide incomplete coverage.

The possibility that the use of angular spirals is an adaptation to a specific decorative need is raised because of the trend running across all cultures for a high degree of curvilinearity suggesting that more circular forms are usually found desirable.

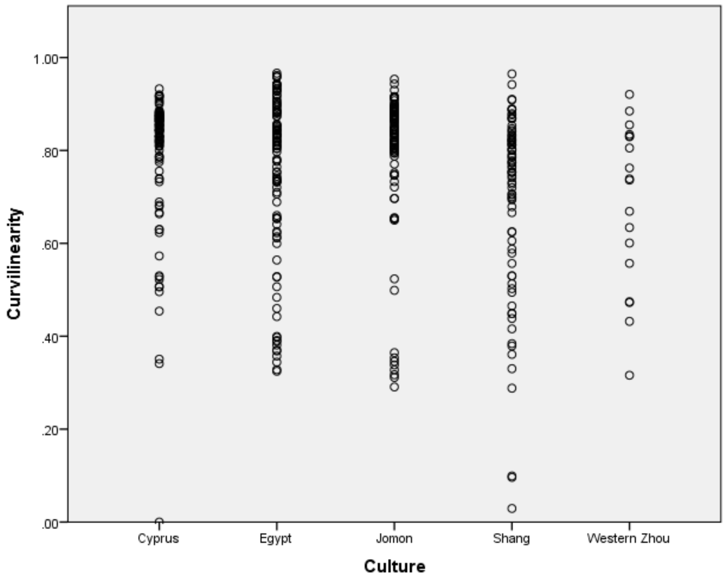


Figure 5.21 Distribution of curvilinearity values by culture.

That four distinct culture groups should show such commonality in motif structure suggests that some underlying principles guiding the shapes of the spirals do run across the culture studies.

5.3 Endogenous visual phenomena

The clustering of EVP spirals to identify type spirals for comparison with the spirals in the cultural case studies yielded five type groups (Appendix 2, Table A2.15). The large majority of the spirals sampled fell into two groups (named Type 1 and Type 3). The three remaining types consisted of a small group of six spirals (Type 4) and two individual spirals which were sufficiently differentiated in the clustering that it was necessary to keep them as separate types (2 and 5). These two spirals, FC12.4 and FC1.1, were excluded from further analysis due to the small sample size of the clusters.

Type 1 spirals include all the theoretical EVP examples modelled by Tass (1997). The strongest style characteristic of this group is a low rotational length ranging from 4.86-10.79 radians. The majority of this type are computer generated models so regularity is generally high although the total range of regularity is large. Path width and spacing median values were highest in this type group. Type 1 also showed greatest variance in path width and spacing trend values. This can be accounted for by the majority of the computer generated models having a high expansion rate of both path width and spacing and the small number of drawn spirals in this group having much lower values. The few drawn spirals in the type 1 group tended to be those of low rotational length and relatively high median path width.

The majority of the type 3 spirals were longer, but overlapped in rotational length with the type 1 spirals. Spirals in all three main type groups showed generally high curvilinearity but, within this group, curvilinearity showed a bimodal distribution. This difference was more apparent in measurement than visually and reflects the presence of short straight sections within largely curvilinear spirals. Type 3 and 4 spirals both had a very low mean median path width, although the range of type 3 path width median values overlaps almost completely with type 1 examples. This reflects the spirals sampled from Becker's (2005) test which were drawn by most subjects as a single line, the width of the drawing implement, with no width represented. As with the drawn spirals in the type 1 group, the type 3 and 4 spirals tended to have a low spacing median and trend values for path width and spacing are clustered around zero, reflecting little change in values along the length of the drawn spirals.

The spirals drawn as representations of EVP are notably more irregular than those found in decorative contexts (Figure 5.22). There may be a number of explanations for this – the subjects are being asked to represent what they see rather than produce a work of art so aesthetic considerations will be reduced; most of the subjects were not artists and were not selected on the basis of perceived artistic talent or draughtsmanship ability; EVP are difficult to focus on and to draw (Maclay & Guttmann 1941) so this may encourage tentative and sketchy reproduction and the apparent association of spirals with rotating images may exacerbate this difficulty. The tidying and smoothing of imagery in artistic representation may also arise from the artists drawing on the secondary experience of those who had entered a trance state (Lewis-Williams and Dowson 1988). Knoll *et al.* (1963 cited in Lewis Williams & Dowson 1988) found that the passage of time after experiencing subjective visual phenomena caused people to generalise what they had seen and to create more discrete and defined representations.

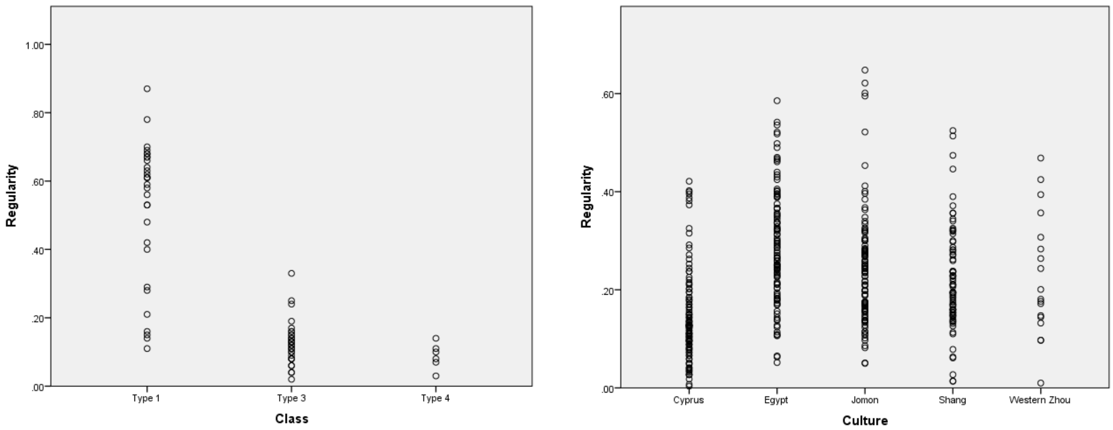


Figure 5.22a. Irregularity of EVP spirals. Types 3 and 4 represent the majority of drawn examples. b. Irregularity of the decorative case study spirals. Higher values indicate greater regularity.

Type 4 spirals exhibited the highest rotational length and irregularity and exhibited the greatest homogeneity in path width and spacing. Amongst the drawn spirals there was no apparent difference according to the nature of the stimulus.

Representations of EVP spirals by those who have experienced them differ markedly from those in Tass's theoretical models. The modelled spirals more closely resemble Klüver's (1967 cited in Ermentrout & Cowan 1979) classification which uses the term spiral in reference to high-expansion-rate whorls. There may be a poor match between the modelled and actually experienced spirals. Alternatively, it could be that the drawn spirals represent an attempt on the part of those experiencing them to convey rotational movement rather than a perceived spiral form. One drawn example includes motion arrows around the spiral form. The impact of training cards in the experimental examples cannot be ruled out.

Discriminant analysis used the form correlation of three spirals to separate the type classes (Figure 5.23).

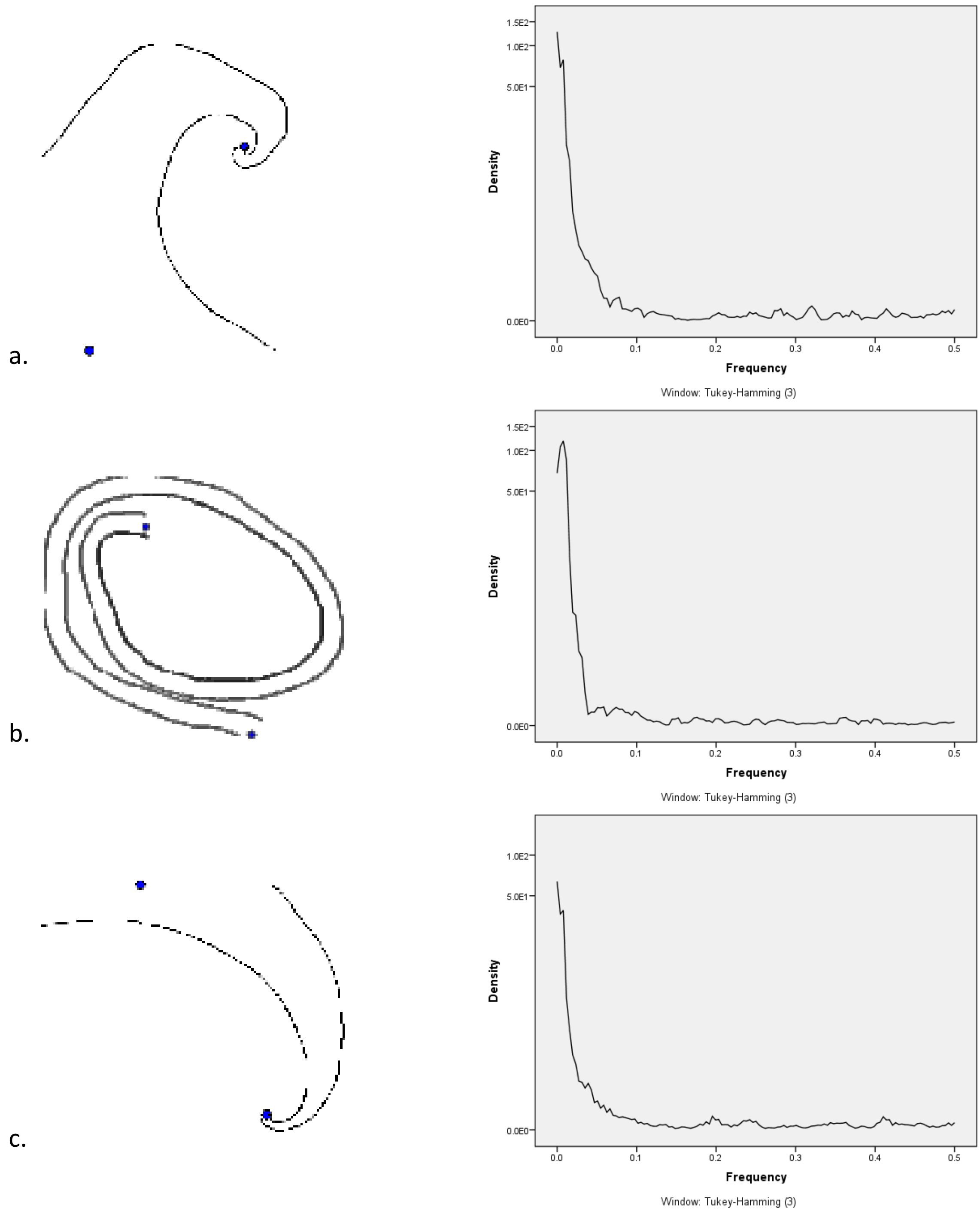
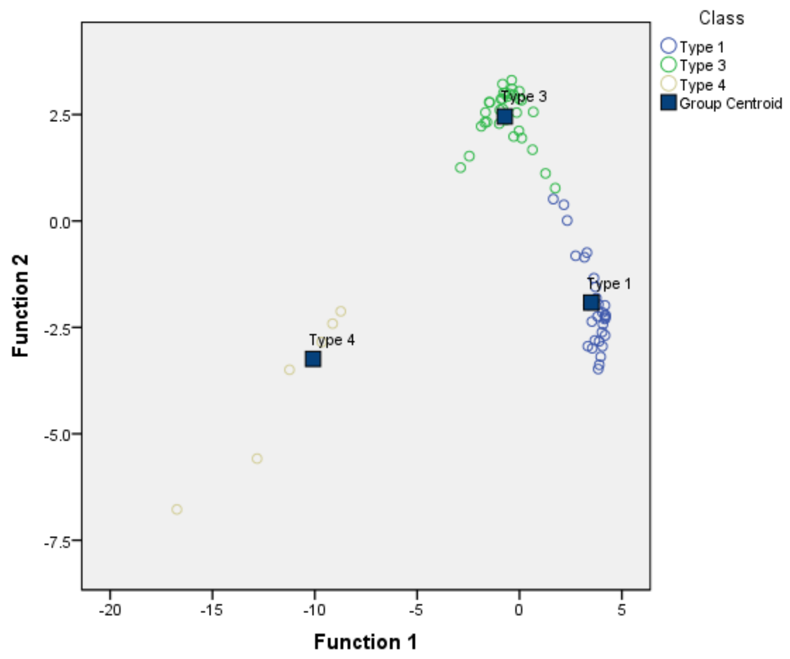


Figure 5.23 Form correlation spirals and density spectra for spirals a. FC20.8, modelled by Tass (1997); b. FC1.2, drawn by a person with schizophrenia (Horowitz 1964); and c. FC14.2 modelled by Tass (1997).

The form variables were loaded on two discriminating factors. The first, with an eigenvalue of 18.177, dividing types 1 and 3 from type 4 (Figure 5.24). Type 4 spirals tend to have the greatest rotational length and a low expansion rate with little fluctuation in spacing and path width. Types 1 and 3 are not visually similar although they are grouped closely together on both functions. The contrast between the visual assessment and the clustered results probably arises from the tendency for shorter rotation to create a sudden drop in signal density from the peak so creating a resemblance to the spirals and spiraloids of type 1 with the very high expansion rate. The second factor had an eigenvalue of 6.044 and primarily discriminates type 3 spirals from types 1 and 4 although the distinction is not strong and for any type on this function. That the most separated group is type 4 is visually inappropriate and difficult to explain. It appears to show up a flaw in the method which has not arisen in the case study analysis. The discriminant plot showed a high variance around the centroid in each type cluster. This lack of coherence within each type weakens them as a basis for identifying a single type spiral for comparison with the decorative examples.



	Function 1	Function 2
FC20.8	0.725	0.164
FC1.2	0.705	0.142
FC14.2	0.571	0.474

Figure 5.24 Scatter of EVP spiral types and variable loadings on the discriminant functions.

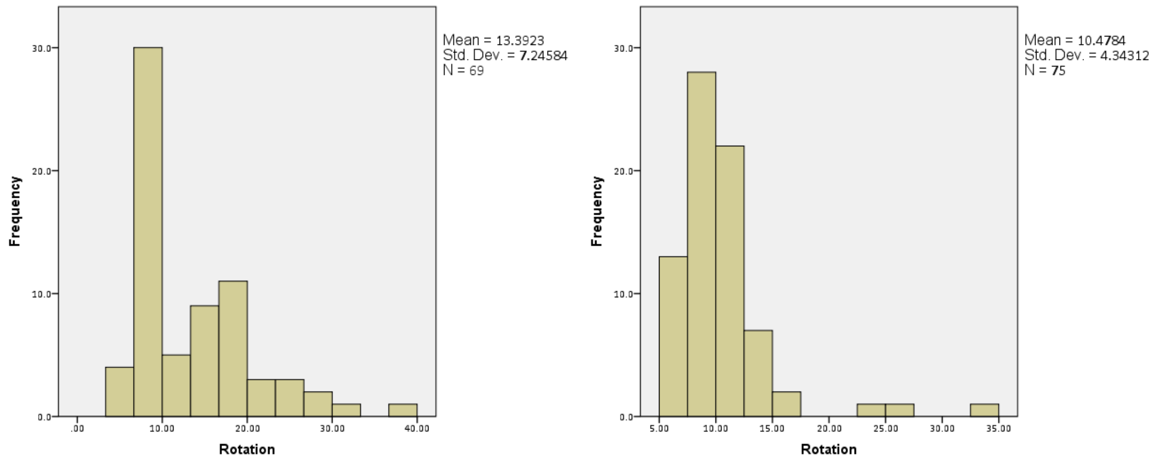
5.3.1 Comparison with decorative spirals

In testing the EVP type spirals against the decorative spirals within the case studies, spirals which fell within one standard deviation of the mean for each of the diagnostic variables were deemed to be a potential match to an EVP form (Appendix 2 Table A2.15). The Cypriot and Shang/Western Zhou spirals had the highest number of spirals which accorded with the parameters of type 3. Types 1 and 4 did not have a high representation in any of the culture groups. Two Cypriot spirals fell within type 4 boundaries and one each into type one within the Shang/Western Zhou and Egyptian studies. The type 1 Shang example is part of a representational image – a *taotie* horn. This illustrates the risk of overlap of potential EVP inspired spirals with natural real forms. Within the range of spirals in each case study the chance of a random match to any of the type groups was less than 0.000. This suggests that the numbers of spirals which accord with type 3 are significant. The variance on each of the discriminating variables in each of the cultural case studies overlaps with the EVP spiral types with the exception of type 4 spirals. These had a low overlap on the Egyptian case study with only five of the nine variables having a range which overlaps with the range of expressions of the Egyptian spirals.

The occurrence of the type 3 matches across these three cultures suggests that there may be a culturally independent common source, such as EVP but other exogenous factors cannot be discounted by this study. The stamped gold spirals make up all but one of the Cypriot type 3 group and, as noted above (section 5.2.4), there is a possibility that these were created to resemble coiled wire decoration rather than referencing any natural form. An alternative explanation for the prevalence of this type group can be offered in a fit to a natural spiralling hand movement. The spirals sampled from Becker (2005), in particular, have a tendency towards an elliptical form which is not seen in any of the modelled spirals or those published as type examples of EVP spirals. An elliptical tendency would accord with a natural hand movement in which lateral hand movement is freer than the perpendicular axis. The majority of type 3 Shang Dynasty spirals are slightly angular. As rounded angular forms register similarly to ellipses in their spectral density, this would account for the matches with the ellipses in the EVP group. It is not possible to separate out the influence of the physiology of hand movement from a possible perceptual influence arising from EVP.

Both the Cypriot and the Shang Dynasty type 3 spirals form part of two-dimensional ground covering patterns. It may be that the appeal of this spiral type's dense shape and constant expansion rate lies in its potential to create a regular covering pattern without substantial gaps and so is unlikely to be of EVP origin.

Although not sufficient evidence on its own, the distribution of rotational length across the case studies might be used to support an interpretation of decorative spirals as having been inspired by EVP since a distinction can be drawn on this variable from the decorative representational forms. The range of distributions seen in Figure 5.19 (p.175) is not significantly different from the rotational range seen in the EVP forms (the modelled forms are represented by the spike at seven to ten radians) whereas the distribution of rotational length found in spirals of known representational origin is significantly different (p=0.006) (Figure 5.25). This suggests that it is not imitation of natural real examples governing this distribution, although it might be mechanical or visual economy.



a. b.

Figure 5.25 Distribution of rotational length (radians) for: a. EVP spirals; b. representational decorative spirals

The necessary use of secondary imagery in drawings inevitably reduces the ability to identify clear EVP type spirals. In the sample used in this research, some spirals were drawn by experimental subjects who had been guided in what to look for. Examples derived from pathological abnormal visual function had often been assigned representational interpretation by the subject which may have influenced the presentation of the drawings (Appendix 2, Table A2.6). The first factor could be controlled for in experimental conditions but the inclination to interpret visual effects (also seen in the perceptual survey) is always likely to affect their presentation. It is likely that type groups derived from drawings will always be subject to uncontrollable external influences. It was not possible within this study to obtain evidence of a clearly defined EVP spiral type. As a result of this, although the form and rotation variables of the sampled spirals were not inconsistent with an EVP influence, other influencing factors could not be excluded and no influence of EVP spirals could be identified.

5.4 Inspiration for spiral decoration

The question of whether natural representational inspiration for decorative spirals affected the form and style of the spirals in a cross-culturally consistent manner was difficult to address with the data from the case studies as there was relatively little overlap in representational types between case studies and representational meanings may have been missed restricting the data set even further. The identification of representational meaning in itself can be subjective. Hirschfeld (1977) noted that there was not consistency of attribution of representational meaning by the producers of embroidered designs. This implies both that representational meaning is flexible and that a strong contextual basis is needed for attempting to assign a representational meaning to abstracted spirals motifs. The meanings attributed in this study were used on the basis of consistent references across a number of publications and in most cases there was sufficient contextual information in the decoration to identify representations at their most basic level such as tail or horn.

Spirals with a known representational meaning from all four case studies were collated in a single clustering test to see if the spirals separated according to subject (Appendix 2, Table A2.16). Shang/Western Zhou spirals made up most of the data set and these depictions tended to be elements of mythical creatures for which there were no comparable equivalents in other culture samples. There was a very high form correlation between spirals in this clustering group, with the exception of the three spirals separated out in the cluster analysis, the lowest mean correlation was 0.957 and the three outliers were all above 0.7. The highest mean correlation within the full data set was 0.858. In clustering, the majority of spirals were placed in a single group and only four clustering steps were required to bring together all the spirals.

Three spirals were strongly segregated from the main group. One of these (CSBM30.46) was part of a conventionalised depiction of a cicada. The other two spirals separated from the main group were both from the same Western Zhou Dynasty vessel and depicted snakes with a constant path width and a low and constant expansion rate in contrast to most of the larger group. The three separated spirals are most strikingly different from the rest of the group in their rotational length and it is probably this that caused the separation. Discriminant analysis was not carried out on this study because of the small size of classes 2 and 3. There is neither a significantly high correlation nor an apparent strong visual similarity between the form of Western Zhou Dynasty, Jōmon and Egyptian scarab snake representations even though the Jōmon and scarab examples were placed in the same group. Snake depictions might have been expected to differ from the rest of the natural spirals in their expansion rate, in the manner of the Western Zhou examples but the Jōmon snake depictions tend to fall at the opposite end of the spectrum with some of the highest expansion rates. The only other representational theme with sufficient cross-cultural representation to make a comparison was depictions of plants on scarabs and on Cypriot vessels. These all fell into the first large cluster which drew together several different representational types.   All of the plant spirals had a high degree of overlap with the hyperbolic/logarithmic mathematical spiral group. Unsurprisingly, given the high path width of some of the plant depictions (e.g. CYMM12.2), path width median showed a significantly higher value (p=0.033) for the plant depictions than for the other types of representational spiral but form correlations were not significantly higher within the plant group than with the rest of the sample.   The mix of representational types and the split of snake depictions between clusters both suggest that it is not possible to differentiate spirals clearly by subject between cultures.

Discriminant analysis on the full, cross-cultural data set to divide representational and non-representational spirals identified three discriminating variables: form correlation to JKAE15.2; median spacing value; and irregularity (Figure 5.26) operating on a single function with an eigenvalue of 0.145. Of the identified variables, median spacing did not load strongly.

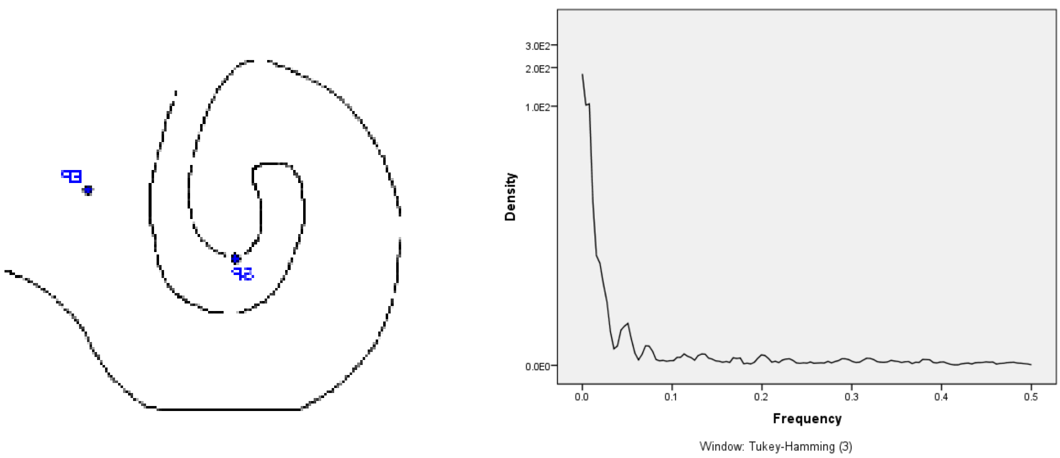
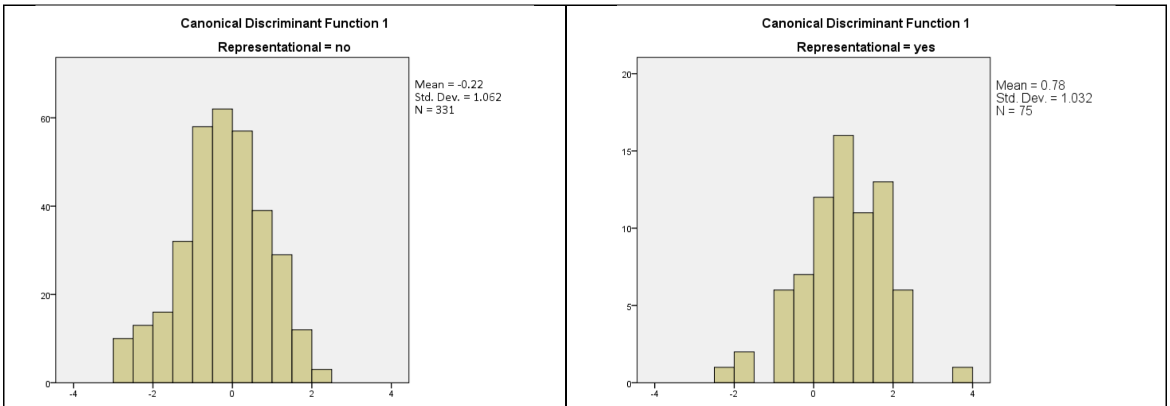


Figure 5.26 Spiral JKAE15.2 and its spectrum density.

The representational and non-representational spirals showed a very high degree of overlap (Figure 5.27) although the variable means of JKAE15.2 and irregularity both showed a significant difference between the two groups. The slight positive skew in the representational motifs reflects agreement with the spectrum of JKAE15.2 which resembles a logarithmic spiral with higher frequency peaks, characteristic of angular spirals. This possibly reflects the high proportion of Shang/Western Zhou Dynasty spirals in the representational group. There is no clear reason for the representational group to be more regular than the non-representational group so the higher regularity in the representational group may reflect their shorter length and be a factor of digitisation. Excluding irregularity from the analysis did not have a large impact on the results.



a.	b.
	Function 1
JKAE15.2	0.612
median spacing	-0.078
irregularity	0.523

Figure 5.27 Distribution of representational (a) and non-representational (b) spirals and variable loadings on the discriminant function.

The difficulty in discriminating representational spirals from the larger non-representational group does not imply that natural forms are not important as a basis for the shape of decorative spirals. It could imply the use of shapes associated with natural forms in decoration even when the intention is not to represent the natural form. It is also probable that some of the spirals in the non-representational group did have representational meanings to the cultures producing them which have now been lost.

The preference for high curvilinearity seen across the case studies is consistent with a natural inspiration for spiral forms which are rarely highly angular although Gestalt principles of good continuity and the nature of the object on which the spirals are drawn might also account for a preference for curvilinearity. When creating a large motif on a two-dimensionally curved surface an angular motif would be liable to appear more distorted than a curvilinear example. The angular Shang/ Western Zhou spirals could avoid this problem as they are smaller than the decoration on vessels from the other case studies so apparent distortions of curvature would not be obvious. Within each case study culture, both mathematical spiral grouping and cluster analysis proved effective at bringing together spirals that are of representational origin.

Differentiation analysis was also carried out on classes defined by the technique used to create the spiral. This was intended to identify both whether the motifs split into markedly separated groups on these lines and, if so, the variables which were affected by variation in contextual attributes. Imitation of technical artefacts and the method of construction may explain some of the consistencies between spiral shapes. A distinct technological basis for angular spirals from curvilinear forms may have arisen in woven textile patterning or possibly more distantly to basketry although this latter is more speculative. Although angular spiral forms are highly associated with woven textiles, their earliest known occurrence at Mezin (Figure 1.5, p.26) predates woven textiles and in the context of the other decorative forms found at Mezin (examples shown in Gimbutas 1989, p.5; Iakovleva 2009) suggests an alternative possible origin as an elaboration of chevron patterns. As with woven spirals, the early creation of decoration with straight lines may be a product of the type of decoration which the technology available best lent itself to – carving straight lines with the edge of a stone tool would be easier than carving curves, particularly on a non-flat surface, where using a smaller cutting edge to enable the creation of a curve would be more likely to cause the tool to slip across irregularities in the surface.

Tight coiling with no spacing between coils is widely found in decorative spirals created using wire. There are clear practical advantages in tight coiling in this medium: the wire guides itself; the decoration becomes more visible than separated strands of wire would be; and the consecutive coils support each other and are less susceptible to damage than an open structure.

Discriminant analysis of the method of production was run on the cross-cultural data. Eight methods of production were classified: free painted, found only in the Cypriot study; guided painted, also only in the Cypriot study; carved and carved/moulded found in the Egyptian study; stamped, found in the Cypriot study; modelled, found in the Jōmon study; incised, found in the Jōmon study, two examples of Cypriot goldwork and a single scarab; and cast, making up the whole of the Shang/Western Zhou sample. Since the Shang/Western Zhou sample were cast into incised clay moulds similarity might be expected between these last two groups if technique is an important influence on spiral shape. Four functions were identified, the first two accounted for 87% of variance and the third for 9.3%. Eigenvalues of the first two functions were, however, low at 1.147 for function one and 0.399 for function two. Three form correlation variables and median spacing were identified as significant (Figure 5.28).

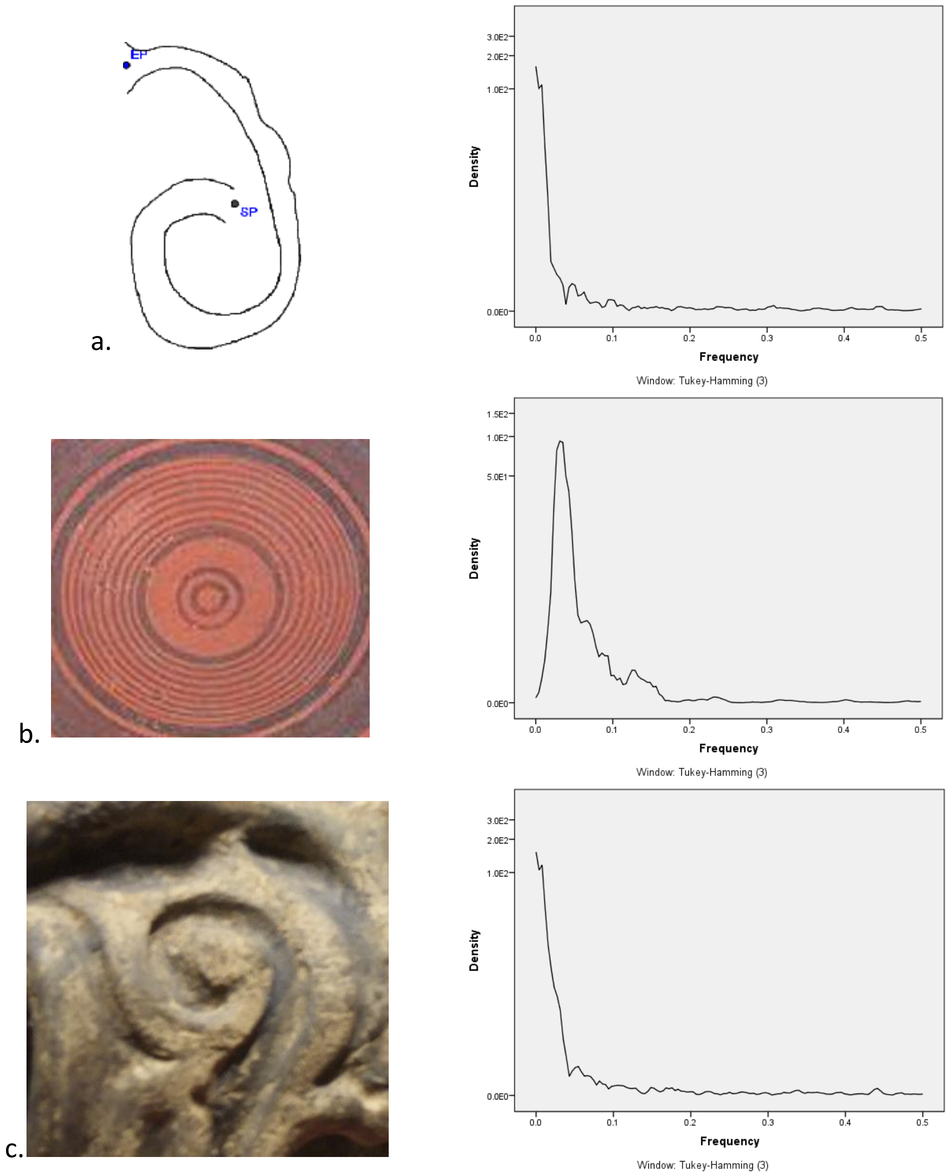
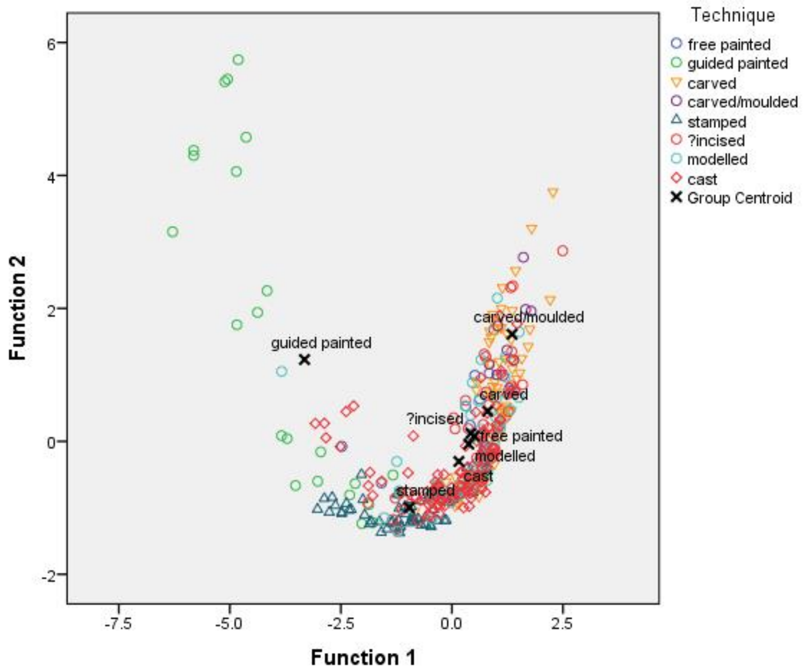


Figure 5.28 Discriminant variables for construction technique: a. JKAE10.2. b. CYMM24.1. c. JBM4.1 and spectral density plots.

The distribution of technique groups on functions one and two separated the guided painted spirals most strongly on function one (Figure 5.29). This matched the opposite loadings of the extended spiral of low expansion rate and the short spiral of high expansion rate on this function. Although no group was entirely distinct the guided spirals were most different, also having the greatest extreme of positive variation on function two. The two strongest loadings on this function would have opposite impacts on the guided painted spiral group with form correlation increasing the values and the positive association with median spacing lowering them. Median spacing also separated out the stamped spirals, the only other group which showed some distinction from the general cluster. That both these Cypriot groups are distinct probably does imply a distinction by technique rather than culture because the two spiral types are separated by 300-800 hundred years so cannot be considered an idiosyncrasy of a single culture. No other technique showed any strong distinction from the majority of the data which clustered around zero with a slightly positive trend on both functions. Although the Cypriot guided painted spirals were somewhat separated, the extent of variation in the whole sample does not suggest that differences in the manner of production have a strong impact on spiral shape.



	Function 1	Function 2	Function 3
JKAE10.2	0.922	0.149	0.073
CYMM24.1	-0.714	0.497	0.430
JBM4.1	0.954	0.022	0.076
median spacing	0.527	0.646	-0.461

Figure 5.29 Distribution of spirals by production technique and loadings of the variables on the first three functions.

The chart of cultures in which spirals were commonly used motifs (Appendix 2, Table A2.1) was produced to assess whether there was an apparent link between the introduction of a new type of material or a technological development and the introduction of spiral motifs. No pattern emerged from this assessment.

5.5 Evaluation of the method

In the development of the method used in this research, the aim was to devise a system which provided an objective quantitative description of spiral motifs which could be used to differentiate the motifs and to assign them to classes according to visually important properties. If the method were to be practical in building up a set of data for cross-cultural comparison, it needed to be accessible and simple to apply.

Application of the method to the case studies showed that the variables included within the method could be used to create groupings of spirals for which plausible justifications could be offered based on visual assessment and that these groups differed from each other at a statistically significant level. This suggests that the variables chosen for measurement are appropriate for judging visual divisions, at least according to the cultural perspective of the author. How much these classes reflected the cultural choices of the producers and consumers of the decoration is, of course, uncertain. This caveat must be applied to any cross-cultural comparison.

Having quantified the decoration, it is possible to carry out discriminant analysis to identify the key variables which cause one set of motifs to be considered different from another. This is more readily achieved with a set of quantified data than with subjective assessment where the impact of individual variables may be difficult to separate from the cumulative effect on the viewer.

Subjective classification of the spiral motifs in isolation would avoid some of the obviously aberrant outliers which arose in the quantified classification but attempts to create subjectively assessed class groups based solely on visual criteria prior to the spiral clustering showed that many class divisions were unclear. This method allows decoration to be considered along a continuum of variation and measures of similarity and of the variability within a group to be made.

Where subjective judgment does have an advantage over this classification system is in the ability to assign subtle weight gradations to variables according to the perceived importance of the variable within a single motif. This involves a complex interaction of the expression of each variable within the motif. Provided that their judgement is culturally valid, it is likely that a human's assessment of visual difference will be better than a quantitatively based system but, where an assessment is being made without a means of identifying local perceptual judgment, a stronger case can be made for using a quantitative description.

One of the main difficulties in developing the method was in ensuring that the method was robust across the full range of decorative spirals. Many of these problems arose in the accommodation of factors where the appropriate manner of measuring a variable was visually clear but computationally ambiguous so liable to create aberrant results in the automation of the method. As an example, the measurement of path width at the end of spirals could not consistently measure to the end of both sides of the spiral to produce results which gave an accurate impression of the actual path width (Figure 5.30). The difficulty shown below of calculating path width appropriately was resolved by stopping measurement of path width if the same point of one line was measured repeatedly as the closest so causing measurement to stop in Figure 5.1b when the lines are no longer parallel

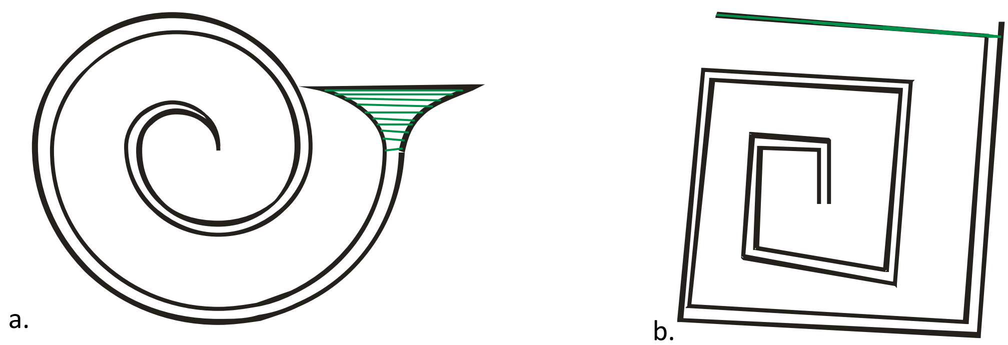


Figure 5.30 Variability in the appropriate interpretation of path width at the end of a spiral. Calculated path width to the closest point on the outside line at the outer end shown in green.

A learning process has operated within the method as it was applied to the case study data allowing its implementation to be refined as previously un-accommodated spirals were encountered. The analysis method in its current implementation is believed to cover a wide range of decorative spirals and the addition of further data can be used to continue the learning process as new forms and stylistic expressions are encountered.

Although it was intended that the classification system should be objective, subjective judgements were employed at several stages of image processing and the degree of class division accepted within the clustering results was also based on the visual inspection and the subjective assessment of similarity. To devise logical rules for identifying, for example, the distinction between figure and ground, a common understanding of decoration between cultures would have to be assumed. This would require a substantial quantity of contextual data be included within the analysis extending to the surrounding decoration on the object and to the decorative styles seen on other objects within that culture. Although some variables could be tested according to objective rules which allowed consistency, it proved impossible to implement the analysis method as an entirely objective system.

The reliability of the analysis may be affected by the subjective placement of the start point of the spiral and the consequent placement of the centre point. The measurements of irregularity, path width and spacing were dependent on the placement of these points. Subjectivity in assessment of type clusters would have a less negative impact on reliability than variation at the stage of data collection since clustering results will be specific to the research question posed. It is of greater fundamental concern that the raw data can be said be reliable.

The implementation of a classification flowchart in the manner of Washburn and Crowe's (1988) symmetry classification was inappropriate to a construct which shows continuous variation. This factor and the number of sampling points needed to produce a precise description of shape made automation of the measurement of variables the most appropriate approach. In its final form as an applet within Geogebra, the method is easy to apply and could be made easily accessible over the internet. Given a detailed specification, the method could also be implemented in other software.

In each of the case studies quantitative outliers occurred which did not have a good visual match with the class in which they were placed. This suggests that there is scope for refining the method and improving some of the ways of measurement. During the application of the method to the case study data, some possible improvements which could be made to the digitisation of motifs, the measurement of style variables and the quantification of spiral form were identified. These are detailed below.

5.5.1 Digitisation

Tracing error is highest at the start and end of the spiral and at the start and end of interpolated sections when the stylus is lifted from the tablet. Error at the start and end cannot be eliminated. Interpolation error can be reduced by changing the method of recording the start and end of interpolated sections to a key press without needing to lift the stylus.

Further errors in tracing are introduced where the diameter of the spiral reached a point where hand movement and change in the angle of the stylus are required to continue tracing. At such points, the stylus could be kept in contact with the tablet but some erratic movement arising from the adjustment inappropriately increased measurement of irregularity. This was particularly evident in the Cypriot case study. With longer spirals, fatigue and increased tremor from gripping the stylus for a prolonged period may have had some negative effect on the accuracy of tracing and measured irregularity. This problem is more difficult to resolve. The ideal solution would be an effective means of automatic edge detection which could be manually edited to control interpolation and location of the ends of the spiral. Failing this, a rig which allowed the stylus to be held upright and provided a larger gripping area might reduce, though not eliminate, these errors.

5.5.2 Irregularity

The problem of minor damage affecting the assessment of irregularity might be resolved by introducing two levels of interpolation into the tracing of the spirals. Interpolated parts of the spiral which are clear enough to be included within the assessment of other variables could be excluded from assessment of irregularity. This would, however risk making irregularity unmeasurable for some spirals. As noted in 5.5.1, there is a cost in tracing accuracy in increasing the number of times the stylus needs to be lifted and re-placed.

5.5.3 Curvilinearity

In application, the measurement of curvilinearity proved to have a drawback in that the appropriate maximum angle of curvature and minimum number of path segments that fell within that range to determine a straight section within the spiral varied according to the average curvature of each individual rotation (Figure. 5.31). This problem was manifest in two ways. The first produced an overestimation of the number of straight segments when irregularities in spirals with low curvature registered wrongly as separate segments within what would be visually assessed as a single straight line (as might be considered the case in the right hand side of the outermost rotation of Figure 5.31 which would record as three straight segments).

The second caused an underestimation of the number of straight segments when spirals featured high resolution irregularity or patterning which prevented segments which appeared straight at a lower resolution being recorded as such (the left hand side of Figure 5.31 would not record as a straight segment).

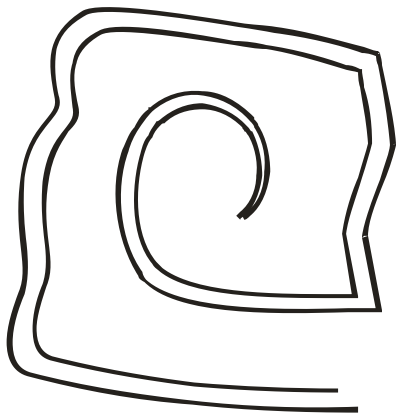


Figure 5.31 Ambiguities in recording curvature.

The applet identifies, a straight segment where there is a sequence of at least eight segments in which the change in angle from the first segment is less than 0.035 radians. A future method to test for improving the measurement of curvature would be whether calculation of the average curvature of each rotation of each spiral was more appropriate although the calculation of curvature of irregular shapes is complex and might be difficult to accommodate as a small number of comparable values within the classification system.

5.5.4 Orientation

Orientation is given the same importance regardless of the spiral form. From a visual point of view it would seem to make sense to weight the importance of orientation according to how far the spiral deviates from a circular shape. Orientation is likely to be considered perceptually more important in spirals with strongly differing maximum and minimum axis lengths than in those where the difference is negligible. This would also permit the isolation of spiral motifs where orientation is more likely to be a discernible variable for separate consideration of this variable.

5.5.5 Path width and spacing

The fitting of polynomial curves to describe changes in the trend of path width and spacing imposes an external order on measurement in a manner which this method is trying to avoid. Any form of parameterisation of trend in path width and spacing to make it comparable in a quantitative system will require some degree of imposed artificial structure. The mean square error (MSE) of the trend line varied quite considerably, with some spirals being poorly described. The spiral EGLIV7.4 for example had a path width trend MSE of 235.759 due to a fluctuating path width (Figure 5.32). In this instance a ninth degree polynomial would provide a better fit but increasing the degree of polynomial without good reason can result in overfitting – including random noise within the trend and reducing its predictive value (Blöschl & Grayson 2000). Where fluctuating variation was not adequately accounted for by a third degree polynomial in multiple spirals, the fitting of a higher polynomial curve of a higher degree might be appropriate but the full scarab case study, of which EGLIV7.4 was a part, showed an average MSE for path width of 5.843 so a third order polynomial was felt to be acceptable.

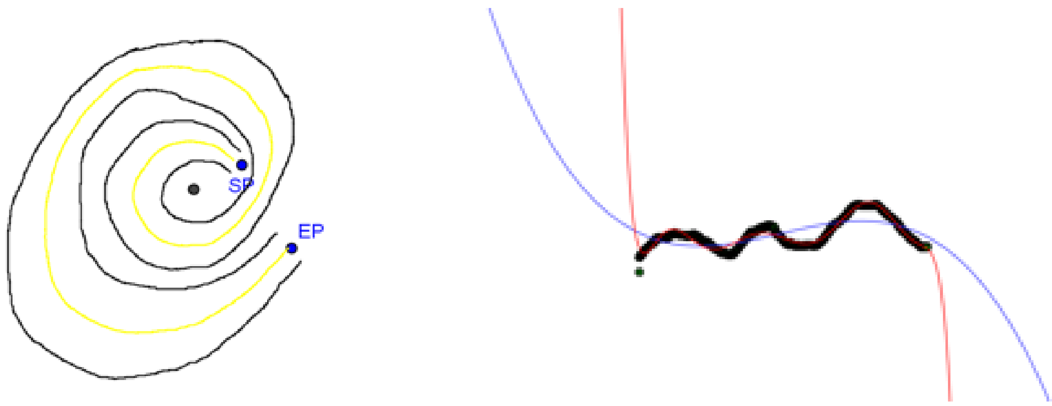


Figure 5.32 Path width trend for spiral EGLIV7.4 (left, primary path in yellow), right: actual path width measurements in black, third degree polynomial shown in blue, ninth degree polynomial in red.

Non-parametric regression such as spline fitting which takes a bottom up approach to extracting trend (Klasson 2008) and would appear more appropriate than predetermined curves does not yield results in a form which could be included within cluster analysis. A polynomial curve was therefore felt to be the best compromise in giving an impression of the perceptually important variables of path width and spacing trend.

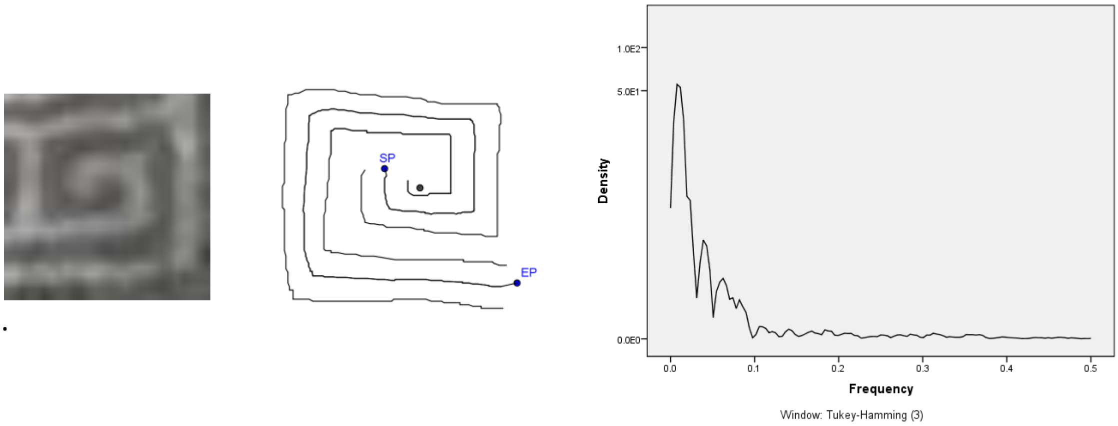
5.5.6 Interpretation of the spectral density plots

The form of the spirals is represented by a spectral density plot of the tangent angles of the spirals transformed into a sine wave (section 3.4.1). By identifying frequencies of signal with particular characteristics of decorative spirals they can be used to identify features of the spiral form. The frequency value of density peaks in the plot represents the length of rotation needed for the tangent angle of the spiral to return to its starting value, calculated as (rotational length in radians/number of sampling points)x(1/frequency). For a circle, which is represented by a single sine wave, a single density spike would appear at a frequency of 0.0039 so the calculation would be (6.283/256)x(1/0.0039)=6.293 showing that (allowing for rounding error) the tangent angle of the circle takes one rotation to return to its starting angle. For spirals, the movement of the path away from the centre causes the sine transformation of the tangent angles to a wave plot composed of a high number of sine waves of differing frequencies. The average expansion rate of the spiral is therefore represented by a main frequency peak and peaks of lower magnitude following this representing the manner in which the spiral expands.

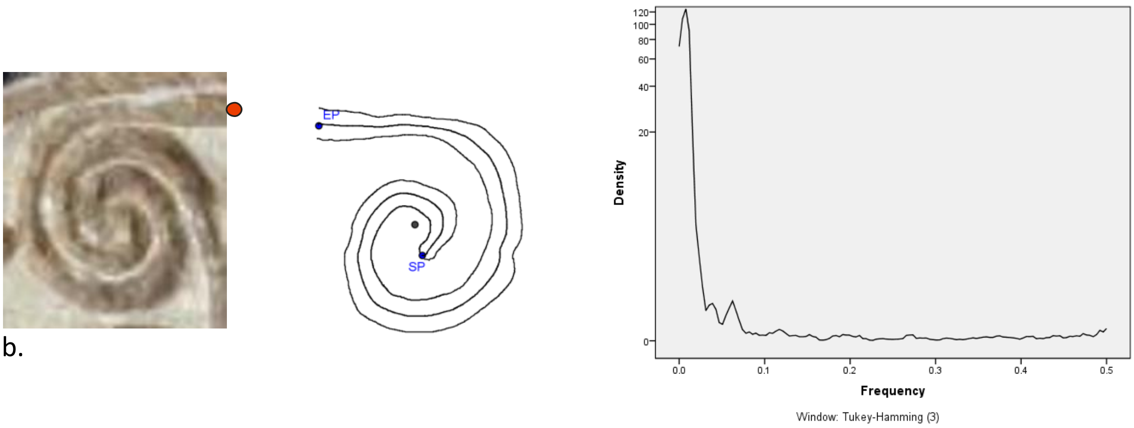
For the purposes of describing the effect of expansion rate on the shape of the spectral density plot, mathematical spiral types with clearly defined characteristics are used as exemplars, decorative spirals may be expected to have much noisier density signals than mathematical forms due to small or large scale irregularities of the curve. The tangent angle of logarithmic and hyperbolic spirals (Figure 5.1d and e, p.152), with an increasing expansion rate, takes more than one full rotation to return to its starting value. The average value of these curves results in the highest magnitude peak falling at a frequency close to zero due to the reducing curvature at the outermost end of the spiral. The constant expansion rate of Archimedes' spirals (Figure 5.1b), causes the tangent angle to return to its starting value in less than one rotation so the signal peak falls at a higher frequency than that of a circle at around 0.047. Parabolic spirals (Figure 5.1a) with a decreasing expansion rate have the highest maximum peak frequency. Euler spirals (Figure 5.1c) are the only type of spiral which can link a circle to a straight line without a cusp (sharp change in angle of the line). Although at their outermost end they have a low curvature, tending towards that of logarithmic spirals, expansion rate is much lower in the centre of the spiral so the average signal peak across the spiral falls between that of a logarithmic spiral and an Archimedes' spiral.

The change in expansion rate is reflected in the shape of the spectral density plot around the maximum peak. A more rapid change in curvature is represented by a more rapid decline in density values so the Euler spiral, changing from a circle to a line shows a rapid fall following the density peak to almost zero. Logarithmic and hyperbolic spirals show the next most rapid decline after the peak and Archimedes' spirals the most gradual. Parabolic spirals strongly resemble Archimedes spirals in their decline following the maximum peak but have a discrete frequency peak preceding the maximum peak which is not seen in Archimedes' spirals. Characteristic discrete frequency peaks or changes in the gradient of decline are also seen in logarithmic, hyperbolic and Archimedes' spirals (marked on Figure 5.1d, e and b). Average expansion rate is reflected in the magnitude of the maximum density peak with a higher expansion rate producing a peak of greater magnitude. The magnitude and frequency of the maximum density peak are also affected by the rotational length of the spiral with a greater rotational length tending to increase both values.

The noise seen in decorative spiral density plots that reflects small scale irregularity measured by the irregularity variable is represented by low magnitude peaks at high frequencies and has little impact on the measurement of similarity. More substantial variations in spiral shape found, for example, in elliptical or quadrilateral spirals are represented by spikes in the density plot. The jagged frequency peaks created by angular spirals can be seen in the contrast between the spectra of spirals CSVAM3.2 and EGPET12.1 (Figure 5.33). The profile of CSVAM3.2 differs from that of an Archimedes' spiral in not being a smooth decline in frequency.



a.



b.

Figure 5.33 Contrast of angular and curvilinear spiral signal density profiles. a. CSVAM3.2. b. EGPET12.1 (marked with a red dot), (detail from UC61187 ©Petrie Museum of Egyptology, University College London).

The effect of rotational length on the density spectrum created problems in classification. The highest variation in rotational length was in the Cypriot case study resulting in visually inappropriate groupings being made. It is anticipated that the method would be improved by transforming the density spectra to eliminate the effect of rotational length, possibly by dividing the spectrum values by the rotational length of the spiral. Spiraloids and spirals of very short rotational length tend to fall rapidly to zero after the maximum peak. This short rotational length created little higher frequency noise. The single rotation is more equivalent to a circle in its restricted signal range and can mimic the sudden frequency change in spirals with a rapid expansion rate causing confusion between the two forms.

The variation that is a factor of rotational angle in non-stationary data is masked by an averaging effect in spectral density plots, preventing individual sections of the spiral being compared. Discrete wavelet transform is more sensitive to variation and may allow individual sections of spirals to be compared and the form of the spiral to be represented more precisely.

Both the variables of curvature and rotational length appear to be encompassed within the form spectrum density signal so future development of the method might be used to extract these values from the form data, particularly if wavelet transform, rather than spectrum density, were used to create a more clearly defined signal.

5.5.7 Context of the proposed method.

Studies focussing on the overall structure of decoration or design in an ethnographic and archaeological context either using geometric terminology or perceptual impressions of the overall design structure are not directly comparable to the study of individual motifs in terms of their potential applications. Analyses of design structure have been extended to make comparisons between the structure of decoration and other aspects of cultural life for example social structure in addressing whether egalitarian or hierarchical social structures are reflected in symmetry repetition and the extent of ground covering within a design as a whole (Fischer 1961). Peregrine (2007) extended Fischer's research to the archaeological record to identify further correlations between assessed design complexity and social structure in political autonomy and social stratification. These assessments relied on the analysis of the full set of design or decoration.

Analyses of symmetry, in isolation or as a variable in a broader scheme take the geometric concept as a means of classifying since it has repeatedly been shown to be a valid concept in decoration even where the manner of measurement has varied (e.g. Brainerd 1942; Washburn 1990; Grünbaum 2004). With geometric constructs such as spirals which represent a physical construction rather than an organisational principle, reference back to mathematical principle directly has not proved appropriate in the context of decoration. In these cases the value of a geometric structure as a basis for analysis lies in providing a set of fundamental values to define a shape across the cultures in which it appears. The geometric construct forms the basis for deciding to classify the motif rather than the means of classifying it. These two approaches provide breadth of analysis in different manners. Symmetry and similar structural concepts such as modularity and proportions can be analysed in a wider range of cultures than is permitted by the study of a single geometric shape where cultures must be identified where its use it sufficiently common to argue that its presence is not coincidental. However, within these cultures, a broader range of perceptual variables can be assessed within the expression of the motif than in the identification of the presence and manner of expression of a structural concept.

It is true, as Douglass and Lindauer (1988) note, that some properties of design are not applicable to individual motifs and can only be applied to the structure of the whole design. However, the simplicity of a single geometric motif makes it easier to define that a more complex design composed of multiple elements and the possibility of assigning a limited set of variables to its detailed description may allow perceptual properties to be assessed in a single motif that could not readily be addressed in the full design. As has been discussed in Chapter Four, the isolation of motifs has been criticised. Bradley (1997, pp.5, 8) especially, opposes recording motifs in isolation as losing meaning which requires the full design for interpretation. He points out that simple geometric motifs such as crosses may have a diverse range of meanings in different societies (1997, p.11). Analysis of motifs in isolation may not be effective in identifying meaning. Even within the well-defined scope of the natural representational forms studied in this thesis, it was not possible to subdivide the spirals by what they depict so to go further and interpret abstract meaning would be fraught with difficulty.

Perceptual preferences occurring at a much earlier level of visual processing may be assessed independently of assigning conscious meaning and it is suggested that these may be drawn from the analysis of geometric motifs rather than meaning in the motif itself. Some of the variables analysed in this research are motif specific (for example rotational length) and could not be used easily in broader cultural analogy but preferences, for example, for regularity or curvilinearity/angularity might well be expected to reflect or be reflected in the broader environment and Fischer (1961), Takashi (2009, p.140) and Pittard *et al.* (2007) have suggested social constructions attached to curvilinearity in masculine/feminine associations or symbolic links to aggression. Preferences in regularity; the openness of design and ground covering could similarly have broader relevant analogy. Filatova (2008) used similar principles drawn from the broader design scheme to classify Neolithic pottery of the Lower Amur region.

The large majority of studies of perceptions of individual motifs have been carried out in laboratory conditions with a necessarily constrained sample group. Studies carried out in these conditions were used to support the choice of variables used in this method. The measurement of perceptual grouping values in decorative motifs might be used to assess whether similar observations of preferences could be seen in created decoration.

Prior studies of spiral decoration have used two main approaches to their analysis. The approach usually taken in classification of decoration and the study of cultural transmission is qualitative assessment of their shape either as a class of motif within a broader decorative typology (e.g. Loehr 1953) or in relation to their conformity to mathematical classes. The second approach to analysis, uses quantified assessment either, again, in relation to mathematical spiral forms (e.g. Andrey & Galli 2004) or in terms of measured values which would equate to those of style used in this thesis (e.g. Herner 1989). The method proposed in this thesis tends strongly towards a quantitative approach. This has not filled the function of cultural individuation where qualitative assessments of spirals as one decorative class amongst several have usually been used. The approach taken is most similar to that of Herner but with the addition of a more detailed description of form (Herner (1989, pp.22-37) uses three shape classes to describe form). Since form was consistently the strongest differentiator of the spirals, this aspect of the method is felt to be a useful addition that might be used alongside studies of broader decorative schema to enhance the information that can be obtained from them.

5.6 Summary

The analysis method proposed in this thesis proved capable of identifying perceptually coherent differences between decorative spirals. However, application to the studies in this thesis has highlighted several areas in which improvements could be made to the method particularly in the discriminatory power of the form variable for which a wavelet transform summarisation approach is suggested in future. In comparison with mathematical spiral classification, both systems were shown to have some advantages and disadvantages, but the classification method applied in this thesis is felt to offer greater flexibility and make fewer assumptions about the data under consideration than the use of mathematical spiral classes.

In all of the cultures analysed it was possible to differentiate between spirals using clustering to create a gradient of variation across the sample and to identify some strongly outlying classes of decoration. This illustrates that a graduated approach to the description of the motifs was more appropriate than assigning them to separate classes. By far the strongest theme to come out of cross-cultural analysis was that of restriction on the range of variation. In assessing possible reasons for this restriction, depiction of substantive natural spirals appears the most likely determinants of spiral shape. Some forms of technical production process also produce characteristic shapes but there is substantial overlap in the shapes of spirals produced by most technical methods suggesting that this is not a strong controlling factor on spiral shape. On the current analysis no case can be made for the presence of a type of EVP inspired spiral decoration that can be distinguished from the influence of mechanical, representational or hand movement constraints.

6 Summary and conclusions

Ethnographic and archaeological studies of the structure of decorative patterns have established that they show cultural variation and that the identification of characteristic employment of decorative structure can be used to highlight similarities between cultures or to separate those using fundamentally different decorative structures (Brandmüller, Hrouda & Wickede 1986; Filatova 2008). Within a culture, the geometric structures underpinning decorative patterning have been found to reflect architecture and the structure of settlements and even the social organisation and values of a society (Washburn 1983a, p.4). Studies in this area have tended to focus on the structure underlying the organisation of a pattern, considering, for example, symmetry (Washburn & Crowe 1988) and modularity (Jablan 2002). The analysis and classification method proposed in this thesis is intended as a test of the hypothesis that the measured properties of individual geometric motifs can be similarly used.

Spiral motifs are found across a wide geographical and temporal spread of cultures. Their identification is based on a single defining property – a line winding around a central point at an increasing radius. This definition forms the basis for comparison. The manner of coiling of the spiral and any decorative embellishments to the line can be taken as variables whose expression is controlled by factors within or outside the conscious control of the creator of the decoration. It was anticipated that measurement and comparison of these variables would aid understanding of some of the processes governing their expression.

The method applied in this thesis was first compared with one of the more commonly used classification systems for decorative spirals which assigns them to classes according to their resemblance to mathematical spiral forms. Following this, it was tested on four cultural case studies to establish whether differences could be identified within and between cultures on the overall variable expression and shape of the motifs. Commonalities of variable expression were searched for within the full data set and an explanation for their occurrence sought in naturally occurring spirals either as real forms such as coiling plants and animals or in relation to spiral visual effects arising from abnormal functioning of the visual cortex and in the technological process used to construct the spirals.

6.1 Summary of the method

The development of the method used to analyse the spiral motifs was underpinned by published studies of perceptual grouping and by the survey of the perceptions of spiral motifs carried out during the development of the method. These two sources were used to provide evidence for the validity of choice of variables and to determine constraints on the definitions of spiral motifs. It had been hoped that these two sources of data would provide a basis on which to weight perceptual variables in the application of the method but both sources were too culturally restricted to provide a basis for weighting. A further difficulty arose in that literature review highlighted the variation in weight placed on perceptual grouping variables depending on their absolute values and how they interrelated demonstrating that a single set of constant weighting values would not be appropriate.

The method uses seven variables to describe and classify spirals, one describing the basic form of the motif considered as a notional infinitely thin line and the others, classed as variables of style, describing decorative embellishment applied to that line in the form of irregularity, the path width and spacing between coils and the curvilinearity, rotational length and orientation of the motif.

Key considerations in the development of the method were that it should, as far as possible avoid subjective description and the application of prescriptive top-down mathematical constructs in the description of the spirals. These influences were minimised but the method was not entirely successful in either of these objectives. It may be possible to find an alternative to the use of parametric curves to describe spacing and path width but it seems unlikely that it will be possible to entirely remove subjective judgement from the analysis process and the analyst would need to be aware of this factor.

At the level of practical implementation, considerations were to create a method which was accessible and simple to run. These objectives are largely felt to have been achieved; a low level of computer programming skill would be needed to implement the method as an applet and once that is done operation is simple and there is facility to freely distribute the applet within some geometry software applications. Statistical analysis could have been carried out using freely available software and demands for unusual computer hardware were not high requiring only a graphics tablet for digitisation.

The form data were summarised for the purpose of comparison as density spectra of the tangent sine values. Correlation matrices were used to make these values comparable between spirals. Classification of spirals within and between cultural groups was carried out by hierarchical cluster analysis and discriminant analysis was used to identify the key characteristics of the identified classes and to assess how much they differed.

Problems arising in the application of the classification method to the case study data discussed in Chapter 5 highlight potential to improve the discriminatory power of the method particularly in the interpretation of the spiral form which is too strongly influenced by rotational length and where spectrum density peaks at low frequency allow confusion between spirals with sharply angular turns and those of a constant expansion rate. Improvements to the measurement of the spiral path width and spacing; the curvilinearity of the spiral, should it remain as a separate variable; and orientation could also increase the ability of the classification system to capture finer detail of variation in spiral shape and give the orientation greater weighting when appropriate.

It is possible that the power of the method to distinguish spirals of different cultures could be improved by a different choice of perceptual variables to better reflect the shape and decorative properties of the motifs since visual assessment prior to analysis of the traced spiral outlines resulted in a better differentiation of cultures. The chosen analytical variables might be improved by the application to a larger sample size and broader range of case studies by discarding variables currently being measured if they show consistently non-significant distributions and by identifying more important visual variables with reference to a greater range of data.

Despite the problems with the method identified during its application to the case studies, hierarchical clustering on the recorded data was able to segregate some visually coherent groupings in each case study and to place the motifs which made up the main, and fairly homogeneous, clusters of each study on a scale of variation which broadly reflected changes in form of the spirals. In the creation of decorative typologies within a culture clearer groupings can be proposed by assessing material, object form and the full decorative scheme found on the objects. Although some of the clear divisions in the shape of the spirals could have been identified by visual analysis without measurement, and some aberrations of the statistical classification system avoided, it would be difficult to create a consistent graduated scale of variation on visual assessment alone because of the number of variables affecting the decorative appearance of the spirals.

6.2 Potential for future development of the method

Beyond the improvements to the measurement of individual variables which may improve the precision and accuracy of measurement, there are two possible areas in which the method could be expanded. The first would improve the range of objects from which decoration could be analysed and the second could increase the range of motif types which could be analysed.

6.2.1 Surface curvature and three-dimensionality

The potential to expand the analysis method to encompass motifs on highly curved surfaces would improve the accuracy of results and allow the inclusion of more material. Two cultures which would have added interesting comparative material to those included in this research Spirals on pre-dynastic Egyptian Naqada II period pottery and spirals and spiraloids on Neolithic Chinese pottery of the Banshan and Machang cultures would have added interesting comparative data to the case studies included in this research but both studies had to be excluded because the size of many of the spiral examples in relation to vessel curvature (Figure 6.1) caused distortion in digitisation that made their inclusion within the current set of case studies impractical.

Figure 6.1 Spiral and spiraloid motifs on vessels with high curvature: a.Naqada II period vessel, Petrie Museum b. Banshan culture burial urn, Victoria and Albert Museum, C.286-1938.

Figure 6.2 shows the distortion of a regular logarithmic spiral caused by surface curvature. Solutions to this problem might be found in the use of rectified photography or by reconstructing an approximation of the three dimensional profile of the object and projecting the traced image onto this surface so allowing measurements of distance and angle to take curvature into account. Accuracy in this approach would depend on the accuracy of the profile. Laser scanning now allows highly accurate reconstructions to be made and, where the decoration is three dimensional could, in some instances create a direct reconstruction on the modelled object surface. A lower precision method of creating object profiles by a sequence of diameter measurements and reconstructing these in a three dimensional design programme would create a more accessible means of compensating for a curved object profile. Although this could clearly only be used with objects with a simple curvature profile, its implementation would considerably improve both the accuracy of measurement and the range of objects from which motifs could be analysed.

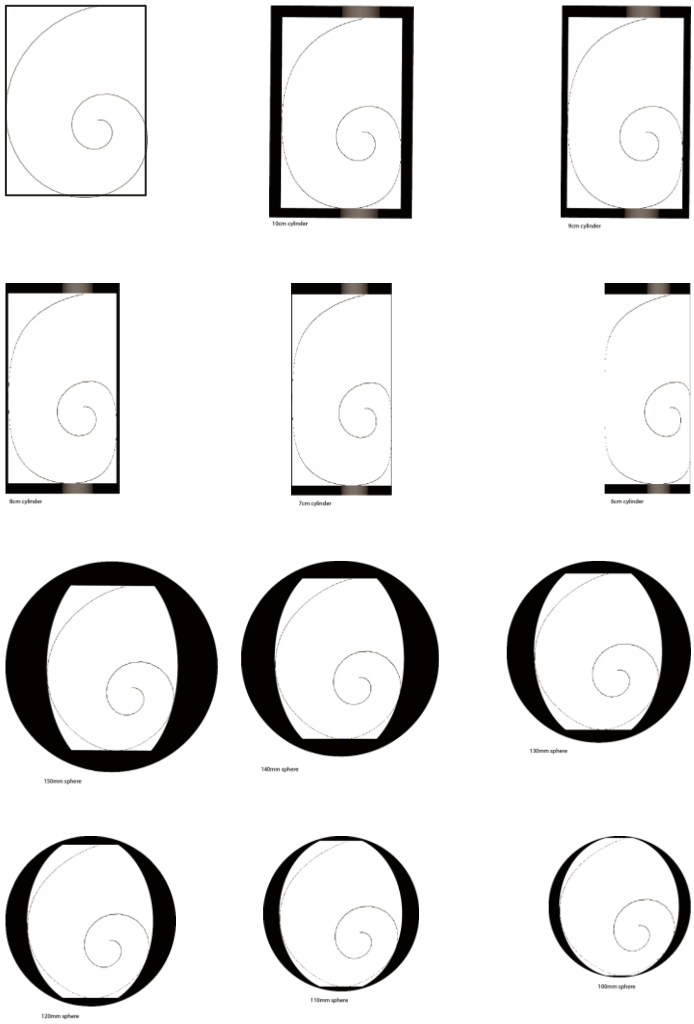


Figure 6.2 Distortion of a logarithmic spiral on cylinders and spheres of increasing curvature.

6.2.2 Expanding the range of motifs

This research focuses solely on single spirals without consideration of their relationships with other decorative elements on the object or the common decorative phenomenon of two linked spirals. This approach was chosen because it allowed comparisons to be made in terms of a single, clearly defined construct. As the scope of the application is broadened to consider relational context, so definitions would broaden beyond the properties of single motifs towards examining the overall structure of decoration which has been the focus of a large body of research particularly in terms of proportioning systems and symmetry. However, it was clear during data collection that it was not always appropriate on a visual level to consider spirals in isolation from other motifs.

There is a clear visual continuum between spiral and false spiral (linked concentric circle) motifs (Figure 2.7, p.41) and both the survey of perceptions of spiral motifs and a number of decorative typologies separated spirals which were linked together as single motif types in themselves rather than collections of spiral motifs (e.g. Petrie 1920, p.20; Jernigan 1986) suggesting that, at least at the level of direct contact relationships, links between spirals need to be considered as an important perceptual factor.

The arguments above support the extension of the method to consider a broader range of motifs under the same set of terms so that they can be placed on the same continuum of change for measurement of similarity. In practical terms, the current implementation of the analysis applet might be adapted to include non-spiral unclosed motifs composed of a single line without great difficulty although the inclusion of closed or self-intersecting motif forms would be more complex. Some motifs which are visually similar such as running spirals and linked concentric circles are very different in terms of the way they would be described. The false spirals would have to be described as a set of separate shapes which link to form a single motif and at that stage problems arise with identifying the limits of what constitutes a single motif. If more types of motif were analysed, it seems probable that the range of variables would have to increase and some variables included for the purposes of analysing spirals would be irrelevant to some other motif types.

6.3 Comparison with mathematical spirals

Studies of decorative spiral motifs have tended to use the terminology of mathematical spirals to either describe decorative spiral shape or as the basis for classification (Zhushchikhovskaya & Danilova 2008; Clegg 2010, p.51; Takaki & Ueda 2007). Andrey and Galli's (2004) study of construction methods for volutes from Renaissance architectural treatises found that matching decorative spirals to mathematical spiral equations was either impossible or produced ambiguous results with equally good matches to more than one mathematical type arising. This, and the findings from two of the classification studies that decorative spirals fell into hybrid classes between mathematical types (Zhushchikhovskaya & Danilova 2008; Takaki & Ueda 2007), should mitigate against the use of mathematical spiral types as class descriptors. There are, however, reasons relating to the production method and source of inspiration for spiral motifs that suggest that conformity to Archimedes' or logarithmic spirals might be expected in decorative spirals. Visual assessment of decorative spirals in the early stages of this research suggested that some spirals appeared to show good agreement to both these forms and also to hyperbolic spirals but that others could be assigned to more than one mathematical class. On the strength of these observations, conformity to mathematical spirals was tested, at a less precise level than that used by Andrey and Galli, by measuring correlation to the density spectra of mathematical template spirals to see if general trends towards particular types of mathematical spiral could be said to exist.

A strong trend towards a logarithmic or hyperbolic spiral form was identified in the decorative spirals and correlation of the spirals to the mathematical type groups was high. There may be a case for making reference to logarithmic spiral forms in studying associations with real natural spirals which are known to have a logarithmic form but, ideally a sample would be taken of spiral shapes from the natural forms themselves as a more accurate description. However, as a more general system it was felt that reference to mathematical spiral forms for description or classification was not ideal because it imposes an arbitrary external class system to which the spirals with lower correlation scores showed a poor visual match and encourages assumptions about shape and precision of measurement which may not be appropriate for decorative spirals. Assigning spirals to mathematical classes as the sole means of classification would also miss the stylistic data which, by its non-random distribution across all four case studies has been shown to be an important set of data to consider in the assessment of spirals as decorative constructions.

6.4 Results of case studies

The intention at the start of this research was to use spiral motifs to differentiate between cultures and to study cultural exchange. From this initial approach, the results of measuring the properties of geometric motifs have shown little potential to use these to characterise culture groups.

Cluster groupings within each of the cultural case studies showed low differentiation in most cases. The Shang/Western Zhou and Egyptian studies had small outlying classes which were visually distinct from the rest of the sample but these contained few spirals with the other classes showing little or no separation in discriminant analysis. The Jōmon study showed high levels of continuity of variation across all identified classes. Only the Cypriot case study had a separated class of reasonable size in the

Class 3 guided painted spirals which also stood out as the most distinctive group in the comparison between manufacturing techniques across the four case studies. Although, to a large extent forming into single groups, a continuum of change in form, rotational length and, in the Shang/Western Zhou study, curvilinearity was detected across the spirals when ranked in their clustering order suggesting that in cases where motif variation were stronger, viewing motifs as displaying graduated change in shape rather than assigning class groups would be the most appropriate way of viewing them.

Cross-cultural analyses of the four case studies using discriminant analysis of the full range of variables also showed a very high degree of similarity. Although the Cypriot and Egyptian studies had extreme values which separated from the main body of data, there was no basis for separating any of the cultures. Similarly, analysis of distribution according to production technique showed no clear separations apart from the Cypriot guided painted spirals.

In Chapter Two, the difficulties of identifying which aesthetic variables are important in cross cultural studies when perceptions are culturally varied and identifying the interaction of grouping variables with each other were discussed. It is inevitable when considering two very separated pairs of cultures viewed from the perspective of a third culture that the chosen variables for analysis will not reflect the full range of factors governing the production of spiral motifs and that, at best, only some of these variables will have been consciously considered in production. In favour of the method proposed in this research, it can be argued that, for the purposes of cross-cultural comparison, the ability to apply a consistent assessment of similarities and differences is important even though it does not necessarily represent the conscious design processes of those constructing the decoration.

Taking a single motif in isolation allows variables to be analysed which would be too complex to address when considering the full range of decorative forms found in a culture. Where these variables can be shown to have a significantly non-random distribution of expression, there begins to be a basis for suggesting coherent preferences, which must be assumed to reflect either deliberate or unconscious perceptual choice or technologically driven constraints on decoration. The findings of the four case studies highlight most strongly the homogeneity of the dataset as a whole. In the analysis of separate variables this was expressed in the commonality of form tending towards a high expansion rate and in low rotational length and high curvilinearity amongst the case studies. The perceptual values of prehistoric and early historic cultures must be largely or completely assessed through the material record. If an expanded data set and analyses of a broader range of motifs could be used to consistently identify common expressions of form and style variables then these might be used with caution to shed light on the perceptual judgements or preferences of the makers of the objects.

6.5 Spiral source

Two possible sources of inspiration for decorative spirals were considered in the research questions of this thesis arising from naturally occurring forms. In the course of running the case study analyses, the distinctive nature of mechanically assisted methods of constructing spirals in the Cypriot study became apparent so variation in production method was considered as another potential influence on the shape of decorative spirals.

6.5.1 Cortically generated spiral forms

Spirals are amongst the geometric motifs identified as visual effects (endogenous visual phenomena – EVP) generated by the abnormal functioning of the optical cortex. Lewis-Williams and Dowson (1988) amongst others have suggested that these appear in art work in cultures which practice religious trance states. This has been attested to by informants in ethnographic studies (e.g. Reichel-Dolmatoff 1978). On this account, the third research question sought to establish whether a 'typical' EVP spiral shape could be identified and, if so, whether there was evidence for this shape influencing decorative spirals.

The type spirals were obtained from external representation of internal visual phenomena produced by those who had experienced them and from theoretical models of visual phenomena so their accuracy must be assessed cautiously. This is especially so given the limitations on the available data in the number of subjects whose experiences were being measured, the homogeneity of the culture group of these subjects and in the range of causatory factors of these stimuli. The theoretically modelled spirals which made up 28% of the data for generating the type spirals showed a low similarity with the drawn spirals so may not be representative of the spirals experienced.

Most studies of the artistic expression of EVP have linked them to trance states (e.g. Lewis-Williams & Dowson 1988; Bednarik 1986; Reichel-Dolmatoff 1978; Dronfield 1994a and b). Although there are indications that states of abnormal consciousness could be associated with religious practices in the case study cultures, in no instance is there sufficient evidence to suggest that EVP were a relevant part of religious practices in any of the cultures studied. The Jōmon case study comes closest to a possible link in the use of spiral decoration in association with figures interpreted as trance dancers (Takashi 2009, pp.136, 140). Any suggestion that EVP were represented in decoration would therefore depend on a strong correlation with EVP spiral test forms and a differentiation from other likely sources and would need to be supported by contextual evidence of other geometric EVP structures featuring in decoration. Three classes of EVP spirals created by clustering were used as the basis for type spirals but there is a high degree of variance in all three groups so no clearly defined types emerged.

Type 3 EVP spirals were the group with the largest number of similar spirals from the decorative case studies and significant numbers of the Cypriot, Shang, and Jōmon spirals correlated with this type. The low average rotational length of the decorative spirals could also fit with the typical characteristics of EVP spirals. These results suggest that an EVP influence on the decorative spirals cannot be ruled out but the variance within the type classes and the possible alternative explanations for the shape of the correlating Cypriot spirals in a technological source; of one of the Shang Dynasty spirals in a representational source; or in the natural trend of human hand movement means that there is not sufficient basis to identify an EVP influence with certainty.

Future work could consider expanding the EVP data set to see if clearer type groups could be identified. A larger sample might allow the division of the generated type spirals according to the generating stimulus. As it stands, characteristic forms arising from individual stimuli may have been lost in the merging of types of stimulus. Culturally the time gap between the studied decorative spirals and the available data for creation of EVP type spirals cannot be overcome but, as Bahn (1988) noted it would be useful to broaden the contemporary geographical scope of studies of EVP as one test of whether inter-cultural consistency pertains. However, it is likely that spirals generated by the human visual system will show the same logarithmic tendency that is characteristic of many natural real spirals and the problem of a potential overlap may mean that the analysis of a single motif type is insufficient to identify the influence of EVP.

6.5.2 Naturally occurring real spirals as sources of inspiration

Although some interpretations of decorative spirals which represent real natural forms are speculative, in most cases, context or supplementary decoration of the spiral could be used to identify a representational source. These spirals were used as a basis for assessing whether cross cultural consistency could be seen in the shape of representational spirals and whether influence from different natural forms could be separated. As a whole, the representational spiral group showed a very high intra-sample correlation suggesting that there is commonality in the manner of representing decorative spirals across the four studied cultures. These spirals tended towards an increasing expansion rate which would be expected from the characteristics of natural spiral forms. Although two of the snake representations were separated from the main cluster, it was not possible to segregate spirals across cultures on the basis of their specific representation. In many ways it is unsurprising that spirals intended to represent natural forms should resemble them in their shape characteristics but there is some evidence in high average curvilinearity values and the prevalence of high expansion rate forms that an influence of EVP or real natural spiral forms can be identified extending into apparently non-representational decorative spirals.

6.6 Potential for expanding the application of the analysis method

Analytical methods based on quantitative description of a set of attributes of a motif have the benefit of largely being able to develop organically to encompass new forms as they are encountered without revision of the stored description of previously analysed motifs whereas descriptions which assign named types to motifs may force re-evaluation of the basic description in the light of new data being received. The quantification of motif shape permits the descriptions to be stored as a dataset which could be added to in future work to increase sample sizes and therefore the robustness of analysis and the range of comparative material available.

It would be interesting to expand the scope of the chosen case studies to include more recent cultural developments. Spiral decoration continued to form a significant part of the decorative canon from the Jōmon into the subsequent Yayoi period; in the later Cypro-Archaic and Classical Aegean periods and into the Eastern Zhou period following the Western Zhou so there would be scope within three of the case studies to continue the analysis forwards and to consider, particularly how the introduction of new technologies and mathematical knowledge may have affected the more recent spiral decorative styles. Low numbers of spirals in some of the clustering groups within the case studies examined limited the power of analysis in some cases. Expansion of the data sets might strengthen results and aid in establishing whether some outlying spirals which were consistently clustered on their own were genuine outliers or whether a larger dataset could associate them as part of a class.

6.7 Conclusion

This research covered a small sample of objects from four cultures working on a single motif as a test of a principle. The proposed method was able to operate across the breadth of variation in spiral motifs in the four studies and to segregate decorative spirals into visually coherent orders reflecting a graduation of change according to the form and certain style properties of the motifs. In the application of the analysis and classification system, the range of overall shape expressions found in spiral decoration indicates that certain expressions of the measured variables are preferentially expressed across the cultures. Evidence for the presence of EVP spirals could not be identified but the range of decoration found across all four cultures was consistent with the influence of natural real spirals and it was shown that some technological variation has characteristic shape expressions which can be identified from this approach. This suggests that there is similar potential value in the analysis of geometric motifs to that found in pattern structure to assess perceptual preferences and change and consistency in decorative expression.

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Appendix 1: Perceptual Survey

The perceptual survey was designed to test perceptions of spiral motifs with four aims: to guide the definition of a spiral; to provide a basis for identifying start and end points; to guide the choice of appropriate variables; and to provide a basis for applying a weighting to variables during cluster analysis. To make this assessment, three types of test were used. Similarity measures were used to judge whether possible variables were perceptually important and were intended to suggest the weighting that should be placed on variables.

Motif descriptions using keywords entered by the survey participant, or chosen from a list presented to participants, were used to support the assessment of perceptions of spiral form, orientation and curvilinearity in addition to similarity tests. Free choice and list-selected descriptors were used to identify the limits of what was considered to be a spiral to help to define the term. Free descriptors were also used to highlight the symbolic and emotional associations participants made with motifs and to highlight the potential for culturally variant interpretation.

The final type of test asked participants to mark the centre or end points of motifs. These tests were mainly used in the development of the method. The centre point tests were used to assess whether any consistent means of identifying the centre of a decorative spiral could be identified. End point tests were used to judge what types of deviation from a smooth curve could be perceptually accommodated as part of the spiral and to identify tracing lines and the effect of disruption to the spiral path.

A1.1 Participants

33 participants with normal or corrected to normal vision were recruited for the survey. 26 of the participants studied design or participated in leisure activities which might imply an interest in design. Participants were informed that the purpose of the test was to identify their perceptions of motifs. They were not told that the main focus of the study was on spirals.

Participants were asked their sex, nationality and age as these variables have been shown to influence perceptual judgement. Gibbs and Anderson (1977), for example, found that contrast variation affected women more than men. Faubert (2002) and

Gutherie, Seely, Beacham *et al.* (2009) found age variation, not necessarily diminution with increasing age, in perceptual discrimination. The influence of cultural background has been shown to have a strong influence on some areas of perceptual judgement (e.g. Chua *et al.* 2005; Yamasaki 1985; Stokrocki 2001). The influence of cross-cultural variation on the assessment of perceptual values is discussed in greater detail in Chapter 2.

Of those survey participants who answered the nationality question, 23 identified as British or English with one participant each from Greece, Syria, Germany, South Korea and Australia and one participant identifying as European. The sample of participants who were not British was too small and too varied to assess the influence of nationality on perceptions. The only instance in which a culturally attributable difference from the British sample could readily be identified was in the description, by the Greek participant, of test motif 90 as the Greek letter gamma when the majority description of this motif was as an L-shape.

Two participants did not state their sex, 25 were female and six male. The influence of the participants' sex could not be measured in individual tests due to the low numbers of male participants. There was no significant difference in the aggregate scores for assessment of similarity between men and women.

The survey participant's ages showed two frequency peaks in the 28-37 (10 participants) and 58-67 (8 participants) groups. To create a clear division in the assessment of age variation, data from participants within the two peak frequency groups were compared. Faubert's (2002) research suggested that the ability to detect bilateral symmetry decrease with age. If the perception of rotational symmetry were also affected this might be expected to affect the placement of centre points within spiral motifs and tests of orientation similarity. Gutherie *et al.* (2009) found that younger participants showed a greater ability to identify shapes from their low frequency structure than older participants. No significant differences were found in identification using higher frequency signals. Within this survey, this might have been expected to affect perception of similarity in irregularity. The placement of the centres of spirals showed no clearly differentiated clustering by age. Equally, the distribution of similarities for irregularity and radial symmetry were not significantly different between the age groups. These results show that age of participants did not have a significant influence on the survey results.

A1.2 Apparatus and stimuli

The survey was conducted online. The motifs were presented in random order on 480x480 pixel squares using a colour matched background to highlight only the intended motif rather than the card shape itself. 196 stimulus cards were used in the survey (Table A1.6, p.263). Nine cards used photographs of decorative spirals, the rest of the cards showed line drawings designed for the purposes of the survey. With one exception, all cards were designed as abstract motifs. The exception, showing a line drawing of a flower (test motif 51, Table A1.6) was intended to test whether the identification of a representational meaning skewed geometric assessments in placing centre point.

A1.3 Procedure

Participants were asked to adjust the screen to ensure that the motifs were fully visible on the screen. There was no limit on the length of time the motifs were displayed and participants chose when to move on to the next test motif. In tests of similarity, pairs of motifs were shown together and participants entered a similarity rating from one to ten. Motif descriptions were tested by free entry text fields for which participants were either asked to enter a short description of the shape of the motif or to describe the motif using up to five keywords. A second test of descriptors asked participants to select from four predefined keywords all those which they felt described the shape accurately. To identify centre and end points of motifs, participants were presented with two copies of each motif and asked to click to place the centre on the right hand motif causing a dot marking the point placed to appear on the left hand motif. The survey participants were allowed to adjust the motif as many times as they wanted. The use of two motifs in placing the centre and end points prevented placement of the point affecting subsequent adjustments. Alongside the test questions, twelve control questions using named non-spiral motif shapes were added asking for binary responses to motif description or placement of a marker. These were intended to reduce the sense that the survey was investigating only spiral motifs as this could have biased participants answers. However, since the majority of test motifs are spiral, this effect may not have been eliminated. The first motif each participant was presented with was used as a practise motif for the placement of the centre point. Participants did not have to answer all questions.

A1.4 Results

The results of the perceptual tests are discussed in detail within the main body of the thesis where appropriate. This section presents the aggregated results of the tests; describes how responses were recorded; and discusses problems and alternative testing methods that might have been employed. Because participants were not obliged to answer all questions, some tests had a relatively low response rate. The lowest number of responses to any question was 18. This figure includes both missing responses due to not having completing the survey and therefore not having been presented with the test question and those participants who chose not to answer a question. Numbers of participants who chose not to answer a question were low when asked to assess similarity or asked only to place a centre or end point. A maximum of two voluntary non-responses were obtained for these types of questions. Higher non-response rates to other questions are discussed in the relevant sections below.

A1.4.1 Similarity

The aggregated similarity results show a skew towards rating motif pairs as similar. Since the question asked participants to assess 'On a scale of one to ten, with one being least similar, how similar are these [two motifs/descriptive motif name]?' it is possible that this trend towards similarity arises from an agreement bias with the participants seeing a response towards the 'similar' end of the scale as more desirable. Possibly a more appropriate approach would have been to use the method employed in a number of published similarity tests where participants are asked to separate clusters of motifs into groups (Beck 1966) since that approach would be more likely to encourage a neutral response. Significant results particularly tended towards higher similarity which meant that differences between the modal scores of variables were minimal and made differentiation for weighting difficult. Because similarity results were high and because the sample group was culturally homogeneous, similarity results were not used to assign weightings to variables in the creation of type clusters. Some similarity pairs of motifs tested more than one variable, for example when testing path width it is necessary to also vary spacing or diameter. It had been hoped that by pairing each variable under consideration with a range of other variables, the impact of having multiple uncontrolled variables could be balanced and a meaningful aggregate similarity score obtained. The very low numbers of significant results hampered this aim and made the assessment of the value of individual variables difficult.

Table A1.1 Similarity values by test motif

motif number	**comparing**	**significant (chi square)**	**modal value (10 represents most similar)**
TG131	irregularity	0.038	8
TG132	irregularity	0.003	10
TG133	orientation, irregularity	ns	
TG134	curvilinearity	ns	
TG135	spiraloids vs. concentric circles	ns	
TG136	spiraloids vs. circles	ns	
TG137	curvilinearity	ns	
TG138	irregularity (low vs. high)	ns	
TG139	irregularity (none vs. low)	ns	
TG140	irregularity (low), colour	<0.001	9
TG141	irregularity (low vs. medium)	ns	
TG142	patterning (type)	ns	
TG143	direction of turn	<0.001	9
TG144	patterning vs. solid fill	ns	
TG145	patterning/local irregularity/curvilinearity	ns	
TG146	spacing, rotational length	ns	
TG147	diameter, spacing	ns	
TG148	diameter, rotational length	<0.001	9
TG149	diameter, spacing	ns	
TG150	spacing (none vs. constant present), path width, eye presence	ns	
TG151	form, path width, spacing (none vs. increasing)	ns	
TG152	path width (constant vs. increasing), form	ns	
TG153	spacing (none vs. increasing), path width (constant vs. increasing), form	ns	
TG158	orientation	ns	
TG159	rotational length (more than 360˚ vs. less than 360˚)	ns	
TG160	rotational length (more than 360˚ vs. less than 360˚)	ns	
TG161	orientation	0.03	9
TG162	spacing (constant vs. fluctuating), position of centre	ns	
TG163	form, diameter	ns	
TG164	interrelationship (linked vs. unlinked)	ns	
TG165	interrelationship (radiating vs. scatter)	ns	

TG158A	orientation	0.001	9
TG158B	rotational length, centre diameter	ns	
TG158C	rotational length, spacing	ns	
TG158D	rotational length, spacing	0.016	9
TG163A	form, spacing (constant vs. fluctuating)	ns	
TG163B	form, spacing (constant vs. fluctuating)	ns	
TG163C	form	<0.001	8
TG164A	interrelationship, orientation (consistency within group)	0.018	8
TG164B	orientation	0.001	8.5
TG164C	interrelationship three-stemmed spiral vs. three-stemmed wave	ns	
TG164D	interrelationship three-stemmed spiral vs. three-stemmed circle	ns	
TG164E	interrelationship three-stemmed spiral vs. three-stemmed arc	ns	
TG164F	interrelationship centre linked vs. border linked	ns	
TG164G	interrelationship (varying direction of turn), form	ns	
TG164H	interrelationship (centre and border linked vs. centre linked), rotational length	ns	
TG137B	curvilinearity	ns	
TG139B	colour	0.003	10
TG139C	colour	0.004	9
TG142B	direction of turn, local irregularity	ns	
TG142C	direction of turn	ns	
TG147B	irregularity (low), spacing (fluctuating low vs. fluctuating higher)	ns	
TG151B	form, spacing (none vs. increasing), eye presence	ns	

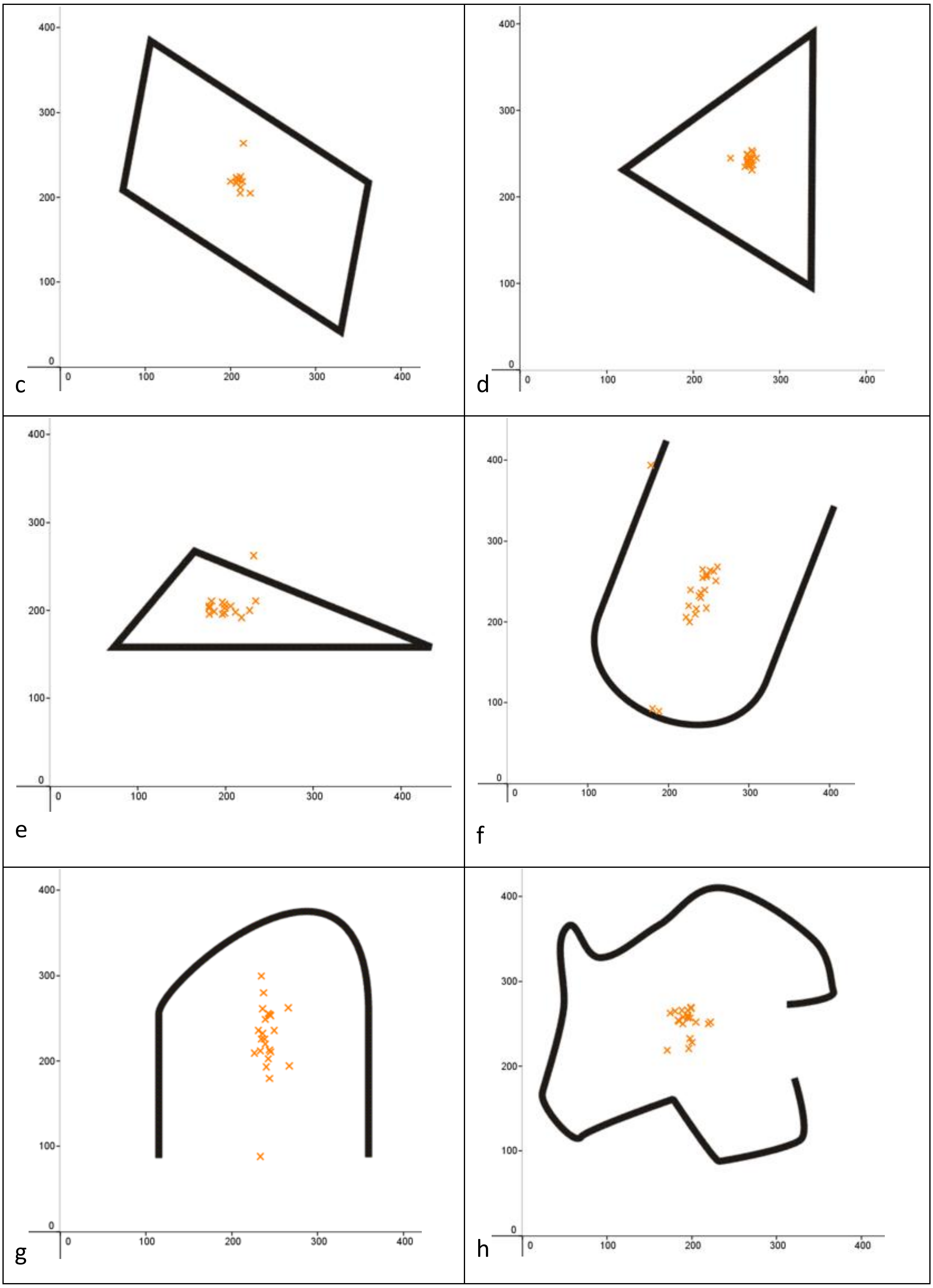
Table A1.2 Overview of similarity ratings by variable

variable	**number of times tested**	**significant similar (mode above 5.5)**	**significant dissimilar (mode below 5.5)**	**median score across all significant tests**
diameter	4	1	0	9
direction of turn	4	1	0	9
rotation	8	2	0	9
orientation	5	4	0	8.75
irregularity	9	3	0	9
path width	4	0	0	n/a
spacing	13	1	0	9
form	9	1	0	8
colour	3	3	0	9
curvilinearity	4	0	0	n/a

A1.4.2 Placement of centre and end points

Five polygonal test motifs (Figure A1.1a-e) were used to assess how precisely participants placed points and to test the extent of centre agreement between participants with simple shapes which exhibited a high degree of symmetry. These results showed a high level of agreement for the regular heptagon and the parallelogram. A similar result was obtained for the regular hexagon, although it is possible that the three participants who placed points above the main group were abstracting a cube. In both cases clustering is tight indicating a precise placing of points. With any degree of irregularity, however variation in the placement of centre point increased. For unclosed shapes (Figure A1.1f-h), there was a further increase in variation in the placement of centre points. A regression to the axis of symmetry is visible in unclosed symmetrical or near-symmetrical shapes but the spread of points along the axis of symmetry suggests that either the centre of gravity or the centre of the bounding rectangle could have been used as a basis for assessment of the centre and no consistent basis for preferring any one centre determination method emerged.

Figure A1.1 Symmetrical polygons: a. test motif 166, b. test motif 168, c. test motif 167, d. test motif 56, e. test motif 169. Unclosed shapes: f. test motif 54, g. test motif 55, h. test motif 29. (Continues onto next page.)



Some results for the tests of placement of centre or end points were excluded where participants were believed to have misread the question (for example marking the outermost end point of the spiral on the innermost end point). These results were excluded from analysis as were points which were placed too far from the motif to draw accurate conclusions about the point they were trying to indicate. In tests to identify the outermost end point, points which were a distance of more than six times the line width from the termination of the line and more than two point diameters from any part of the motif path were discounted. Points which were far from the black or coloured line of the motif might indicate that the participant was identifying the ground as the dominant motif but there was too little consistency in the placement of off-motif points to suggest any common interpretation of the ground as the dominant spiral.

In tests to mark the centre of the motif, a greater latitude had to be allowed, only points which fell outside the bounding rectangle of the motif were excluded. In 18 tests (test motif nos. 92-101, 100a-c, 166-169), participants were asked to both describe the motif shape and mark the centre point to test whether interpretation of the shape had an influence on the perception of its geometric properties as indicated by the centre point location. This was assessed by coherence of grouping of point placement amongst participants who assigned representational or non-representational meanings. There was a markedly lower response to the placement of centre points for these questions than for questions which only asked for placement of a centre marker. This is probably due to participants forgetting to answer both parts of the question; it would have been appropriate to introduce a prompt to encourage answering both parts before continuing.

A1.4.3 Motif descriptions

The use of descriptors in defining a spiral assessed both free text descriptions of shapes to see how frequently the term 'spiral' or synonyms were used and to identify which motifs were readily identified as spiral. Table A1.3 presents the results of motif shape descriptions. Table A1.4 shows the terms used when participants were asked to describe the motif without an emphasis on its shape. These values were used to assess culturally variant responses to motifs in Chapter 4. Where keywords were difficult to interpret or could be assigned to more than one conflicting category (representational or geometric) they were recorded as ambiguous. The predetermined keyword test was used to identify the rotational length needed to define a motif as a spiral (Table A1.5). Questions asking for description had the lowest response rates including some responses stated as 'don't know'. As noted in Chapter Two, this non-response has implications for cross-cultural validity.

A1.5 Potential expansion of the perceptual survey

To refine the method it would be useful to expand the perceptual survey to a more varied sample group and to explore how appealing participants find different spiral motifs – this could be used to add to the assessment of whether spirals which conform to subjective or objective natural forms would be likely to be represented in decoration by assessing whether they appeared to be consistently preferred as spiral types. It would also be interesting to introduce some tests in which participants are asked to draw spirals to look for commonalities and to see what attributes are assigned to spirals when subjects are given a free choice to draw spirals. Asking participants to copy or draw a natural spiral form with and without a visual cue could be used to assess how far the drawings differed from actual spiral shape in the representation of natural forms and what the key characteristics of the form appeared to be.

Table A1.3 Free text descriptors used for motif shape by test motif number and survey participant number.

Test motif number	86	87	88	89	90	91	92
P1							
P2						iron cloths	
P3						An iron	Sleeve
P4						rhombus	unsure
P5							
P6	wave	loops	wavey spiral		upside down L		hook
P7	wave	extended spring	spiral with ripples from centre	triangular key pattern	rectangle with rectangular shape removed from bottom right		angular spiral
P8	wave						
P9	wave	twisted wire	ammonite	celtic carving	irregular hexagon	spiral	spiral bend
P10	wave	random curly	segmented spiral	triangular spiral	L shaped	geometric spiral	random
P11	wavy line	swirl	starburst	triangular key	L shaped	key	irregular
P12				Triangular	L shape		
P13	wavy	spring	spiral	triangle	rectangular	angular	angular
P14	wave	wiggle	waves		box	trapezoid spiral	
P15	wave	looped wave	spiral	triangular spiral	upside down L	rectangular maze	broken angular rectangle
P16		bent spiral	double anti clockwise spiral	triangular key	L shaped	angular square clockwise spiral	irregular broken pentagon

Test motif number	86	87	88	89	90	91	92
P17	wave	looped	spiral	spiral	don’t know	spiral	spiral
P18	wave		fossil	maze	L		kite
P19	wave	freehand loops	helix	triangular curl	hook	stylized helix	stylized curl
P20	wave	loops	sunburst	knot	L shape	angular coil	angular spiral
P21	wave	a curvey line	wavey sunlike spiral shell	triangle with in a triangle	upside down L	a maze	
P22	wave	Squiggle		Triangular Spiral	Upside down L shaped box	domestic iron shap[e]	
P23	wave	scribble loops	ammonite	triangle		iron	kite
P24							
P25							
P26	zig zag wave	coil	spiral	Triangle			open pentagon
P27							
P28				triangular coil	L-square		collapsed pentagon
P29	W	squiggle	Coil	Maze	Upside down L.	Rhombus	paper clip
P30			sandy sun	triangle spiral	broken rectangle	broken spiral	
P31	wavelength	scribble	well aligned	trianlged spiral	Greek letter gamma	rectangular spiral	almost pentagon
P32	wave	looped line	spiral coil with radial waves from centre point	triangular double spiral	closed rectilinear shape. inverted L	trapezoid spiral	angular line
P33				traingulation repeating motif			

Test motif number	93	94	95	96	97	98	99	100
P1	line or kite		arrow		kite		bowl	
P2			many uncomplete triangles		sleeping pinguin		smile	tornado
P3	Kite	Spaceship	Mountain		Suit	Coffin	Bowl	Spiral
P4								
P5		Spiral	zig zag					
P6	jagged spiral			jagged spiral	jagged spiral	jagged spiral		orange spiral
P7	angular spiral	angular spiral	angular scroll	angular spiral	angular scroll	angular spiral	semicircle	spiral
P8						angled		spiral
P9	spiral bend	spiral bent	squiggle spiral	spiral	spiral	spiral bent	cup	spiral
P10	geometric spiral	geometric spiral	random spiral	random spiral	geometric spiral	geometric spiral	semicircle	spiral
P11	key	asymmetrical key	distorted key	irregular key	asymmetrical key		arc	spiral
P12				Irregular				Spiral
P13	angular	angular	triangular	angular	angular	angular		spiral
P14							bowl	spiral
P15	broken angular rectangle	abstract rectangle	extending right angled triangle	abstract rectangle	exploding rectangle	abstract rectangle	arc	this is a spiral
P16	irregular fractured pentagon		fractured triangle	irregular angular anti clockwise spiral		broken irregular hexagon	bowl	anti clockwise irregular spiral
P17	spiral	spiral	spiral	spiral	spiral	spiral	semi-circle	spiral

Test motif number	93	94	95	96	97	98	99	100
P18		maze	triangle		coffin	house	smile	
P19	stylized curl	stylized helix	stylized helix	stylized spiral	stylized helix	stylized helix	half circle	A spiral
P20	angular spiral	zig-zag coil	hook	angular coil	hook	zig-zag hook	arc	spiral
P21	nearly a box	mis shaped box	broken triangle	several straight lines at different angles	a broken kite	triangle within opensided rectangle	crescent	spiral
P22	e		sharp e	jagged spiral	upside down e	e shape	0	Spiral
P23	paperclip		triangular	diamond	kite	kite	smile	coil
P24								
P25						line		
P26	open pentagon	meander	spiral geometric	geometric spiral	geometric spiral	geometric spiral		spiral
P27								
P28		collapsed heptagon						spiral
P29	Broken pentagon	Broken rhombus	bent triangle	Diamond	broken coffin	paper clip	smile	spiral
P30			open triangle	broken legs lines	broken diamond		half circle	spiral
P31	wanna be pentagon	triangled spiral	abstract and unbalanced	squared spiral	destroyed paperclip	wanna be spiral	half circle	spiral
P32	irregular angular spiral	irregular angular spiral	angular line	irregular angular spiral	irregular angular anticlockwise spiral	irregular angular anticlockwise spiral	semicircle	circular anti-clockwise spiral
P33								

Test motif number	**101**	**166**	**167**	**168**	**169**	**100a**	**100b**	**100c**
P1	line			Hexagon				
P2		7-sided	rectangle	hexaedr	triangle	bowl	pie chart	pie chart
P3	Saucepan	50 pence piece	Window	Hexagonal	Hill	Orange segment	Pram	Pacman
P4					triangle		cheese	
P5								
P6	crooked line		quadrangle			semi-circle	pacman	
P7	rudimentary spiral	heptagon	parallelogram	hexagon	triangle	semicircle	segment of circle	segment of a circle
P8	random			hexagon				
P9	squiggle	heptagon	parallellogram	hexagon	triangle	bowl	packman	packman
P10	random spiral	heptagon	parallelogram rhomboid quadrilateral	hexagon	irregular triangle	semicircle	circle segment	segment of circle
P11	hook	no idea	rhombus	hexagon	triangle	semicircle	no idea of its name - utility clothing mark	part circle
P12					Scalene triangle			
P13	irregular	heptagon	parallelogram	hexagonal	triangular	semicircle	part of a circle	segment of a circle
P14		heptagon	trapezoid	hexagon	triangle	semi-circle	pie	pie
P15	bent hook	septagon	rhombus	hexagon	isosceles triangle	half a circle	three segments of a circle	three quarter segments of a circle
P16		regular heptagon	parallelogram	equilateral hexagon	scalene triangle	half	circle with radial wedge missing	circle with radial wedge missing

Test motif number	**101**	**166**	**167**	**168**	**169**	**100a**	**100b**	**100c**
P17	loop	heptagon	parallelogram	hexagon	triangle	semi-circle	pacman	pacman
P18		honeycomb	rectangle				cheese	pacman
P19	Freeform	heptagon	rhombus	hexagon	scalene triangle	half moon	circle with a wedge removed	circle with a wedge removed
P20	loose coil	heptagon	rhombus	hexagon	triangle	semi-circle	circle segment	circle segment
P21	a worm	7sided penny	rectangle	hexagon	triangle	half a circle	a circle with a 6th cut out	looks like an orange with 2 segments cut out
P22		heptigon	squew wif rectangle	hexagon	Triangle	Semi Circular	Pie	pie
P23	loop			hexagonal	triangle	semicircle	circle	cheese
P24								
P25		heptagon		hexagon	triangle		pie	
P26				Hexagon	Triangle	half circle		
P27								
P28				hexagon				
P29	Lump	heptagon	diamond	hexagon	triangle	semi-circle	part of a circle	part of circle
P30			skew rectangle			half close circle		
P31	dreamt to be a circle	heptagon	skewed rectangular	hexagon	non equilateral triangle	half closed circle	pac man	two-thirds of a circle
P32	irregular curled line	regular heptagon	quadrilateral	regular hexagon	scalene triangle	closed semicircle	two thirds circular segment	2 thirds circular segment
P33								

Table A1.4 Free text keywords for motif description. Participants were asked to enter up to five keywords.

Test motif number	**154**					**155**				
P1										
P2	snail	fossil	stone	spiral		snake	spiral			
P3	Spiral					Spiral	Rope	Snake		
P4										
P5										
P6						spiral	tight	stone	ancient	clockwise
P7	spiral	clockwise	carved			spiral				
P8						spiral	coil	spring	concentric	
P9	spiral	carving				celtic	spiral	carving		
P10	open	spiral	ethnic	ancient	weathered	spiral	regular	organic	textured	ethnic
P11	spiral	bas-relief				coil				
P12										
P13	spiral	thick	complete	perfect	regular	spiral	cicular			
P14	spiral	snail	shell			spiral				
P15	spiral	relief	carved	concave	open	spiral	carved	relief	concave	evenly spaced
P16	spiral	two-dimensional	clockwise			clockwise	spiral	two dimensional	regular	

Test motif number	154					155				
P17	spiral					spiral				
P18	shell	fossil	spiral	wave						
P19	helix	spirl	curl			spiral	curl	helix		
P20	coil	spiral	loop	regular	curlecue	spiral	loop	coil	regular	
P21	spiral	rough	stone	grey	naive	spiral	blue grey	stonework	deep carving	eye like
P22	Spiral	Carved	stone	Old	Snail	Fossill	spiral	snail	stone	old
P23	curly	coil	waves	ammonite		spiral	coil	fossil	ammonite	
P24										
P25						spiral	pattern	stone architect		
P26						spiral				
P27										
P28										
P29	Coil	spiral	snail shell	paisley	twirl	spiral	mosquit o coil	curl	twirl	paisley
P30	Spiral	Deep	circular	Ston	brown					
P31	historic	spiral	stone	timeworn		spiral	stone	homogeneous	balanced	
P32	spiral	coil	clockwise			spiral	coil	anti-clockwise		
P33										

Test motif number	156					157				
P1	spiral	tribal	wave	horn	curl					
P2	bone	six	curl	hook		music clef	spirals	flowers	curvatures	
P3	Loop					Curly	Elegant	Intricate		
P4	spiral					spiral	iron			
P5										
P6	spiral	wave	anticlockwise	bone	thick					
P7	spiral					branching	spirals	swirling		
P8										
P9	spiral	pendant	hook	morphed shape		series	scrolls	interlocking		
P10	spiral	wave	irregular	curlicue	ethnic	scroll	curlicue	floral	art deco	pleasing
P11	hook	curve				scroll	organic	water	fronds	growing
P12										
P13	apiral	curved	thick	white	necklace	spiral	irregular	flowery		
P14	spiral					spirals				
P15	spiral	white	concave	varied in width	hole for hanging	scroll	spiral	metal	ornate	double centre
P16	spiral	flat	oval	clockwise		spiral	asymmetric			
P17	spiral					spiral	swirl			

Test motif number	156					157				
P18						scroll	music note	spiral		
P19	spiral	helix	curl			curl	scroll	spiral		
P20	spiral	coil	irregular	organic		spiral	curlecue	coils	ornate	organic
P21	spiral	delicate	bone like	smooth	wave like	curves	smooth	flows	wave like	dramatic
P22	Spiral	Curved	Loopy	Number	White	curly	spiraly	musical	scroll	beautiful
P23	curls	waves	shell	ammonite		curly	scrolls	loopy		
P24										
P25										
P26	hook	maori	spiral							
P27										
P28										
P29	spiral	curl	paisley	pendant	twirl	spiral	curl	coil	swirl	
P30	white	spiral	light			spiral	black	metal	asymetric	
P31	ancient Greek	abstract	spin			multiple spirals	growing plant	metallic		
P32	spiral					spirals	scroll	curlicue		
P33										

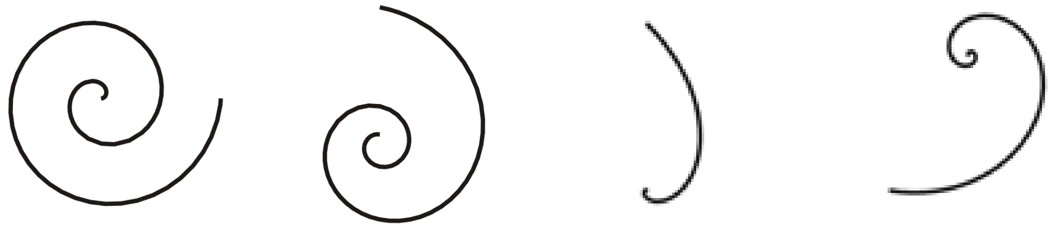
(Table A1.4 continued)

Test motif number	**157b**				
P1					
P2	flower				
P3	Star	Flower			
P4	green				
P5					
P6	plate	pattern	flower	expanding	central
P7	flower	overlapping petals			
P8					
P9	regular	flower	dodecagon	patterned	
P10	geometric	floral	regular	complex	arabic
P11	radiating	Fibonacci	Moorish		
P12					
P13	circular	flowery	symmetrical	hexagonal	
P14	flower				
P15	star shaped	dahlia	daisy centre	interlocking diamonds	extending
P16	flower	mandelbrot			
P17	flower				
P18	hills	stones	trees	peacock	
P19	flower	sun	spirograph		
P20	floral	regular	organic	interweaving	
P21	beautiful	colourful	lovely	dramatic	interesting
P22	Window	Green	centred	flower	plate
P23	flower	mosaic	star		
P24					
P25	flower	plate	repeated	geometrical	leaf
P26	Flower	mosaique	geometrical		
P27	circular	green	curvy	dotted	symmetric
P28	flower	religious	twelve-sided	dots	green
P29	flower	stained glass	plant	curves	symetrical
P30	Pattern	dots	Symetric	green	
P31	circular	flowers	central	dotted	green
P32	radial	spiral	elipses		
P33					

Table A1.5 Frequency of choice of predefined keywords. The division of the 'spiral' keyword by rotational length was carried out during analysis and not presented to survey participants.

test motif number	loop	spiral				hook	coil	figure of eight	double spiral	zig-zag	key pattern	wave	tile pattern	whirl	meander	scroll	curlicue
		<270	270-360	361-450	>450												
102	13			2		6	8										
103	13			2		5	10										
104				6		6		4	11								
105	14			2		7	10										
106	13			3		5	9										
107		0								22	0	5					
108		0								6	1	21					
109			2							1	5	20					
110		5									4		14	13			
111			4							0	4	20					
112			2			5					16				4		
113				8						2	6	15					
114					13					1	10	12					
115					5	3					16				1		
116					10		3									15	6
117			0			2					18	4					
118			0			4					16	2					
119			0			3					15	2					
120			2			9					12	1					
121			0			12					10	1					

Table A1.6 The set of stimulus cards identified by test motif number



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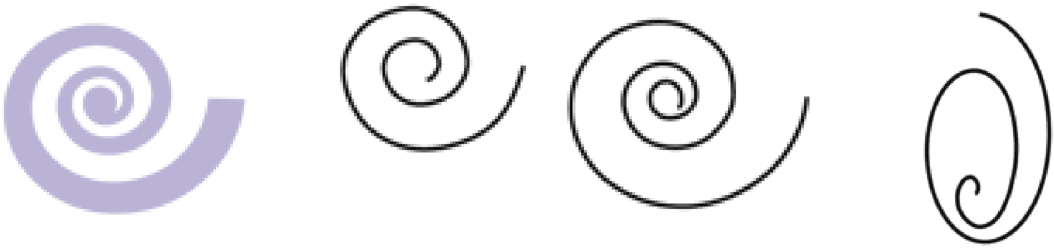

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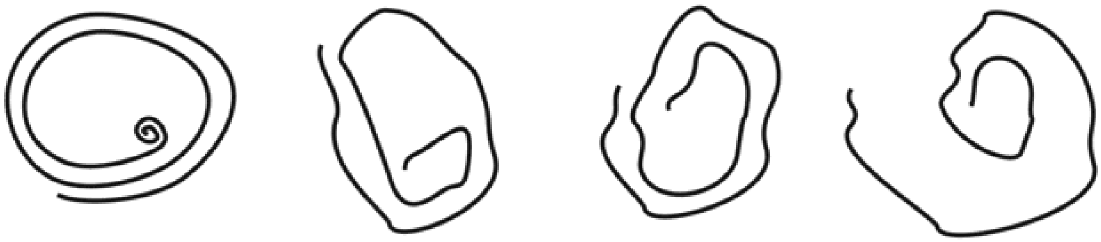

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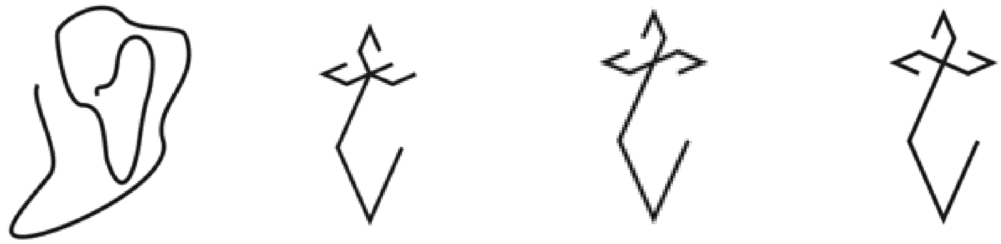

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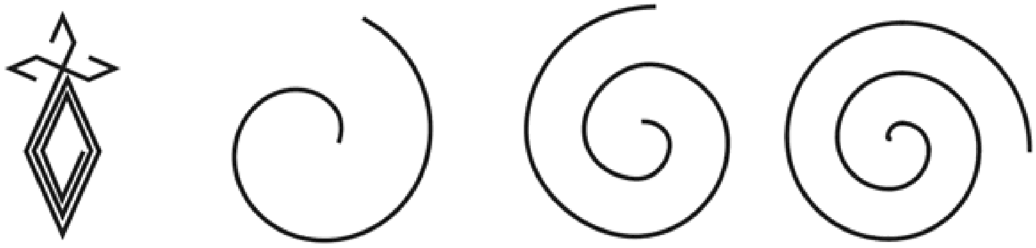

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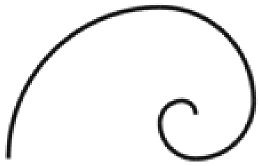
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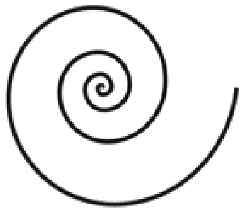
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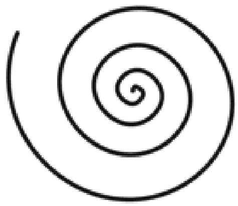
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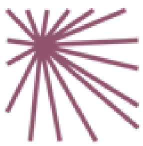
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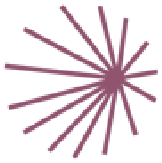
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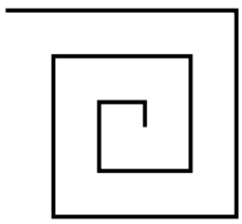
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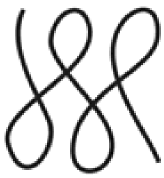
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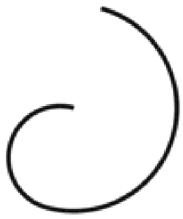
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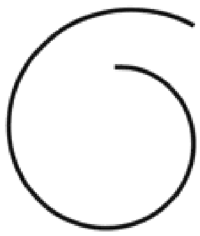
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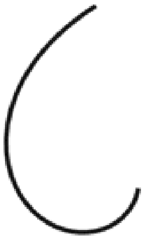
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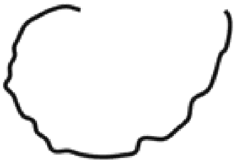
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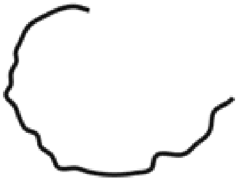
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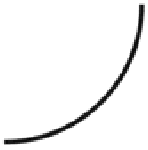
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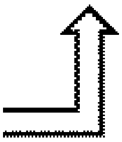
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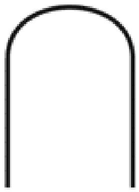
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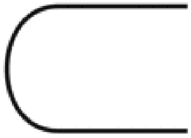
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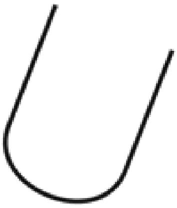
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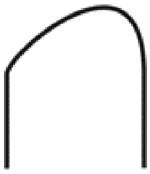
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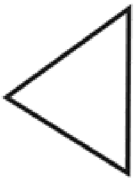
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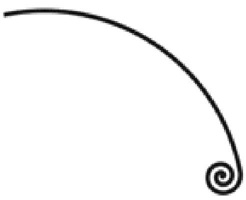
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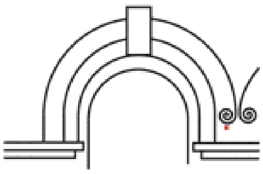
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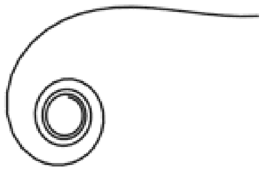
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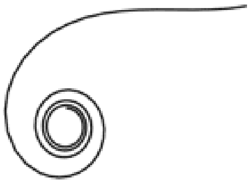
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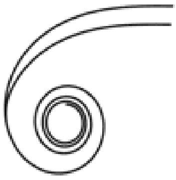
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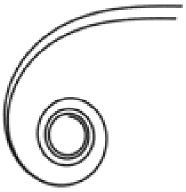
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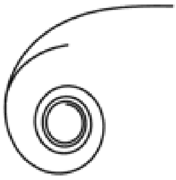
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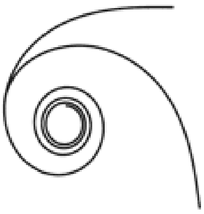
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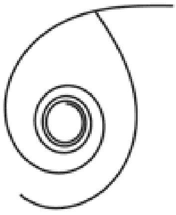
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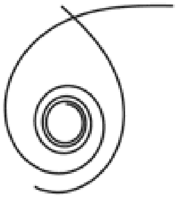
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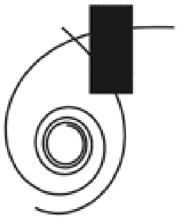
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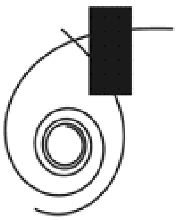
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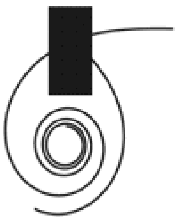
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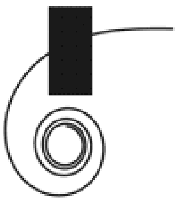
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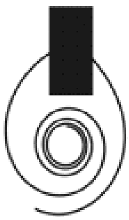
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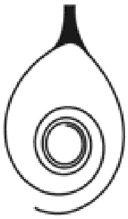
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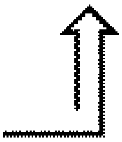
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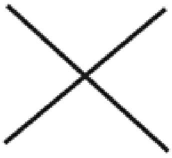
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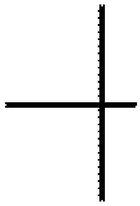
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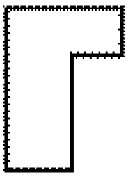
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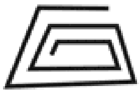
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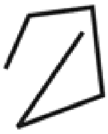
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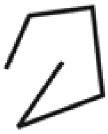
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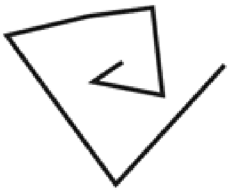
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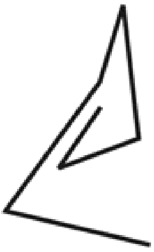
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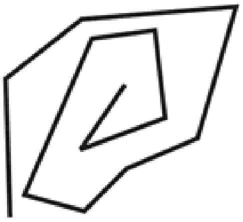
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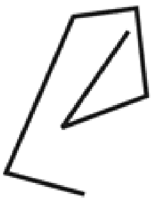
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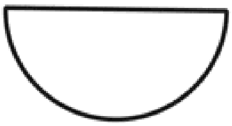
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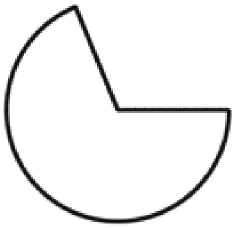
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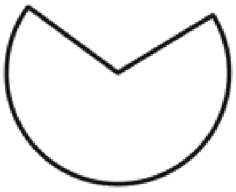
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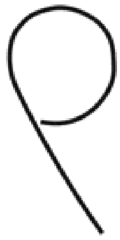
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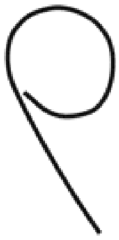
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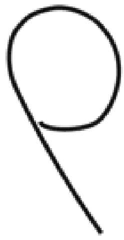
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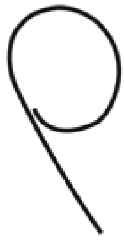
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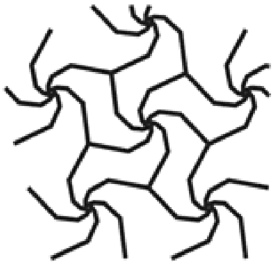
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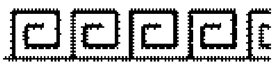
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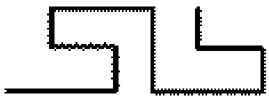
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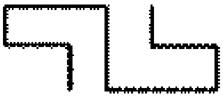
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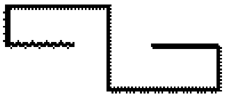
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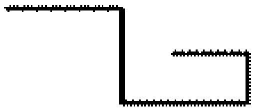
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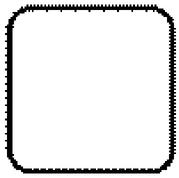
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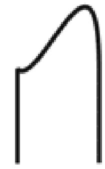
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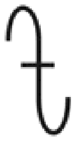
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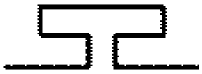
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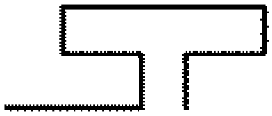
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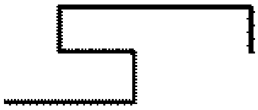
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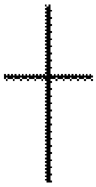
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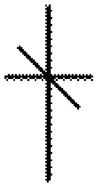
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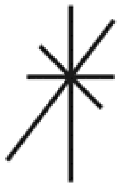
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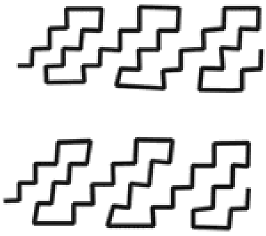
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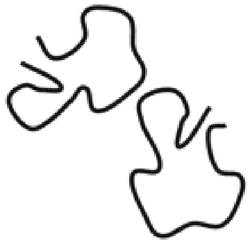
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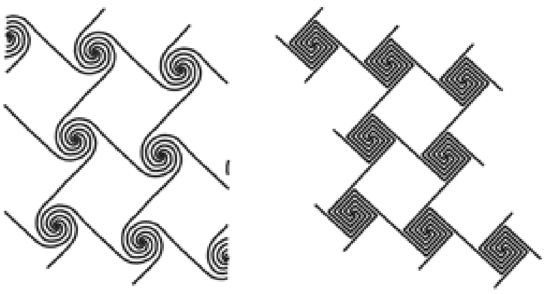
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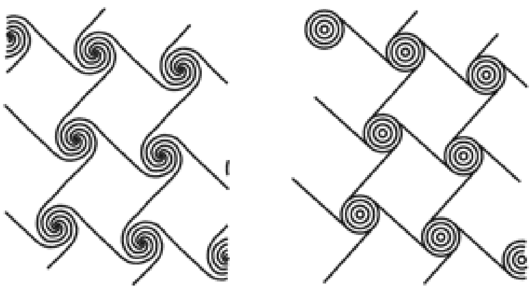
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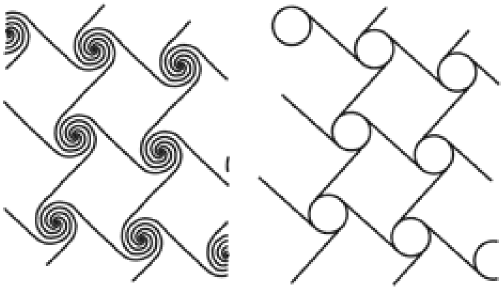

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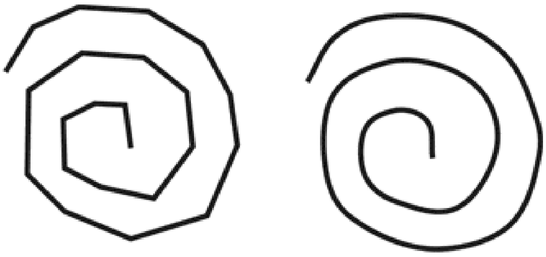

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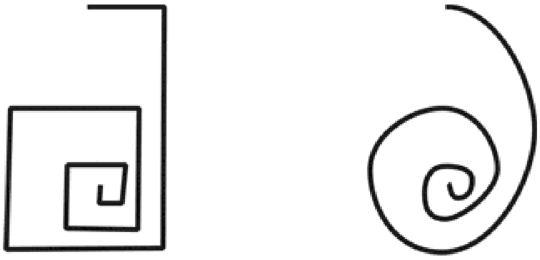

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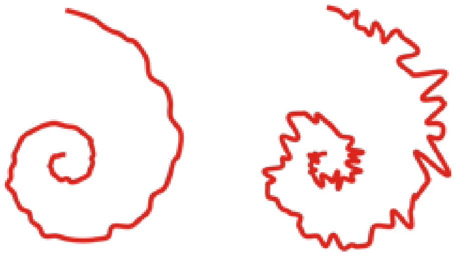

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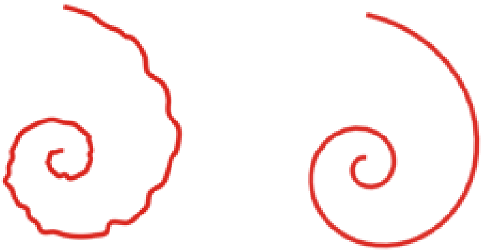

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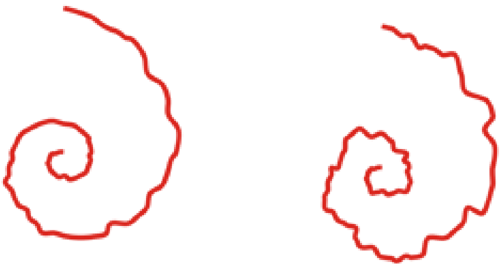

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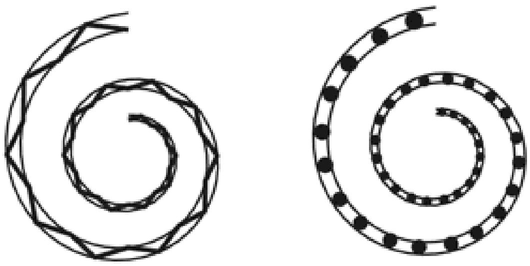

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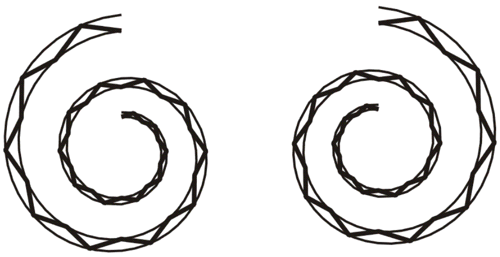

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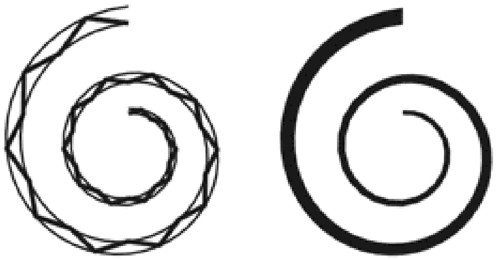

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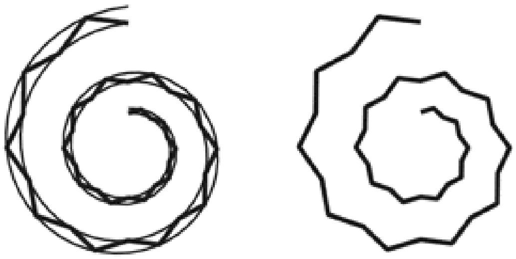

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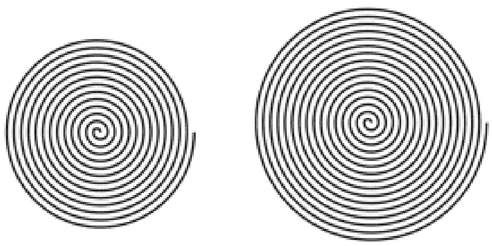

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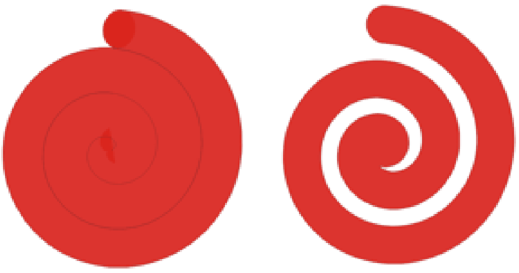

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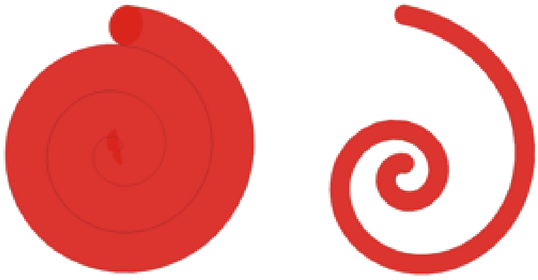

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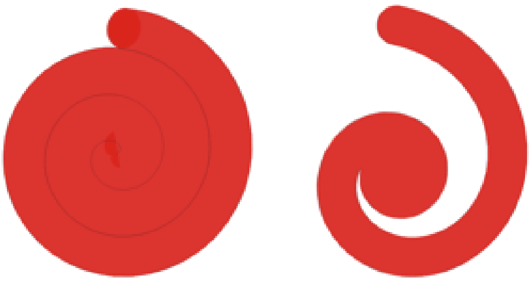

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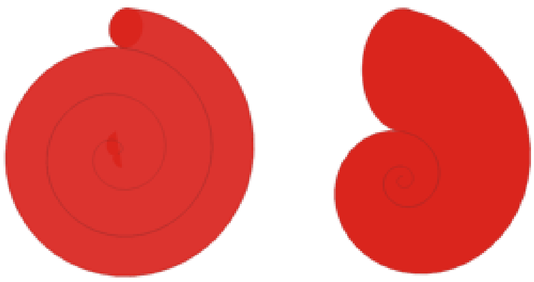

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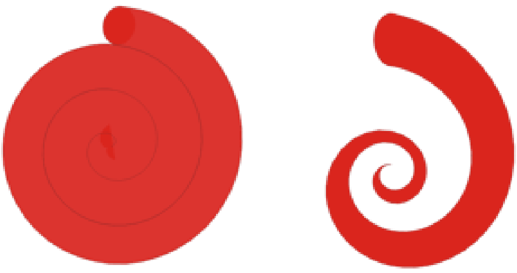

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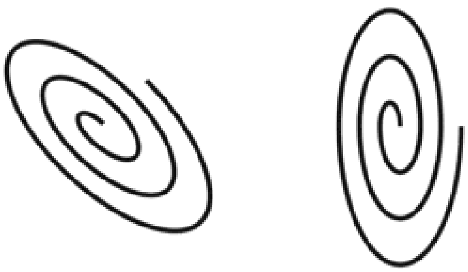

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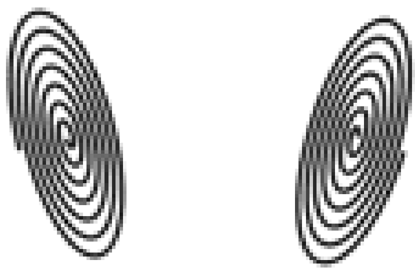

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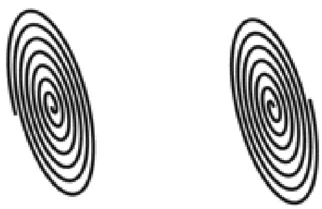

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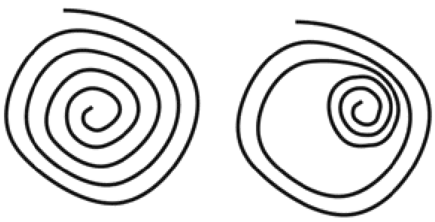

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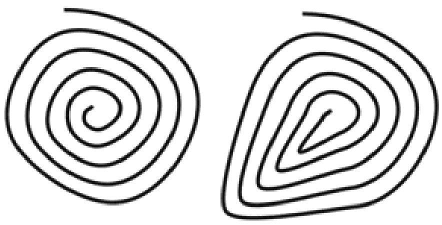

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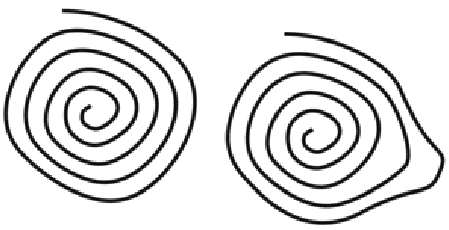

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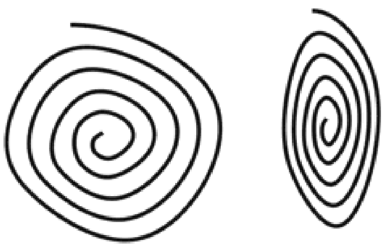
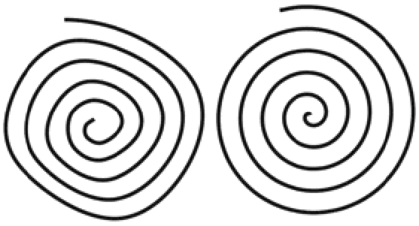


163b



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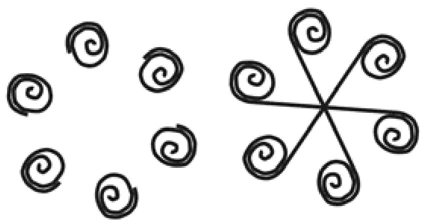

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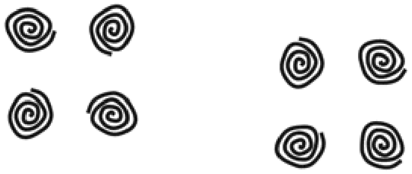

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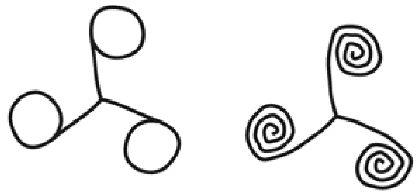

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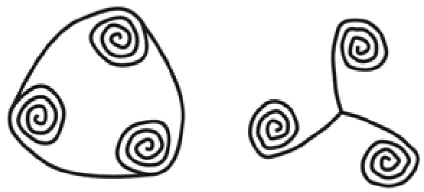

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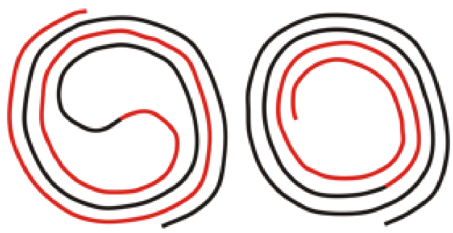

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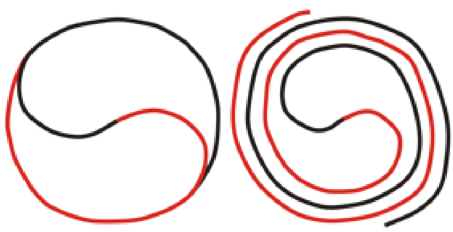
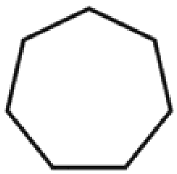


164h

165



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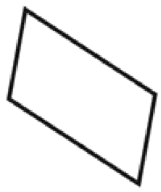

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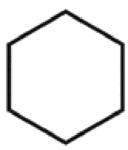

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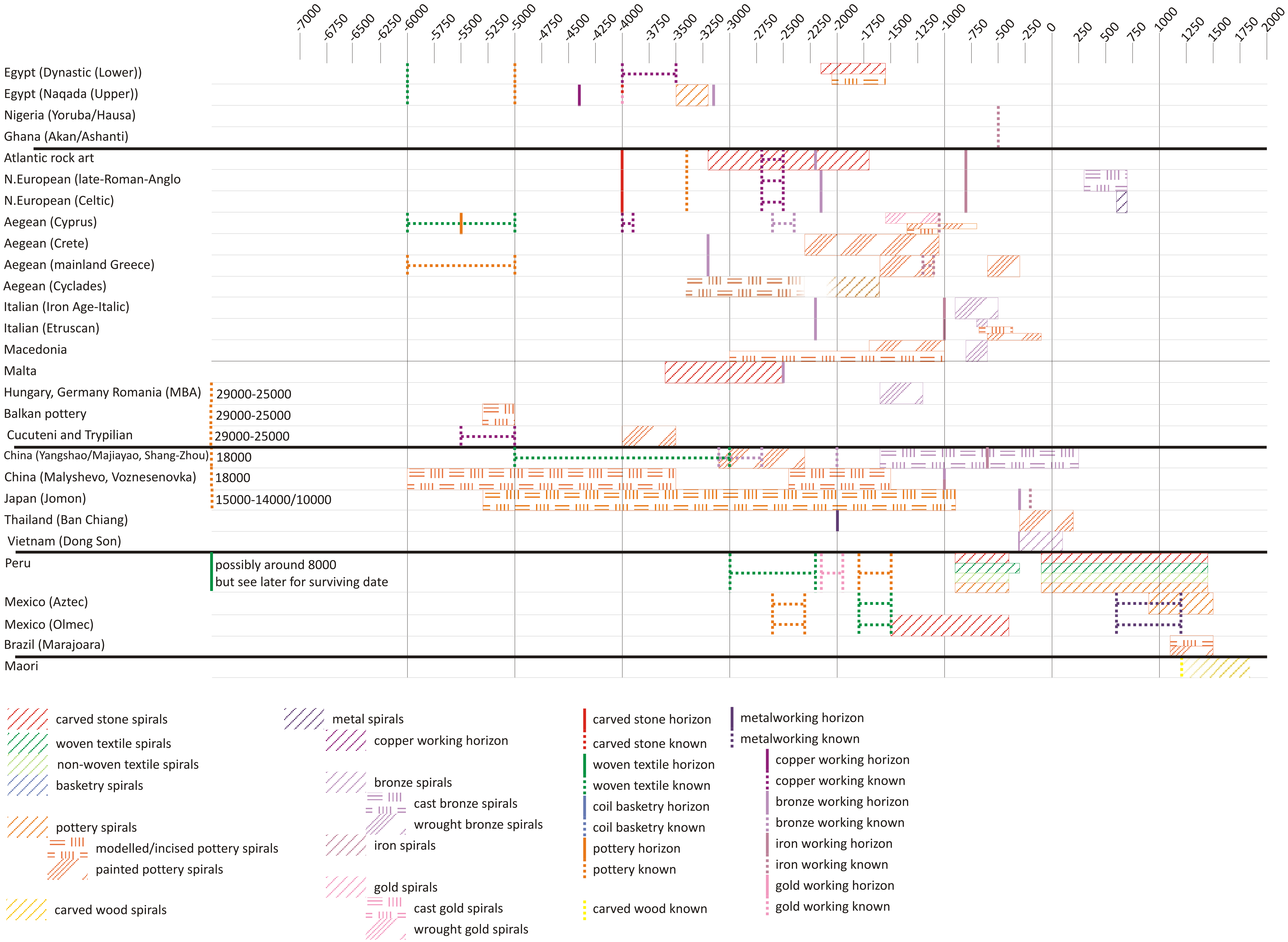


Table A2.1 Early examples of spiral decoration and the distribution of prehistoric and early historic cultures in which spirals were commonly occurring motifs approximate technology horizons indicated reflecting dates of introduction/discovery or earliest known examples

Table A2.2 Contextual and style data for the Jōmon case study

Context data							Style data														
Museum number/ publication	**Museum ID/ plate no.**	**Object number**	**spiral numbers analysed**	**Object notes**	**period***	**place**	**rotation**	**orientation**	**curvilinearity**	**irregularity**	**path width median**	**path width trend error**	**spacing median**	**spacing trend error**	**sampling resolution**	**path width trend coefficients**			**spacing trend coefficients**		
British Museum	1998,1218.1	JBM1	1	pot with spirals/spiraloids	MJ		7.99	0.30	0.65	0.27	1.27	43.22	1.02	1.86	0.04	0.03	-0.37	1.21	0.05	-0.71	1.38
British Museum	OA+.654	JBM2	1	pot with spiraloids	LJ	Hokkaido	6.63	0.36	0.35	0.28	0.74	15.87	2.44	0.01	0.05	0.03	-0.24	0.45	33.88	-24.20	1.52
			2				6.80	2.71	0.75	0.28	0.77	57.14	2.38	0.02	0.05	0.03	-0.24	0.64	-7.82	2.08	-0.11
British Museum	temporary exhibition loan from the Tsunan Town Board of Education, Japan	JBM3	1	crown pot, representational - snakes	MJ	Iwanohara site, Nagaoka City	8.50	2.63	0.79	0.41	1.74	17.58	1.55	6.52	0.04	0.01	-0.08	0.31	0.25	0.33	-1.23
			2				11.37	2.59	0.65	0.40	0.91	19.88	1.38	8.46	0.04	0.00	-0.02	0.10	0.08	-0.43	0.80
British Museum	temporary exhibition loan from the Tsunan Town Board of Education, Japan	JBM4	1	flame pot, prob. same source as Jōmon loan 1	MJ	?Iwanohara site, Nagaoka City (see notes). Kaner 2009, p.168 associated flame pots with the Shinano River area	9.70	2.74	0.84	0.16	1.62	73.27	0.84	1.46	0.04	0.01	-0.07	0.11	0.00	0.23	-1.18
			2				10.68	0.30	0.90	0.31	0.84	21.83	2.11	23.52	0.04	0.00	-0.02	0.13	0.11	-0.60	1.04
Kidder & Esaka	pl.63	JKAE1	1	vessel, Fukura type, h.19.7cm	late EJ	Yamagata	23.81	0.09	0.80	0.13	0.46	10.62	0.72	144.10	0.05	0.00	0.00	0.01	0.00	0.01	-0.09
Kidder & Esaka	pl.VI	JKAE2	1	vessel, Tōnai type, Sori, h.27.3cm	EJ	Nagano	16.70	1.85	0.82	0.12	1.06	75.07	0.37	28.98	0.04	0.00	-0.01	-0.01	0.00	0.00	0.00
Kidder & Esaka	pl.VIII	JKAE3	1	vessel, Toyama, h.37.4	EJ	Asahi	13.99	1.88	0.91	0.15	2.34	147.08	1.99	0.29	0.03	0.01	-0.17	0.93	1.28	-3.43	1.88
Kidder & Esaka	pl.105	JKAE4	1	vessel, Nashikubo type, Nakahara, h.29.5	MJ	Nagano	10.89	1.09	0.93	0.24	0.91	5.85	1.93	0.15	0.04	0.00	-0.05	0.27	-0.05	0.33	-0.23
			2				10.78	0.84	0.89	0.25	1.53	6.78	1.78	0.36	0.03	0.01	-0.08	0.28	-0.01	-0.02	0.39
Kidder & Esaka	pl.121	JKAE5	1	vessel, Katsusaka 3 type, Takikubo, h.36.8	MJ	Tokyo	13.42	2.24	0.87	0.24	1.48	63.36	0.32	3.57	0.04	0.00	-0.02	0.08	0.01	-0.04	-0.02
Kidder & Esaka	pl.122	JKAE6	1	vessel, Tōnai type, Iwakubo, h.64.5	MJ	Yamanashi	12.11	0.57	0.88	0.10	0.45	0.93	1.07	0.01	0.04	0.00	-0.03	0.17	0.00	0.00	0.12
Kidder & Esaka	pl.125	JKAE7	1	vessel, Tōnai type, representational - snake, h.37	MJ	Nagano	6.43	2.07	0.72	0.26	0.84	2.61	2.45	0.01	0.05	0.01	-0.10	0.27	71.95	-10.46	9.92
			2	vessel, Tōnai type, h.37			12.40	2.08	0.90	0.17	1.43	43.58	0.63	1.04	0.04	0.00	-0.05	0.25	-0.01	0.06	-0.14
Kidder & Esaka	pl.130	JKAE8	1	vessel, Katsusaka 2 type, Nakahara, h.37.2	MJ	Tokyo	11.83	0.18	0.89	0.17	1.37	102.42	0.76	1.64	0.04	0.00	-0.04	0.17	-0.03	0.25	-0.54
			2				15.03	2.41	0.86	0.12	1.35	67.39	0.37	5.88	0.04	0.00	0.02	-0.09	-0.01	0.10	-0.42
Kidder & Esaka	pl.131	JKAE9	1	vessel, Katsusaka 2 type, Nakahara, h.35.5	MJ	Tokyo	8.16	0.79	0.86	0.60	0.88	8.20	3.08	1.43	0.04	-0.02	0.21	-0.53	-0.10	1.58	0.62
			2				7.55	1.16	0.89	0.65	1.21	4.19	3.80	0.49	0.04	-0.01	0.08	-0.04	0.59	-0.58	3.87

Context data							Style data														
Museum number/ publication	Museum ID/ plate no.	Object number	spiral numbers analysed	Object notes	period*	place	rotation	orientation	curvilinearity	irregularity	path width median	path width trend error	spacing median	spacing trend error	sampling resolution	path width trend coefficients			spacing trend coefficients		
Kidder & Esaka	pl.136	JKAE10	1	vessel, Katsusaka type, Narahara, h.34.5	MJ	Tokyo	7.67	2.46	0.36	0.17	2.25	2.37	0.91	0.18	0.04	0.01	-0.10	0.39	-0.17	1.23	-1.91
			2	representational - snake			7.27	1.82	0.87	0.30	0.87	19.13	2.97	0.12	0.04	0.01	-0.09	0.15	-6.13	6.69	1.81
Kidder & Esaka	pl.137	JKAE11	1	vessel, Katsusaka type, Takikubo	MJ	Tokyo	15.80	0.67	0.79	0.14	1.27	140.01	0.21	12.89	0.04	0.00	-0.01	0.01	0.00	-0.01	0.07
Kidder & Esaka	pl.140	JKAE12	1	vessel, Tōnai type, h.47.6	MJ	Nagano	12.02	0.11	0.85	0.27	1.24	80.11	0.61	16.38	0.04	0.01	-0.12	0.60	-0.01	0.05	0.00
			3				9.19	1.92	0.81	0.28	1.15	16.25	0.30	6.15	0.04	0.00	-0.03	0.20	0.26	-0.17	-0.29
Kidder & Esaka	pl.142	JKAE13	1	vessel, Katsusaka 3 type, Tsutano, h.59	MJ	Yamanashi	9.61	0.64	0.83	0.11	1.82	81.75	0.55	1.86	0.04	0.01	-0.10	0.40	-0.01	0.08	-0.24
			2				11.60	0.97	0.81	0.23	1.73	29.38	0.56	1.05	0.04	0.00	-0.08	0.40	-0.01	0.14	-0.35
Kidder & Esaka	pl.156	JKAE14	1	vessel, Idojiri type, ?representational - snakes, h.27.5	MJ	Nagano	7.97	1.34	0.88	0.25	2.31	138.80	0.44	0.34	0.03	0.01	-0.12	0.61	0.15	-0.01	-0.49
			3				7.01	1.79	0.86	0.30	1.54	11.00	1.39	0.02	0.04	0.01	-0.06	0.36	-0.11	0.93	-0.58
Kidder & Esaka	pl.159	JKAE15	1	vessel, Katsusaka type, Nakahara, h.36.6	MJ	Tokyo	11.91	0.79	0.87	0.22	1.41	35.95	0.74	10.36	0.04	0.01	-0.09	0.30	-0.05	0.51	-1.26
			2				7.25	0.14	0.75	0.29	2.47	36.48	0.95	0.18	0.04	0.02	-0.28	1.17	0.05	0.26	-0.96
Kidder & Esaka	pl.160,162	JKAE16	1	vessel, Sori type, 42.7cm	MJ	Nagano	7.21	2.00	0.82	0.27	2.26	38.81	1.05	0.10	0.04	-0.01	0.13	-0.42	0.07	0.98	-1.25
			2				7.77	2.86	0.87	0.28	2.92	22.24	0.60	0.30	0.04	0.01	-0.14	0.82	0.27	0.84	-0.92
Kidder & Esaka	pl.170	JKAE17	1	vessel, Katsusaka type, Sakai, h.21	MJ	Yamanashi	7.00	2.95	0.91	0.32	1.22	42.49	1.68	0.01	0.04	0.03	-0.23	0.33	0.96	-1.75	0.69
			2				7.11	2.21	0.89	0.40	2.07	39.95	1.64	0.02	0.04	0.00	-0.03	0.15	1.54	-0.05	-0.98
Kidder & Esaka	pl.172	JKAE18	1	vessel, Sori type, ?representational, 29.5cm	MJ	Nagano	22.75	2.56	0.33	0.20	0.89	46.16	0.34	15.86	0.04	0.00	-0.01	0.09	0.00	0.00	0.04
Kidder & Esaka	pl.176	JKAE19	1	vessel, Sori I type, 61.2cm	MJ	Yamanashi	40.54	0.66	0.90	0.05	0.62	106.81	0.06	12.59	0.05	0.00	0.00	-0.04	0.00	0.00	-0.01
			2				16.48	2.25	0.85	0.18	1.20	58.73	0.22	12.55	0.04	0.00	-0.02	0.14	0.00	-0.02	0.02
Kidder & Esaka	pl.180	JKAE20	1	vessel, Kasori E (Ubayama) type, Miyanome, 59.5cm	MJ	Nagano	10.78	0.32	0.81	0.17	1.08	56.45	1.28	6.09	0.04	0.00	0.00	0.04	0.03	-0.28	0.63
Kidder & Esaka	pl.182	JKAE21	1	vessel, Umataka I type, h.29.7	MJ	Niigata	8.99	2.25	0.75	0.36	1.15	21.98	0.92	1.71	0.04	0.01	-0.19	0.66	0.28	-0.38	-0.14
			2				8.24	1.49	0.87	0.19	1.26	61.43	0.59	0.83	0.04	0.00	-0.04	0.20	0.62	-1.19	0.57
Kidder & Esaka	pl.157	JKAE22	1	vessel, Katsusaka I type, Minebata, h.21.6	MJ	Nagano	10.35	2.43	0.80	0.13	1.54	50.46	1.16	8.07	0.04	0.00	0.02	-0.06	-0.12	0.66	-0.67
			2				7.38	2.56	0.89	0.28	1.23	10.58	3.30	0.20	0.04	0.02	-0.22	0.66	1.05	-2.15	2.96
Kidder & Esaka	pl.187	JKAE23	1	vessel, Umataka 1 type, h.37.5	MJ	Niigata	10.64	2.56	0.87	0.24	1.55	34.61	0.80	11.03	0.04	0.00	-0.02	0.09	-0.05	0.42	-0.75
Kidder & Esaka	pl.192	JKAE24	1	vessel, Umtaka type, some Late Jōmon traits, h.32.5	MJ	Umtaka, Niigata	10.56	2.92	0.35	0.20	1.78	34.13	0.80	1.22	0.04	0.00	0.03	0.07	-0.01	0.14	-0.52
Kidder & Esaka	pl.196	JKAE25	1	bowl, Umtaka type, h.11 cm	late MJ	Umtaka, Niigata	10.02	2.58	0.77	0.27	0.91	57.37	0.70	14.61	0.04	0.00	0.03	-0.25	0.24	-0.65	0.21
			2				8.09	2.80	0.89	0.26	2.58	13.89	0.83	0.31	0.03	0.00	-0.08	0.68	0.99	-2.72	2.46
Kidder & Esaka	pl.199	JKAE26	1	jar, Umtaka 3 type, h.32 cm	(late?) MJ	Umtaka, Niigata	9.10	2.56	0.85	0.21	1.31	19.09	1.04	2.43	0.04	-0.01	0.13	-0.55	0.30	-0.97	0.36
			2				7.55	2.19	0.73	0.45	1.44	21.89	1.64	0.45	0.04	0.02	-0.28	0.85	-1.64	4.82	-2.31
Kidder & Esaka	pl.200	JKAE27	1	jar, Tochikura 2 type, h.23.2	MJ	Tokushōji, Niigata	8.50	2.43	0.80	0.23	1.36	25.39	1.15	0.66	0.04	0.02	-0.16	0.28	-0.07	-0.01	0.10
Kidder & Esaka	pl.201	JKAE28	1	pot, Kasori E 1 type, h.21, representational, bird's wings	MJ	Sakai, Yamanashi	8.89	2.93	0.94	0.14	1.50	46.20	1.13	1.32	0.04	0.00	-0.06	0.27	0.32	-1.10	0.93
			2				10.69	0.06	0.84	0.17	1.24	31.50	0.92	3.62	0.04	0.00	-0.05	0.16	0.11	-0.71	1.20

Context data							Style data														
Museum number/ publication	Museum ID/ plate no.	Object number	spiral numbers analysed	Object notes	period*	place	rotation	orientation	curvilinearity	irregularity	path width median	path width trend error	spacing median	spacing trend error	sampling resolution	path width trend coefficients			spacing trend coefficients		
Kidder & Esaka	pl.202	JKAE29	1	bowl, Daigi 9 type, h.14.8	MJ	Shibahashi, Yamagata	8.94	0.99	0.87	0.19	2.14	144.03	0.39	0.46	0.04	-0.02	0.22	-0.48	0.34	-0.86	0.36
Kidder & Esaka	pl.203	JKAE30	1	jug, Daigi 8b type, h.14	MJ	Shirasuka, Yamagata	12.75	1.96	0.89	0.21	0.97	8.20	0.95	3.26	0.04	0.00	-0.02	0.13	0.00	0.05	-0.25
Kidder & Esaka	pl.204	JKAE31	1	cooking pot (evidence of use), Monzen type analogous to Daigi 8b, pot shape resembles Late Jōmon, h.26.5	MJ	Monzen, Iwate	6.18	1.22	0.50	0.52	1.54	16.79	1.82	n/a	0.04	0.05	-0.45	1.31	0.00	0.00	0.00
Kidder & Esaka	pl.208	JKAE33	1	jar, Daigi 8a type, h.75cm	late MJ	Ochiai, Yamagata	7.79	2.64	0.81	0.32	0.70	2.80	1.76	0.13	0.04	0.00	0.01	-0.06	0.12	0.65	0.87
			2				8.55	0.69	0.84	0.28	0.72	28.67	1.23	1.75	0.04	0.02	-0.20	0.61	-0.51	2.63	-2.98
Kidder & Esaka	pl.215	JKAE34	1	jar, Kasori E 3 (Ubayama) type	MJ	Yosukeone, Nagano	10.98	1.03	0.82	0.17	1.21	74.62	0.63	2.20	0.04	0.00	-0.04	-0.02	-0.02	0.14	-0.13
			2				8.66	0.01	0.65	0.34	1.28	30.90	0.73	0.20	0.03	0.03	-0.26	0.78	-0.13	0.63	-0.80
Kidder & Esaka	pl.217	JKAE35	1	?burial jar (base removed), comparable to Kasori E 2 (Ubayama) type, ?representational - bird's wings, h.48	MJ	Miyaji, Gifu	12.37	2.39	0.82	0.23	1.13	131.41	0.86	15.62	0.04	0.00	0.00	0.04	-0.02	0.18	-0.36
			2				10.22	0.03	0.89	0.16	1.05	23.64	1.18	1.40	0.04	0.00	-0.04	0.18	-0.02	0.41	-1.36
Kidder & Esaka	pl.219	JKAE36	1	vessel, Kasori E 3 (Ubayama) type, h.34	MJ	Tsuru High School, Yamanashi	7.86	0.32	0.87	0.08	1.77	131.62	1.39	0.77	0.04	-0.01	0.03	0.13	-0.05	-0.11	-0.21
			2				9.92	2.22	0.29	0.20	1.29	77.69	1.67	17.44	0.04	0.01	-0.16	0.68	0.03	-0.23	0.24
Kidder & Esaka	pl.220	JKAE37	1	vessel, Kasori E 3 (Ubayama) type, h.78	late MJ	Ōne, Gumma	8.14	1.69	0.85	0.25	1.69	47.26	1.87	0.17	0.04	0.01	-0.11	0.02	-0.35	0.58	0.53
			2				6.71	1.46	0.82	0.20	1.10	11.69	2.37	0.01	0.04	0.00	0.03	-0.19	14.19	-9.12	0.80
Kidder & Esaka	pl.221	JKAE38	1	vessel, Kasori E 1 (Ubayama) type, h.64	MJ	Ōne, Gumma	9.52	2.56	0.87	0.24	1.11	9.40	1.06	4.45	0.04	0.00	-0.02	0.23	0.12	-0.06	-0.35
Kidder & Esaka	pl.223	JKAE39	1	vessel, Kasori E 2 (Ubayama) type, h.25.7	MJ	Narahara, Tokyo	7.92	0.13	0.89	0.33	1.05	1.76	1.56	0.62	0.04	0.01	-0.11	0.22	0.03	1.15	-0.93
Kidder & Esaka	pl.XV	JKAE40	1	boat-shaped vessel, Nusamai type, typical of Kushiro, E.Hokkaido, h. 17.1	MJ	Nusamai, Hokkaido	18.18	1.22	0.70	0.14	1.19	208.29	0.27	2.99	0.04	0.00	0.02	-0.18	0.00	0.01	-0.02
Kaner 2009	39 (pp.136, 132)	JKAN1	1	pot, incised decoration, spirals on lower part said to form the heads of human figures, this may be true of the other pots.	MJ	Dōkunmae, Gunma	11.93	1.83	0.92	0.32	1.12	18.82	2.15	34.31	0.04	0.00	-0.03	0.25	0.08	-0.64	1.69
Kaner 2009	3 (pp.92-93)	JKAN2	1	dogū, incised spiral (part of crown),	MJ	Tanabatake, Nagano	13.03	2.34	0.84	0.21	1.75	96.80	0.33	0.99	0.03	0.00	0.03	0.10	0.00	0.01	-0.04
Kaner 2009	7 (p.99)	JKAN3	1	dogū, impressed spiral on back, ?snake representation	MJ	Imojiya, Yamanashi	9.21	1.43	0.80	0.59	0.72	9.92	2.77	4.63	0.04	0.00	0.02	-0.01	-0.45	2.78	-1.53
			2	dogū, impressed spiral on side ?representational			8.77	2.51	0.34	0.33	1.40	22.79	1.53	23.61	0.04	0.01	-0.12	0.54	-0.21	1.76	-1.80
Kaner 2009	8 (p.100)	JKAN4	1	dogū, incised spiral on hip	MJ	Mekiri, Nagano	6.83	0.44	0.82	0.32	2.49	34.00	3.94	n/a	0.04	0.01	-0.17	0.81	0.00	0.00	0.00
Kaner 2009	10 (pp.102-3)	JKAN5	1	dogū, incised spiral on hip,	MJ	Nishinomae, Yamagata	6.86	1.95	0.81	0.37	2.02	28.43	1.21	0.02	0.04	0.02	-0.28	1.01	-4.11	5.04	0.64

Context data							Style data														
Museum number/ publication	Museum ID/ plate no.	Object number	spiral numbers analysed	Object notes	period*	place	rotation	orientation	curvilinearity	irregularity	path width median	path width trend error	spacing median	spacing trend error	sampling resolution	path width trend coefficients			spacing trend coefficients		
Kaner 2009	11 (p.104)	JKAN6	1	dogū, incised spirals on hair/headdress	MJ	Sakai, Yamanashi	12.19	0.03	0.32	0.05	1.93	151.57	0.69	1.23	0.04	-0.01	0.21	-0.85	0.02	-0.18	0.41
			2	dogū, incised spiral on hip			13.97	1.63	0.89	0.26	1.07	90.12	0.56	24.18	0.04	0.00	-0.04	0.18	0.01	-0.15	0.46
Kaner 2009	17 (pp.110-111)	JKAN7	1	dogū, incised spirals on shoulder	LJ	Gōhara, Gunma	19.01	1.11	0.84	0.16	1.00	48.37	0.63	15.22	0.04	0.00	0.04	-0.32	0.00	0.01	-0.01
			2	spiral over sternum			13.94	0.75	0.52	0.15	1.31	57.93	0.56	4.77	0.04	0.00	0.06	-0.31	0.00	0.04	-0.14
Kaner 2009	1 (p.88)	JKAN8	1	dogū, incised spiral on back	LJ	Chobonaino, Hokkaido	8.72	0.57	0.66	0.62	0.37	2.88	3.52	2.44	0.05	0.00	0.02	-0.01	-0.50	2.61	0.12
Kaner 2009	21 (p.115)	JKAN9	1	dogū, incised spiral on back	LJ	Ushiroda, Yamanashi	21.02	2.16	0.88	0.14	0.81	20.55	0.48	10.91	0.04	0.00	0.00	0.02	0.00	0.06	-0.34
Kaner 2009	22 (pp.116-7)	JKAN10	1	dogū, incised spirals on arm ends	LJ	Nakappara, Nagano	22.52	1.78	0.84	0.10	0.77	24.14	0.38	9.95	0.04	0.00	0.01	-0.06	0.00	0.01	-0.09
			2				22.99	1.18	0.85	0.09	0.67	77.25	0.44	12.30	0.04	0.00	0.02	-0.28	0.00	0.00	0.01
Kaner 2009	25 (p.120)	JKAN11	1	dogū, spirals on chin described as tattoos	LJ	Toriitai 4, Aomori	6.80	1.26	0.92	0.25	1.09	16.35	2.81	0.01	0.04	0.00	0.06	-0.22	7.97	-0.29	-2.10
Kaner 2009	61 (p.159)	JKAN12	1	heart-shaped dogū, spirals down back	LJ	Arakōji, Fukushima prefecture	20.25	0.99	0.83	0.18	0.62	28.91	0.76	47.20	0.05	0.00	0.00	-0.02	0.00	0.00	0.10
			2				7.52	2.89	0.91	0.35	1.12	14.53	2.54	0.43	0.04	-0.01	0.12	-0.42	-3.18	7.10	-2.57
Kaner 2009	57 (p.154)	JKAN13	1	Mother and child dogū, spirals on knees of mother, suggested to represent trousers (Kaner 2009 p.30)	MJ	Miyata, Tokyo	8.71	1.93	0.84	0.15	1.37	14.20	1.35	0.30	0.04	-0.01	0.10	-0.27	-0.23	0.92	-1.21
Kaner 2009	55 (p.152)	JKAN14	1	dogū carrying a child on its back, spiral roughly on back	MJ	Kamiyamada shell mound, Ishikawa prefecture	18.06	2.74	0.88	0.24	0.61	8.42	0.85	113.95	0.04	0.00	0.01	-0.04	0.01	-0.14	0.56
Kaner 2009	43 (p.140)	JKAN15	1	pot with anthropomorphic decoration, spiral in head piece or hair, also spiral in isolation (not analysable) described as 'combining male and female imagery' though not clear if that is the spiral itself or the decoration on it.	MJ	Hayashi Ōji, Kanagawa prefecture	11.06	0.31	0.81	0.14	2.03	142.70	0.35	1.80	0.04	0.00	-0.01	0.29	-0.03	0.21	-0.40
Kaner 2009	42 (p.139)	JKAN16	1	vessel for brewing/grain storage or more probably drum with figure engaging in ritual dance, spiral as ear of figure and as part of border around figure	MJ	Imojiya, Yamanashi prefecture	11.66	0.74	0.88	0.23	1.45	223.82	0.46	1.48	0.04	0.01	-0.11	0.52	0.02	-0.12	0.13
			2				7.54	1.87	0.88	0.30	2.25	70.13	0.65	4.46	0.04	-0.01	0.23	-0.88	4.63	-6.63	2.79
Kaner 2009	41 (p.138)	JKAN17	1	cooking pot, spiral decoration around top, ?representational	MJ	Ōhinohara, Kanagawa prefecture	10.76	1.08	0.82	0.17	1.59	73.28	1.10	2.03	0.04	0.00	-0.05	0.23	0.01	-0.07	0.20
			2				11.03	2.04	0.88	0.22	1.78	29.54	0.43	3.41	0.04	0.01	-0.10	0.47	0.01	-0.11	0.30
Kaner 2009	40 (p.137)	JKAN18	1	lamp, spiral on hair of face surmounting lamp and on front ?representational	MJ	Sori, Nagano prefecture	10.25	0.02	0.83	0.11	1.71	80.62	0.80	1.15	0.04	0.00	0.09	-0.70	-0.02	0.13	-0.13
			2				6.51	2.39	0.31	0.38	2.58	49.50	6.49	n/a	0.04	0.13	-1.13	3.06	0.00	0.00	0.00

*EK – Early Jōmon, MJ – Middle Jōmon, LJ – Late Jōmon

Table A2.3 Contextual and style data for the Shang Dynasty/Western Zhou Period case study

Context data										Style data														
Museum number	Museum ID	Object number	Spiral number	Object notes	period*	start date	end date	place	image source**	rotation	orientation	curvilinearity	irregularity	path width median	path width trend error	spacing median	spacing trend error	sampling resolution	path width trend coefficients			spacing trend coefficients		
Ashmolean Museum EA1956.854	CSASH	1	1	food vessel (gui)	WZ	1050	900	China		11.02	2.36	0.60	0.17	1.03	19.13	1.12	4.53	0.04	0.00	0.08	-0.52	-0.01	0.11	-0.32
			5							14.08	0.57	0.43	0.20	0.83	27.76	0.61	3.69	0.04	0.00	-0.02	0.08	0.00	0.02	-0.08
Ashmolean Museum EA1956.830	CSASH	2	2	food vessel (gui), representational (2.2 ?creature horn 2.3 creature head)	WZ	1050	850	China		7.19	2.24	0.32	0.47	1.33	11.71	2.52	0.06	0.04	0.00	0.00	0.23	-1.77	4.04	0.25
			3							8.80	1.37	0.76	0.31	1.48	21.48	0.63	1.34	0.04	0.01	-0.07	0.39	0.19	-0.51	0.28
Ashmolean Museum b7,LI1301.6	CSASH	3	13	food vessel (ding), 3.13 representational (creature tail)	WZ	1100	950	China		10.47	2.39	0.47	0.28	1.11	16.30	1.53	11.06	0.04	0.00	-0.09	0.63	0.08	-0.50	0.87
			59							8.67	2.58	0.63	0.24	1.82	17.67	1.11	0.57	0.04	0.00	-0.05	0.20	-0.19	0.60	-0.35
Ashmolean Museum EA1956.3516	CSASH	4	3	cooking vessel (ding) 4.4 representational (creature ?taotie whisker)	S, Anyang	1200	1050	China		11.40	0.78	0.91	0.26	1.33	29.56	0.94	1.43	0.04	0.00	-0.01	0.06	0.08	-0.37	0.17
			4							6.95	1.31	0.88	0.33	1.12	15.01	3.68	0.06	0.04	0.01	-0.17	0.74	4.58	-9.44	6.03
Ashmolean Museum EA1956.3517	CSASH	5	68	wine vessel (jiao)	S, Anyang	1200	1050	China		20.19	2.22	0.53	0.18	0.44	9.23	0.62	17.22	0.04	0.00	0.00	-0.04	0.00	0.02	-0.15
			80							10.85	0.92	0.75	0.23	1.09	21.90	1.67	1.52	0.04	0.00	0.08	-0.34	0.03	-0.33	1.04
Ashmolean Museum EA1956.872	CSASH	6	1	wine vessel (you)	S, Anyang	1200	1050	China		17.22	0.04	0.95	0.11	0.55	13.72	0.60	21.15	0.04	0.00	0.01	-0.02	0.00	-0.02	0.09
			4							12.32	3.12	0.75	0.21	0.50	29.41	0.47	70.58	0.04	0.00	0.03	-0.13	0.09	-0.86	2.16
Ashmolean Museum EA1956.838	CSASH	7	1	wine vessel (zhi)	S, Anyang	1200	1050	China		19.26	2.34	0.82	0.19	0.68	27.38	0.43	50.07	0.04	0.00	0.00	0.04	0.00	0.04	-0.14
			19							11.46	2.68	0.80	0.30	1.24	76.75	0.60	2.18	0.03	0.00	-0.06	0.36	0.01	-0.08	0.10
Ashmolean Museum EA1956.833	CSASH	8	1	wine vessel (jue)	S, Anyang	1200	1050	China		14.29	2.30	0.82	0.19	0.84	11.38	0.86	11.66	0.04	0.00	0.00	0.03	0.00	0.00	0.01
Ashmolean Museum EA1956.3515	CSASH	9	23	wine vessel (jue)	S, Anyang	1200	1050	China		7.24	2.32	0.83	0.29	2.07	9.39	1.99	0.08	0.03	0.03	-0.37	1.12	2.26	-3.28	0.78
			54							22.28	2.56	0.85	0.16	0.48	13.75	0.50	74.26	0.04	0.00	0.00	0.03	0.00	-0.01	0.03
Ashmolean Museum EA1956.832	CSASH	10	4	cooking vessel (ding)	S, Anyang	1200	1050	China		11.12	0.90	0.78	0.16	1.21	12.10	1.06	6.53	0.04	0.00	0.01	-0.01	-0.01	0.07	-0.04
			9							12.35	2.09	0.42	0.27	1.28	10.34	0.96	3.73	0.04	0.00	-0.04	0.19	0.02	-0.16	0.42
Ashmolean Museum EA1956.855	CSASH	11	1	cooking vessel (ding), representational (11.1 taotie horn, 11.62 decoration on the horn)	S, Anyang	1200	1050	China		8.15	2.20	0.36	0.51	0.60	3.44	3.02	0.69	0.05	0.01	-0.07	0.22	0.28	0.34	0.05
			62							8.34	1.89	0.80	0.26	2.11	30.14	0.99	0.34	0.03	0.01	-0.15	0.97	0.17	-0.41	0.28
British Museum 1973,0726.13	CSBM	1	1	pou (ritual wine vessel), representational (taotie whisker)	S	1300/ 1200	1100/ 1050	China	b	8.71	0.01	0.85	0.14	0.84	6.78	2.36	3.51	0.04	0.00	0.02	-0.02	0.49	-1.73	1.07
			2	representational (taotie horn)						8.69	2.75	0.89	0.24	2.19	121.34	1.11	0.34	0.04	0.02	-0.23	1.11	-0.03	-0.02	0.54

Museum number	Museum ID	Object number	Spiral number	Object notes	period*	start date	end date	place	image source**	rotation	orientation	curvilinearity	irregularity	path width median	path width trend error	spacing median	spacing trend error	sampling resolution	path width trend coefficients			spacing trend coefficients		
Context data										**Style data**														
British Museum 1959,1020.1	CSBM	2	1	bronze jia (vessel), prob representational (part of a ?dragon),	S	1500	1200	China	b	7.48	0.30	0.79	0.30	2.28	18.81	0.47	0.04	0.03	-0.03	0.38	-0.67	0.87	-1.37	0.43
			2	representational (creature ?dragon tail)						9.75	0.47	0.68	0.45	1.82	17.98	2.38	8.18	0.04	0.00	-0.03	0.46	-0.26	1.94	-1.99
British Museum 1940,1214.267	CSBM	3	18	bronze ding	S	1200	1050	China	b	31.62	0.61	0.58	0.08	0.40	11.19	1.23	98.00	0.04	0.00	0.00	0.01	0.00	0.01	-0.08
			62							26.77	0.82	0.69	0.16	0.41	7.26	0.42	26.98	0.04	0.00	0.00	-0.03	0.00	-0.02	0.13
British Museum 1947,0712.419	CSBM	4	25	bronze carved[?] ding (vessel). 4.25 representational (part of taotie horn), 10.5" high	S	1200	1100	Anyang, Henan		16.37	0.55	0.73	0.24	1.45	65.02	0.42	3.71	0.04	0.00	-0.05	0.41	0.00	0.01	-0.09
			56							18.39	2.71	0.45	0.20	0.32	2031.26	0.24	41.81	0.04	0.00	-0.02	0.40	0.00	-0.05	0.23
British Museum 1980,0512.1	CSBM	5	1	bronze ding (vessel).	S, early Anyang	1300	1100	China	b	9.10	2.31	0.83	0.23	1.23	28.10	0.79	0.31	0.03	0.01	-0.11	0.42	-0.04	0.35	-0.69
			3							10.40	0.78	0.81	0.28	1.54	13.70	0.73	3.02	0.03	0.01	-0.09	0.42	0.02	-0.18	0.31
British Museum 1968,0422.2	CSBM	6	1	bronze fang yi (container), [probably representational (taotie whiskers)],	S, Anyang	1200	1050	China		8.90	0.53	0.81	0.34	2.25	69.32	0.79	1.23	0.03	0.00	-0.06	0.66	0.16	-0.65	0.83
			2							8.91	2.54	0.73	0.32	2.09	131.31	0.76	2.52	0.03	0.00	0.00	0.36	0.00	-0.18	0.74
British Museum 1954,0220.4	CSBM	7	25	bronze zun (wine vessel). Representational (7.25 decoration on taotie face)	S	1200	1100	China	b	8.48	2.03	0.75	0.27	2.59	18.51	0.69	0.86	0.03	0.00	0.03	0.28	0.25	-1.17	1.41
			90							9.81	0.44	0.62	0.22	1.01	53.96	1.45	9.78	0.04	0.00	-0.04	0.25	0.04	0.00	-0.29
British Museum 1973,0726.5	CSBM	8	1	bronze he (vessel), W11.5cm at lip	S, late Anyang	1200	1050	China		16.29	0.95	0.10	0.21	2.35	93.90	0.66	18.31	0.03	0.00	0.00	0.39	0.00	0.04	0.01
			2							14.36	2.41	0.44	0.14	0.74	12.73	0.68	25.47	0.04	0.00	-0.01	0.07	0.00	0.00	-0.06
British Museum 1953,1214.1	CSBM	9	46	bronze li (vessel), spirals are highly abstracted taotie,	S, Transitional Period	1400	1200	China	b	13.40	2.17	0.77	0.16	1.26	113.64	0.57	12.30	0.04	0.00	-0.03	0.13	0.00	-0.01	-0.07
			69							7.47	2.29	0.87	0.13	1.51	52.50	1.38	0.74	0.04	0.00	-0.05	0.24	-0.53	2.33	-2.49
British Museum 1977,0404.1	CSBM	10	1	bronze gui (vessel) 'Kang Hou gui', reign of Cheng Wang, representational (10.1 part of bird, 10.3 animal ears)	early WZ	1100	1000	China		13.18	1.54	0.83	0.42	0.77	26.94	1.16	15.05	0.04	0.00	-0.02	0.14	0.00	0.18	-0.34
			3							8.80	0.68	0.81	0.26	2.10	117.50	1.07	1.05	0.04	0.00	-0.04	0.64	0.26	-0.84	0.76
British Museum 1990,0807.1	CSBM	11	1	bronze gu (vessel)	early S	1500	1300	China	b	8.18	2.63	0.81	0.14	0.70	5.60	2.80	0.11	0.04	-0.01	0.08	-0.20	-0.68	1.41	0.39
British Museum 1983,0318.1	CSBM	12	14	bronze hu (vessel), 12.84 representational (taotie nostril)	S, Anyang	1200	1100	China		7.52	0.85	0.87	0.19	1.58	16.71	0.88	0.25	0.04	0.00	-0.05	0.21	0.04	0.57	-0.80
			84							14.15	2.31	0.61	0.32	0.93	23.23	0.42	3.72	0.04	0.01	-0.09	0.39	0.01	-0.14	0.38
British Museum 1954,0511.1	CSBM	13	62	bronze ding (vessel)	late S, Anyang	1200	1000	China	b	12.83	1.24	0.94	0.01	0.42	12.78	0.34	3.61	0.04	0.00	0.00	-0.01	0.00	0.04	-0.13
			64							9.01	1.96	0.96	0.01	0.43	11.59	0.53	6.84	0.04	0.00	-0.02	0.12	-0.24	0.95	-1.18

Context data										Style data														
Museum number	Museum ID	Object number	Spiral number	Object notes	period*	start date	end date	place	image source**	rotation	orientation	curvilinearity	irregularity	path width median	path width trend error	spacing median	spacing trend error	sampling resolution	path width trend coefficients			spacing trend coefficients		
British Museum 1986,0417.1	CSBM	14	16	bronze zun (vessel) representational (taotie horn)	S, early Anyang	1300	1200	China		11.19	0.68	0.50	0.47	1.91	47.47	0.63	21.52	0.04	0.00	0.05	0.08	-0.02	0.64	-1.38
			41	representational (taotie ear)						11.72	2.61	0.84	0.37	2.35	69.59	0.31	2.78	0.03	0.00	0.04	0.20	0.05	-0.33	0.52
British Museum 1936,1118.2	CSBM	15	1	gui 'Xing Hou gui', ?representational - snake - based on resemblance to Jomon 'snake' motifs]	WZ (early-mid)	1050	771	China		7.76	0.60	0.56	0.36	0.42	7.38	3.84	1.62	0.04	0.00	0.00	0.01	2.87	-6.85	4.58
			2							20.56	1.46	0.74	0.13	0.41	153.01	0.27	52.26	0.04	0.00	0.00	0.00	0.00	0.00	0.02
British Museum 1936,1118.4	CSBM	16	1	bronze you (vessel), Leiwen, 16.1 representational (bird wing)	S, Anyang	1200	1050	China	b	9.34	0.53	0.75	0.52	2.08	63.45	0.16	35.28	0.04	0.01	-0.16	0.89	0.00	0.05	-0.32
			79							31.33	0.86	0.59	0.11	0.50	10.68	0.21	6.47	0.04	0.00	0.00	-0.02	0.00	0.00	-0.03
British Museum 1983,0202.1	CSBM	17	2	bronze you, (spirals quite different from earlier vessels). Representational (snakes), sampled at low resolution	EZ or mid-late WZ	800	700	South or SW China		23.12	0.39	0.83	0.15	0.98	47.04	0.27	8.21	0.04	0.00	-0.01	0.10	0.00	-0.01	0.07
			9							33.79	1.03	0.85	0.10	0.32	6.59	0.60	43.65	0.04	0.00	0.00	0.00	0.00	0.00	0.01
British Museum 1973,0726.1	CSBM	18	24	bronze fang yi (vessel)	S, Anyang	1200	1100	China	b	16.91	2.33	0.70	0.15	0.95	16.39	0.67	12.45	0.04	0.00	0.00	-0.01	0.00	0.01	-0.06
			56							8.79	2.40	0.53	0.34	2.55	32.08	0.56	0.30	0.03	-0.01	0.06	0.26	-0.05	0.06	0.43
British Museum 1956,1016.1	CSBM	19	3	hu (vessel), H11.5" (29.2cm), ?representational (taotie facial decoration)	S	1200	1100	China		13.04	2.87	0.84	0.19	1.18	362.91	0.36	2.31	0.04	0.00	-0.03	0.12	0.00	0.03	-0.08
			22	?representational (decoration on taotie horn)						10.98	2.60	0.79	0.17	1.56	83.13	0.66	3.16	0.04	0.00	-0.03	0.19	0.03	-0.23	0.42
British Museum 1947,0712.429	CSBM	20	1	cast bronze he (alcohol vessel), H19cm	early WZ	1050	900	China	b	9.24	0.02	0.83	0.18	1.31	13.88	1.59	1.51	0.04	-0.01	0.06	-0.09	-0.46	2.02	-1.88
			2							8.79	2.69	0.67	0.01	0.80	23.78	0.95	0.26	0.04	-0.01	0.06	-0.08	-0.01	0.19	-0.61
British Museum 1936,1118.1	CSBM	21	1	cast bronze zun, double ram vessel. Representational (.1 - ram's shoulders, .37 - taotie facial decoration 'faces being executed in thick scrolling reminiscent of style II')	S	1300	1100	Hunan Province		12.31	1.15	0.03	0.32	1.62	57.67	0.41	11.29	0.03	0.00	0.00	0.18	0.07	-0.40	0.65
			37							11.02	2.34	0.82	0.19	2.30	170.38	0.31	2.11	0.04	0.01	-0.12	0.72	0.00	-0.03	0.18

Context data										Style data														
Museum number	**Museum ID**	**Object number**	**Spiral number**	**Object notes**	**period***	**start date**	**end date**	**place**	**image source****	**rotation**	**orientation**	**curvilinearity**	**irregularity**	**path width median**	**path width trend error**	**spacing median**	**spacing trend error**	**sampling resolution**	**path width trend coefficients**			**spacing trend coefficients**		
British Museum 1952,1216.1	CSBM	22	1	bronze pan (vessel), representational (.1 tail of water creature, .3 ear of *long* - dragon)	early WZ	1050	771	China	b	7.78	0.86	0.88	0.39	2.31	10.36	1.28	0.13	0.04	0.01	-0.09	0.73	-0.21	1.41	-0.63
			3							9.72	0.54	0.92	0.10	1.12	32.26	2.25	1.97	0.04	-0.01	0.12	-0.61	-0.02	-0.21	0.90
British Museum 1973,0726.9	CSBM	23	1	bronze li (vessel), H17.5cm	S/WZ	1200	1050	China	b	14.14	2.32	0.74	0.14	0.56	10.45	1.33	16.83	0.04	0.00	-0.02	0.15	0.01	-0.09	0.34
			2							13.95	2.29	0.47	0.18	0.64	5.50	1.03	11.98	0.04	0.00	0.02	-0.08	0.02	-0.19	0.63
British Museum 1973,0726.7	CSBM	24	24	bronze gu, H25.7	S	1200	1050	China	b	14.76	2.53	0.45	0.24	0.85	67.01	0.65	3.11	0.04	0.00	-0.04	0.23	0.00	-0.02	0.10
			38							18.31	2.52	0.70	0.23	0.43	7.53	0.80	16.99	0.04	0.00	-0.01	0.08	0.00	-0.01	0.03
British Museum 1959,0512.1	CSBM	25	1	bronze jue (vessel), H19.5cm	S/WZ	1100	1001	China	b	9.32	1.12	0.83	0.03	0.55	130.50	0.32	5.28	0.04	0.01	-0.17	0.64	-0.08	0.53	-1.04
			7							26.62	1.49	0.72	0.15	0.49	9.60	0.48	17.65	0.04	0.00	0.00	0.01	0.00	-0.01	0.04
British Museum 1947, 0712.420	CSBM	26	17	bronze gui (vessel), representational (.17 cicada, .78 creature ?dragon tail)	S	1200	1050	Anyang, Henan	b	12.96	2.41	0.83	0.22	1.08	15.86	0.69	7.37	0.04	0.00	0.01	-0.05	0.01	-0.08	0.25
			78							10.94	2.32	0.63	0.21	1.20	51.80	1.69	33.72	0.04	0.00	-0.01	0.30	0.06	-0.37	0.61
British Museum 1980,0512.2	CSBM	27	1	bronze zun (vessel)	late S	1200 (c.)		China	b	9.23	0.69	0.77	0.19	0.80	7.84	1.40	8.02	0.04	0.00	0.02	-0.03	0.14	-0.29	0.04
			2							12.23	0.67	0.33	0.19	0.75	25.99	1.16	24.42	0.04	0.00	-0.01	0.07	0.00	0.06	-0.26
British Museum 1957,0221.1	CSBM	28	14	bronze gui (ritual vessel), .14 ?representational (decoration on taotie)	S	1200	1100	China	b	12.69	2.24	0.88	0.16	1.02	74.50	0.47	11.11	0.04	0.00	0.01	-0.08	-0.03	0.28	-0.91
			99							13.87	0.60	0.67	0.13	0.88	13.01	0.76	5.81	0.04	0.00	0.00	0.00	0.01	-0.10	0.30
British Museum 1953,0714.1	CSBM	29	14	bronze you (wine vessel), .14 ?representational (decoration on taotie)	late S	1200	1000	China	b	7.32	2.25	0.82	0.28	1.35	116.16	2.57	0.11	0.03	-0.05	0.52	-1.19	1.74	-2.09	0.32
			37							13.25	0.83	0.76	0.13	1.19	89.88	0.54	2.28	0.04	0.00	0.01	-0.08	0.00	0.03	0.02
British Museum 1945, 1017.191	CSBM	30	46	bronze jia (vessel), .46 ?representational (cicada), .72 representational (taotie facial decoration)	late S	1200	1050	China	b	26.80	0.60	0.89	0.06	0.56	18.75	0.31	13.37	0.04	0.00	0.00	-0.05	0.00	0.00	-0.01
			72							9.79	0.95	0.78	0.36	1.29	28.82	0.96	0.46	0.03	0.01	-0.12	0.38	0.01	-0.16	0.59
National Museums Scotland A.1934.616	CSNMS	1	11	bronze ding	late S	1200	1000	Anyang, Henan	h	17.31	2.33	0.38	0.17	0.77	56.79	0.61	9.78	0.04	0.00	0.00	0.04	0.00	0.00	0.02
			12							10.27	2.40	0.29	0.14	1.73	71.97	1.13	3.33	0.03	0.00	-0.08	0.59	0.05	-0.52	1.30
Victoria and Albert Museum FE.156-1988	CSVAM	1	1	goblet (gu?), 32cm high	S	1150	1050	China	c	36.04	0.79	0.10	0.06	0.42	18.28	0.18	5.64	0.04	0.00	0.00	-0.04	0.00	0.00	0.00
			2							20.83	0.86	0.51	0.15	0.76	14.28	1.76	41.18	0.04	0.00	0.01	-0.09	0.01	-0.08	0.18
Victoria and Albert Museum M.3-1950	CSVAM	2	3	bronze jue, taotie, 21cm high	S	1100	1000	China	c	10.84	2.60	0.38	0.11	0.90	24.18	1.33	19.55	0.04	0.00	-0.04	0.21	-0.09	0.64	-0.98
			4							15.65	2.49	0.71	0.15	0.67	7.24	0.86	30.41	0.04	0.00	0.01	-0.03	0.00	-0.01	0.07

Context data										Style data														
Museum number	Museum ID	Object number	Spiral number	Object notes	period*	start date	end date	place	image source**	rotation	orientation	curvilinearity	irregularity	path width median	path width trend error	spacing median	spacing trend error	sampling resolution	path width trend coefficients			spacing trend coefficients		
Victoria and Albert Museum M.60-1953	CSVAM	3	1	li ding, 3 taotie and cicadas on spiral ground, 19cm	S	1300	1100	China	c	16.95	2.38	0.70	0.17	0.59	9.68	1.24	27.09	0.04	0.00	-0.01	0.03	0.00	0.02	-0.14
			2							9.14	0.78	0.47	0.21	1.48	17.04	1.12	1.99	0.04	0.00	0.00	-0.03	0.18	-0.89	1.03
Victoria and Albert Museum M.3-1935	CSVAM	4	1	bronze li, 26cm high	S	1400	1200	?Shaanxi region	c	11.39	2.29	0.77	0.31	1.60	18.96	0.37	5.94	0.04	0.00	0.04	-0.04	0.02	-0.11	0.26
			2							11.30	0.86	0.49	0.18	1.47	24.16	0.43	1.81	0.04	0.00	0.01	0.11	0.00	0.07	-0.30
Victoria and Albert Museum M.1163:1, 2-1926	CSVAM	5	4	bronze pou/weng?, representational (decoration on a taotie head)	S	1450	1350	China	c	10.65	2.03	0.79	0.27	0.90	10.96	1.68	5.07	0.04	0.00	0.06	-0.26	-0.06	0.54	-0.83
			5							7.77	0.74	0.85	0.15	1.14	8.89	2.15	0.53	0.04	-0.01	0.07	-0.12	0.77	-0.44	-1.98
Victoria and Albert Museum M.4-1935	CSVAM	6	1	bronze zun (wine jar), 28.7cm high	S	1300	1050	China	c	13.39	2.45	0.87	0.17	0.92	42.54	2.10	0.01	0.04	0.00	0.00	0.07	-1.60	3.63	-1.80
			2							8.97	2.50	0.91	0.24	1.29	10.48	1.58	0.51	0.04	0.00	0.09	-0.31	0.03	0.12	-0.52
Victoria and Albert Museum M.2696-1931	CSVAM	7	4	bronze ding, 20.7cm high	S	1100	1000	China	c	22.69	2.54	0.80	0.15	0.72	7.10	1.31	15.50	0.04	0.00	0.00	-0.04	0.00	-0.04	0.13
			8							21.40	0.50	0.84	0.17	0.71	9.89	0.47	6.12	0.04	0.00	0.00	0.01	0.00	0.00	-0.01
Victoria and Albert Museum 195-1876	CSVAM	8	1	bronze fangzun (wine vessel) 45.7cm high	S	1100	1000	China	c	9.95	2.56	0.74	0.28	1.69	35.09	1.31	3.48	0.03	0.00	0.01	0.48	0.08	-0.43	0.80
			2							10.82	2.38	0.70	0.16	1.16	10.32	1.56	1.12	0.04	0.00	-0.04	0.17	0.01	-0.12	0.11
Victoria and Albert Museum M.136-1956	CSVAM	9	16	bronze grain vessel, 9.16 representational (creature ?dragon ear)	S	1100	1000	China	c	9.57	2.47	0.56	0.39	1.78	26.30	1.05	10.81	0.04	0.00	0.08	-0.14	0.38	-1.32	1.28
			32							6.21	0.65	0.89	0.36	2.15	4.55	2.92	n/a	0.04	-0.01	0.12	-0.38	0.00	0.00	0.00

*S – Shang Dynasty, WZ – Western Zhou Period, EZ – Eastern Zhou Period

** image source codes refer to those used on the List of Figures

Table A2.4 Context and style data for the Egyptian case study

Context data									Style data														
Museum number	**Museum ID**	**Object number**	**spiral numbers analysed**	**Object notes**	**date***	**place**	**material**	**image source****	**rotation**	**orientation*****	**curvilinearity**	**irregularity**	**path width median**	**path width trend error**	**spacing median**	**spacing trend error**	**sampling resolution**	**path width trend coefficients**			**spacing trend coefficients**		
British Museum E69522	EGBM	1	1	2.29cm long	12D	Egypt	glazed steatite	b	8.82	1.36	0.40	0.11	0.77	6.02	1.90	0.48	0.04	0.00	0.02	-0.11	-0.04	0.45	-1.12
			10						8.64	1.75	0.75	0.12	0.74	17.01	2.08	0.87	0.04	0.01	-0.10	0.29	-0.17	1.05	-2.39
British Museum 30551/ 1899, 0311.57	EGBM	2	6	25mm long	13D	Egypt	steatite	b	7.53	1.39	0.46	0.32	1.30	43.57	2.99	0.51	0.04	-0.01	0.05	0.02	-0.03	0.84	-0.26
			9						6.36	1.79	0.84	0.25	1.76	23.79	1.63	0.00	0.04	-0.03	0.18	-0.04	0.00	0.00	0.00
British Museum E66159/ 1960, 0514.53	EGBM	3	3	appears to be representational (loops within snakes tails) 2.03cm long	late 12D	Egypt	glazed steatite	b	8.17	1.85	0.65	0.25	1.34	38.51	1.71	0.22	0.04	0.00	-0.05	0.16	0.59	-0.37	-1.46
			8						8.88	1.48	0.66	0.17	1.20	23.30	1.22	1.11	0.04	0.00	-0.03	0.07	-0.03	0.74	-2.07
British Museum 63182/ 1930, 0711.202	EGBM	4	1	representational (Hathor head), 15.1mm long.	1I/ early MK	Mostagedda	glazed steatite	b	12.07	1.44	0.85	0.36	0.84	25.69	0.59	53.18	0.04	0.00	-0.04	0.30	0.02	0.13	-0.61
			2						12.53	1.51	0.83	0.38	0.91	22.56	0.46	50.62	0.04	0.00	-0.02	0.16	0.02	0.10	-0.46
British Museum 63185/ 1930, 0711.205	EGBM	5	2	1.4cm long	1I	Mostagedda	glazed steatite	b	6.36	1.80	0.61	0.52	0.91	7.65	7.34	n/a	0.04	-0.01	0.15	-0.38	0.00	0.00	0.00
			4						8.44	0.57	0.75	0.32	0.85	9.33	1.97	2.89	0.04	0.00	-0.02	0.06	0.67	-0.91	-0.18
British Museum 63150/ 1930, 0711.170	EGBM	6	1	1.15 cm long	1I	Mostagedda	glazed steatite	b	12.48	1.69	0.39	0.23	0.92	26.54	0.89	8.52	0.04	0.00	-0.04	0.24	0.01	-0.12	0.46
			2						13.28	1.71	0.89	0.26	1.05	22.37	0.67	18.05	0.04	0.00	0.01	-0.02	0.04	-0.36	0.92
Oriental Museum, Durham EG2939	EGDUR	1	2		MK	Egypt	glazed steatite		11.25	0.82	0.73	0.17	0.86	34.98	2.23	31.82	0.04	0.00	0.00	-0.02	-0.09	0.73	-1.78
			4						7.12	0.04	0.90	0.07	1.16	25.21	3.36	0.25	0.04	0.00	0.04	-0.21	4.40	-5.40	-0.28
Oriental Museum, Durham EG3047	EGDUR	2	1	Wellcome Collection	MK	Egypt	steatite		13.26	3.08	0.88	0.25	0.65	67.62	0.64	106.06	0.04	0.00	-0.01	0.06	-0.01	0.27	-0.78
			2						11.88	2.69	0.87	0.14	1.31	66.93	0.85	29.88	0.04	0.00	0.01	-0.14	0.05	-0.46	1.19
Oriental Museum, Durham EG6007	EGDUR	3	1	Wellcome Collection, necklace of scarabs	MK	Egypt	steatite		11.46	1.55	0.40	0.34	0.82	11.38	0.80	17.22	0.04	0.00	0.01	-0.04	0.06	-0.17	0.03
			2						12.08	1.55	0.94	0.32	0.90	30.97	1.10	17.90	0.04	0.00	-0.06	0.34	0.07	-0.38	0.32
Oriental Museum, Durham EG6007	EGDUR	4	6	Wellcome Collection, necklace of scarabs	MK	Egypt	steatite		6.28	2.26	0.94	0.47	2.02	12.55	4.14	0.01	0.04	0.01	-0.14	0.61	55.89	-18.81	5.34
			9						6.08	0.58	0.97	0.24	2.16	48.03	3.08	n/a	0.03	0.00	-0.04	0.28	0.00	0.00	0.00
Oriental Museum, Durham EG6007	EGDUR	6	7	Wellcome Collection, necklace of scarabs	MK	Egypt	steatite		6.87	1.81	0.62	0.43	1.10	8.73	3.33	0.08	0.04	0.01	-0.01	-0.03	6.99	-5.73	3.27
			11						6.69	0.71	0.86	0.52	1.14	5.46	3.79	0.07	0.05	0.02	-0.21	0.66	13.07	-5.40	4.18

Context data									Style data														
Museum number	**Museum ID**	**Object number**	**spiral numbers analysed**	**Object notes**	**date***	**place**	**material**	**image source****	**rotation**	**orientation*****	**curvilinearity**	**irregularity**	**path width median**	**path width trend error**	**spacing median**	**spacing trend error**	**sampling resolution**	**path width trend coefficients**			**spacing trend coefficients**		
World Museum, Liverpool 56.20.428	EGLIV	21	1	Spurrell	18D on	Egypt			11.75	1.92	0.88	0.30	0.81	34.56	0.44	11.29	0.04	0.00	-0.02	0.11	0.09	-0.48	0.60
			3						15.73	2.30	0.51	0.29	0.96	38.83	0.49	33.79	0.04	0.00	0.01	-0.05	0.02	-0.20	0.54
World Museum, Liverpool 56.20.431	EGLIV	22	2	Spurrell	18D on	Egypt			5.67	1.27	0.91	0.54	1.19	4.74	6.14	n/a	0.04	0.02	-0.17	0.48	0.00	0.00	0.00
			4						5.86	1.17	0.96	0.43	1.25	5.78	4.69	n/a	0.04	0.02	-0.14	0.31	0.00	0.00	0.00
World Museum, Liverpool 56.20.423	EGLIV	24	3	Spurrell	18D on	Egypt	[bone/ ivory?]		8.69	0.47	0.44	0.26	0.88	32.58	2.19	2.70	0.04	0.00	0.02	-0.06	0.64	-1.59	0.67
			16						6.73	0.60	0.33	0.37	1.18	13.70	3.39	0.03	0.04	0.01	-0.12	0.38	1.98	-0.21	2.47
World Museum, Liverpool 56.20.433	EGLIV	26	1	Spurrell	18D on	Egypt	[?steatite]		9.46	2.30	0.84	0.06	1.31	27.26	1.40	2.70	0.04	-0.01	0.15	-0.73	0.17	-0.89	1.10
World Museum, Liverpool M13737	EGLIV	27	1	Meyer Collection published Petrie plate 20AE, cartouche Kheperkzie	2I	Egypt	[glazed probably faience]		7.52	1.12	0.93	0.31	1.03	23.39	2.62	0.24	0.04	0.00	0.04	-0.10	1.89	-3.14	2.00
			2						7.33	1.52	0.39	0.25	1.31	7.06	2.38	0.11	0.04	0.00	-0.01	0.01	1.12	-0.47	-0.50
World Museum, Liverpool M12474	EGLIV	28	4	*assumed from 'MK' on catalogue card.	MK*	Egypt			6.48	2.40	0.80	0.59	1.56	4.82	4.27	0.01	0.04	0.03	-0.33	1.05	22.39	-7.87	3.89
			11						7.12	1.88	0.32	0.37	1.70	17.03	2.30	0.03	0.04	0.01	-0.19	0.83	0.73	-0.18	0.23
World Museum, Liverpool 56.20.417	EGLIV	29	4	Spurrell	18D on	Egypt	glazed faience		6.38	2.38	0.83	0.34	1.69	104.96	3.08	0.00	0.04	0.01	-0.10	0.12	-67.26	20.44	-0.61
			7						5.35	1.59	0.94	0.39	1.79	17.35	5.35	n/a	0.04	0.06	-0.49	1.27	0.00	0.00	0.00
World Museum, Liverpool 23.8.10.1	EGLIV	33	1	ring, found reused in New Kingdom tomb. Petrie & Mackay 1910, pl. XXVII, p.36) Meydum and Memphis (III). London: British School of Archaeology in Egypt & Egyptian Research Account 16th Year.	Hyksos period (Petrie & Mackay 1910)	Meydum	?		16.75	1.88	0.90	0.11	1.15	35.65	0.48	15.05	0.04	0.00	0.00	0.04	0.00	-0.01	0.00
			4						15.31	1.06	0.93	0.14	1.13	57.67	0.72	88.09	0.04	0.00	0.01	0.01	-0.01	0.09	-0.43
National Museums Scotland A.1965. 146	EGNMS	1	7	0.81" long (20.6mm)	MK	Egypt	glazed steatite	h	13.91	2.87	0.53	0.35	0.74	22.74	0.82	9.35	0.04	0.00	-0.01	0.04	0.03	-0.24	0.39
			8						6.09	0.54	0.82	0.35	0.93	14.11	4.24	n/a	0.04	0.02	-0.20	0.46	0.00	0.00	0.00

Context data									Style data														
Museum number	**Museum ID**	**Object number**	**spiral numbers analysed**	**Object notes**	**date***	**place**	**material**	**image source****	**rotation**	**orientation*****	**curvilinearity**	**irregularity**	**path width median**	**path width trend error**	**spacing median**	**spacing trend error**	**sampling resolution**	**path width trend coefficients**			**spacing trend coefficients**		
National Museums Scotland A.1921. 1092	EGNMS	2	1	representational (Hathor head), 0.5"long (12.7mm)	MK	Egypt	glazed steatite	h	10.77	1.59	0.63	0.24	0.87	35.11	1.50	23.51	0.04	0.00	-0.02	0.12	0.12	-0.70	1.30
			2						11.58	1.30	0.36	0.31	1.06	29.31	1.27	10.63	0.04	0.00	-0.01	0.05	0.04	-0.27	0.62
Petrie Museum UC11131	EGPET	1	5	Tomb 1653, 1.5cm long	MK	Sedment	glazed steatite	e	5.23	1.92	0.89	0.34	1.71	78.06	6.11	n/a	0.04	-0.06	0.48	-0.90	0.00	0.00	0.00
			6						7.81	2.45	0.72	0.46	0.85	26.68	3.15	3.09	0.04	0.01	-0.06	0.20	-0.03	0.74	1.83
Petrie Museum UC11150	EGPET	2	19	2.1cm long	late MK	Lahun	faience	e	7.87	1.55	0.92	0.21	1.37	49.14	2.34	2.54	0.04	0.01	-0.10	0.34	0.44	-0.64	-0.12
			25						7.65	2.93	0.61	0.05	1.06	23.63	3.13	0.12	0.04	0.00	0.04	-0.21	1.58	-2.85	-0.68
Petrie Museum UC28372	EGPET	3	1	1.8cm long	12D	Lahun	not stated	e	8.87	0.01	0.90	0.40	1.31	13.64	1.52	8.99	0.04	0.00	-0.08	0.38	0.02	0.85	-0.65
			2						8.52	0.32	0.94	0.42	1.28	23.96	1.34	7.44	0.04	0.00	-0.04	0.27	0.16	0.67	-0.13
Petrie Museum UC18125	EGPET	4	1	?representational (papyrus)	9D	Qau	not stated	e	8.37	2.07	0.83	0.11	1.09	46.64	1.07	9.98	0.04	-0.01	0.18	-0.84	0.57	-1.39	0.55
			2						8.13	0.92	0.73	0.11	0.95	12.81	1.52	3.78	0.04	-0.02	0.29	-1.26	-0.65	1.48	-0.46
Petrie Museum UC26118	EGPET	5	2	2.7cm long, 0.9cm wide	MK	Koptos	obsidian	e	8.86	1.56	0.85	0.24	0.82	18.46	1.90	1.76	0.04	0.00	0.00	-0.04	-0.27	1.99	-3.33
			3						8.89	1.67	0.82	0.22	0.78	4.53	1.84	0.99	0.04	0.00	-0.05	0.14	-0.09	1.16	-2.77
Petrie Museum UC29061	EGPET	6	1	1.35x0.9cm, ?representational ('lotus and scroll')	MK	Nubt LXXX, 71	glazed steatite	e	11.96	2.44	0.81	0.27	0.95	21.26	0.89	6.49	0.04	0.00	0.01	-0.11	0.07	-0.39	0.48
			2						11.10	0.77	0.69	0.30	1.13	18.69	0.58	10.71	0.04	0.00	0.00	-0.04	0.05	-0.08	-0.08
Petrie Museum UC29070	EGPET	7	5	1.3x0.9cm	MK	Nubt LXXXI, 82	steatite	e	12.62	1.81	0.93	0.25	1.09	26.68	0.76	7.14	0.04	0.00	-0.04	0.26	0.04	-0.29	0.55
			6						6.27	1.80	0.53	0.33	1.66	21.25	4.01	n/a	0.04	0.05	-0.50	1.41	0.00	0.00	0.00
Petrie Museum UC29073	EGPET	8	2	2.2x1.6cm	MK	Nubt LXXXI, 85	steatite	e	6.49	1.83	0.89	0.29	1.10	21.19	2.82	0.00	0.04	0.02	-0.31	1.07	22.04	-2.47	0.32
			3						6.89	0.03	0.34	0.29	1.45	16.07	2.96	0.02	0.04	0.00	-0.09	0.45	6.65	-2.51	-0.09
Petrie Museum UC11173	EGPET	9	1	1.8x1.3cm	late MK	Lahun	steatite	e	11.45	1.66	0.87	0.28	1.41	18.02	0.78	13.88	0.04	0.00	-0.01	0.08	0.06	-0.41	0.92
			2						8.20	1.42	0.56	0.28	1.42	21.73	1.74	1.67	0.04	0.00	-0.03	0.18	1.34	-3.20	2.51
Petrie Museum UC11165	EGPET	10	1	1.7x1.2cm	late MK	Lahun	glazed steatite	e	9.84	1.53	0.37	0.40	0.37	6.96	5.52	11.11	0.04	0.00	0.02	-0.17	-0.96	4.19	-1.69
			2						10.64	1.51	0.78	0.54	0.39	2.76	3.68	14.08	0.04	0.00	0.00	-0.03	-0.37	2.53	-2.51
Petrie Museum UC11154	EGPET	11	3	1.8x1.2cm	late MK	Lahun	steatite	e	7.80	0.82	0.81	0.37	1.08	3.88	2.22	0.26	0.04	0.01	-0.06	0.22	1.69	-2.78	1.25
			9						8.46	2.34	0.76	0.33	1.21	23.13	1.92	0.39	0.04	0.01	-0.08	0.30	0.77	-1.84	1.05

Context data									Style data														
Museum number	Museum ID	Object number	spiral numbers analysed	Object notes	date*	place	material	image source**	rotation	orientation***	curvilinearity	irregularity	path width median	path width trend error	spacing median	spacing trend error	sampling resolution	path width trend coefficients			spacing trend coefficients		
Petrie Museum UC61187	EGPET	12	1	1.4cm long	MK	Tell el Yehudijeh	steatite	e	9.97	0.81	0.65	0.25	1.13	28.41	1.63	9.69	0.04	0.00	-0.02	0.21	0.04	-0.05	-0.06
			6						7.91	0.76	0.84	0.35	1.32	39.39	1.78	0.60	0.04	0.00	-0.05	0.19	-0.20	1.99	-1.62
Petrie Museum UC11171	EGPET	13	3	2x1.4cm	late MK	Lahun	glazed steatite	e	10.56	0.26	0.90	0.25	1.26	29.69	0.98	4.06	0.04	0.01	-0.08	0.26	0.16	-0.98	1.49
			4						7.52	0.14	0.92	0.30	1.67	33.46	1.01	0.11	0.04	0.02	-0.22	0.57	0.75	0.64	-1.02
Petrie Museum UC11167	EGPET	14	10	1.8x1.2cm	late MK	Lahun	faience	e	7.05	1.22	0.71	0.46	0.70	4.36	4.44	0.08	0.04	0.00	-0.02	0.26	2.16	-2.29	4.27
			12						5.68	1.01	0.88	0.50	0.92	9.57	4.36	n/a	0.04	-0.03	0.24	-0.52	0.00	0.00	0.00
Petrie Museum UC11166	EGPET	15	1	1.8x1.3cm	late MK	Lahun	faience	e	6.70	1.92	0.96	0.29	1.12	36.53	3.34	0.07	0.04	0.02	-0.17	0.28	-1.26	1.73	4.00
			2						7.93	2.00	0.84	0.39	0.89	16.99	2.49	0.61	0.04	0.01	-0.09	0.31	1.32	-2.50	2.30
Petrie Museum UC11151	EGPET	16	4	2.1x1.6cm	late MK	Lahun	steatite	e	7.25	2.65	0.91	0.25	1.05	72.13	3.01	0.07	0.04	-0.03	0.31	-0.60	3.74	-8.08	5.34
			9						6.92	2.83	0.96	0.30	1.63	43.16	2.48	0.18	0.04	0.01	-0.09	0.22	-4.75	4.88	-1.09
Petrie Museum UC11170	EGPET	17	4	1.7x1cm	late MK	Lahun	glazed steatite	e	14.90	1.76	0.85	0.19	1.18	37.27	0.40	17.40	0.04	0.00	0.00	-0.07	0.01	-0.07	0.18
			5						16.35	2.24	0.85	0.20	0.93	20.08	0.39	25.03	0.04	0.00	0.02	-0.17	0.01	-0.14	0.45
Petrie Museum UC11172	EGPET	18	1	2x1.4cm	late MK	Lahun	steatite	e	7.06	0.82	0.93	0.40	1.37	7.35	2.63	0.04	0.04	-0.01	0.05	0.11	-0.47	3.33	-0.20
			2						11.34	0.42	0.88	0.19	1.80	24.02	0.37	3.47	0.03	0.00	-0.01	0.25	0.05	-0.37	0.72
Petrie Museum UC11354	EGPET	19	3	L2.2cm	late MK	Lahun	glazed steatite	e	8.07	2.16	0.83	0.16	0.89	5.09	2.66	0.24	0.04	0.00	0.05	-0.16	1.01	-2.12	-0.62
			8						8.48	1.73	0.74	0.17	0.81	2.87	2.25	4.40	0.04	0.00	-0.03	0.00	0.07	0.46	-2.03
Petrie Museum UC7550	EGPET	20	5		late MK	Lahun	glazed steatite	e	17.42	1.72	0.85	0.21	0.91	19.30	0.79	16.16	0.04	0.00	-0.01	0.04	0.00	-0.01	0.08
			6						17.71	1.71	0.88	0.18	0.82	34.33	0.72	30.75	0.05	0.00	0.00	0.02	0.00	-0.01	0.05
Petrie Museum UC11158	EGPET	21	6		late MK	Lahun	glazed steatite	e	17.01	2.24	0.83	0.18	0.89	10.33	0.62	24.23	0.04	0.00	0.01	-0.07	0.01	-0.09	0.35
			10						7.40	0.91	0.82	0.39	0.91	5.29	2.42	0.08	0.04	0.00	-0.02	0.04	1.34	-1.42	1.36
Petrie Museum UC11161	EGPET	22	1		late MK	Lahun	glazed steatite	e	7.59	0.25	0.93	0.44	1.00	6.74	2.65	0.41	0.04	0.01	-0.07	0.27	-0.27	2.73	-1.57
			4						6.33	2.64	0.81	0.39	1.18	34.23	4.88	n/a	0.04	-0.05	0.37	-0.45	0.00	0.00	0.00
Petrie Museum UC11164	EGPET	23	2		late MK	Lahun	glazed steatite	e	7.05	2.57	0.94	0.41	1.21	57.40	3.03	0.20	0.04	0.00	0.03	-0.17	6.46	-8.43	5.41
			3						6.62	2.02	0.84	0.47	1.70	13.67	3.41	0.02	0.04	0.02	-0.21	0.76	-6.20	7.12	0.14

Context data									Style data														
Museum number	Museum ID	Object number	spiral numbers analysed	Object notes	date*	place	material	image source**	rotation	orientation***	curvilinearity	irregularity	path width median	path width trend error	spacing median	spacing trend error	sampling resolution	path width trend coefficients			spacing trend coefficients		
Petrie Museum UC11169	EGPET	24	5		late MK	Lahun	glazed steatite	e	8.29	2.54	0.73	0.24	1.01	82.61	2.12	1.49	0.04	0.00	-0.02	0.22	0.31	-0.91	1.17
			8						9.14	1.92	0.60	0.49	0.54	7.84	1.83	9.30	0.04	0.00	-0.06	0.25	0.02	0.99	-1.11
Petrie Museum UC11348	EGPET	25	6		late MK	Lahun	glazed steatite	e	5.78	1.73	0.74	0.23	0.95	5.39	3.43	n/a	0.04	0.01	-0.08	0.17	0.00	0.00	0.00
			8						5.66	1.41	0.83	0.14	1.16	10.54	3.44	n/a	0.04	-0.01	0.02	-0.01	0.00	0.00	0.00
Petrie Museum UC11349	EGPET	26	5	name scarab - title deputy secretary	late MK	Lahun	glazed steatite	e	8.29	1.81	0.82	0.26	1.04	18.80	2.00	1.31	0.04	0.00	0.04	-0.22	-0.48	1.83	-1.43
			11						7.87	2.44	0.37	0.34	0.90	6.19	2.42	1.33	0.04	0.00	-0.01	-0.03	0.78	0.11	-1.11
Petrie Museum UC11353	EGPET	27	1	personal name scarab	late MK	Naqada	gold	e	5.35	1.18	0.71	0.18	1.39	17.62	4.53	n/a	0.04	0.02	-0.16	0.30	0.00	0.00	0.00
			3						5.66	1.50	0.74	0.27	1.02	6.01	4.45	n/a	0.04	0.01	-0.09	0.24	0.00	0.00	0.00
Petrie Museum UC11366	EGPET	28	3	personal name scarab - title inspector of guards	late MK	Lahun	brown jasper	e	8.81	1.25	0.64	0.20	0.92	11.14	2.10	0.18	0.04	0.00	0.01	-0.05	0.03	0.48	-1.61
			6						8.51	1.92	0.80	0.13	0.76	8.37	2.98	1.62	0.04	0.00	0.03	-0.15	-0.53	2.12	-2.59
Petrie Museum UC11385	EGPET	29	2	personal name scarab - title inspector of guards	late MK	Koptos	glazed steatite	e	5.88	1.76	0.73	0.21	1.19	28.63	3.52	n/a	0.05	-0.01	0.02	0.20	0.00	0.00	0.00
			3						5.86	1.65	0.66	0.15	1.04	17.00	3.44	n/a	0.04	0.04	-0.30	0.65	0.00	0.00	0.00
Petrie Museum UC16142	EGPET	30	2		12D	Hawara	glazed steatite	e	10.01	2.92	0.48	0.18	1.44	16.24	0.94	3.55	0.04	0.00	-0.02	0.02	0.18	-0.97	1.23
			3						10.46	2.57	0.78	0.19	1.24	9.66	1.08	11.71	0.04	0.00	-0.03	0.09	0.17	-1.16	1.94
Petrie Museum UC20732	EGPET	31	1	tomb 1595	9D	Qau	steatite	e	8.80	1.00	0.38	0.23	0.69	28.47	2.18	1.56	0.04	0.01	-0.07	0.21	-0.69	2.32	-1.24
			5						8.72	1.68	0.83	0.23	1.38	69.63	0.63	1.07	0.04	0.03	-0.41	1.37	0.71	-2.17	1.13
Petrie Museum UC20857	EGPET	32	1	tomb 1735, Found in shaft tomb probably strung as part of a necklace originally (Brunton 1927, p.40). representational context - papyrus.	9D	Qau	steatite	e	10.02	2.14	0.80	0.27	1.20	82.28	0.88	7.59	0.04	0.01	-0.13	0.52	0.36	-1.75	2.30
			2						10.59	0.83	0.78	0.32	1.03	48.21	0.83	17.75	0.04	0.00	-0.05	0.22	0.19	-0.88	0.99

*1I – First Intermediate, MK – Middle Kingdom, 2I – Second Intermediate, D - Dynasty

** image source codes refer to those used on the List of Figures

***underlined orientation assumed from cluster group

Table A2.5 Contextual and style data for the Bronze Age Cypriot case study

Context data										Style data														
Museum number	**Museum ID**	**Object number**	**spiral numbers analysed**	**period***	**start date**	**end date**	**place**	**Object notes**	**image source****	**rotation**	**orientation*****	**curvilinearity**	**irregularity**	**path width median**	**path width trend error**	**spacing median**	**spacing trend error**	**sampling resolution**	**path width trend coefficients**			**spacing trend coefficients**		
Pottery																								
Ashmolean Museum AN1958.62	CYASH	1	1		1375	1300	French tomb 5, Ayios Iakovos, Enkomi	cup, 'Mycenaean style'		16.57	2.66	0.78	0.15	0.70	55.80	0.89	77.47	0.05	0.00	0.03	-0.26	0.00	-0.07	0.34
			2							14.80	2.85	0.86	0.15	0.89	19.48	0.76	48.35	0.04	0.00	-0.03	0.15	0.00	0.00	-0.22
British Museum 1938,1120.5	CYBM	1	1	?late LC IIC, ?LC III	1250	1200	Enkomi	krater, Pastoral style, White Painted Wheelmade III ware, ?representational	b	20.10	0.24	0.82	0.42	0.38	11.70	0.33	97.11	0.04	0.00	0.00	-0.01	0.01	-0.09	0.25
British Museum 1873,0320.187	CYBM	3	1	CG II-III	950	750	Idalion	plate, White Painted II style, W33cm	b	25.07	2.54	0.86	0.10	0.57	9.07	0.35	7.22	0.04	0.00	0.00	0.03	0.00	0.00	0.03
British Museum 1873,0320.191	CYBM	4	1	CG I-II	1050	900	Idalion	plate, White Painted I style, diam 30.5cm	b	18.58	1.71	0.86	0.08	0.66	4.61	0.31	7.73	0.04	0.00	0.00	-0.05	0.00	0.01	-0.11
British Museum 1880,0710.9	CYBM	5	1	CA I	700	600	Aradhippou tomb, Larnaka	dish, Black-on-Red IV ware, wheel-made, spiral on interior. Sampled at low resolution.	b	32.99	2.54	0.84	0.03	0.26	9.66	0.13	8.17	0.05	0.00	0.00	0.01	0.00	0.00	0.02
British Museum 1896,0201.333	CYBM	7	1	LC IIIA, LC IIC	1250	1150	Episkopi-Bamboula Site D tomb 96, Kourion	bowl, White Painted Wheelmade III ware, spiral on inside. Sampled at low resolution.	b	50.19	1.5	0.81	0.07	0.38	36.27	0.23	68.55	0.05	0.00	0.00	0.00	0.00	0.00	0.01
Medelhavsmuseet S.011:006 or St.011:006	CYMM	1	1		c.725	600		kylix, painted, representational (plant), diam. 19.8	g	6.73	1.93	0.88	0.26	2.22	9.68	0.78	0.04	0.04	0.04	-0.43	1.44	-0.02	0.28	-0.50
			2							6.95	1.05	0.88	0.24	2.44	27.01	0.84	0.08	0.04	0.04	-0.43	1.53	-0.06	0.48	-0.57
Medelhavsmuseet A. 019:012	CYMM	2	1	CG I-II	1050	850	Amathus tomb 19	bowl, painted, chamber, level 15.	g	19.99	1.71	0.88	0.08	0.60	9.93	0.27	5.44	0.05	0.00	0.00	0.03	0.00	0.00	-0.02
Medelhavsmuseet SHM 17946:048	CYMM	3	1	CA I	700	600	?Marion	bowl, painted, spiral on base of foot. Sampled at low resolution.	g	28.33	1.5	0.81	0.05	0.26	8.01	0.27	10.79	0.05	0.00	0.00	0.02	0.00	0.00	0.06
Medelhavsmuseet SHM 17946:0013 or SHM 17946:0013	CYMM	4	1	CG III	900	750	?Idalion, ?Amathus	barrel jug	g	14.73	2.13	0.63	0.08	0.46	12.81	0.37	27.82	0.05	0.00	-0.01	0.03	0.00	-0.03	0.11
Medelhavsmuseet SHM 17946:0018 or SHM 17946:018	CYMM	5	1	CG III	900	750	?Paphos [Palaepaphos]	barrel jug, White Painted III ware. Sampled at low resolution.	g	37.13	2.80	0.84	0.02	0.17	6.98	0.07	7.12	0.05	0.00	0.00	0.00	0.00	0.00	0.00

Context data										Style data														
Museum number	**Museum ID**	**Object number**	**spiral numbers analysed**	**period***	**start date**	**end date**	**place**	**Object notes**	**image source****	**rotation**	**orientation*****	**curvilinearity**	**irregularity**	**path width median**	**path width trend error**	**spacing median**	**spacing trend error**	**sampling resolution**	**path width trend coefficients**			**spacing trend coefficients**		
Medelhavsmuseet A. 007:021	CYMM	6	1	CA I	700	600	Amathus tomb 2 Chamber, Stratum 3, Level 88	bowl, Black on Red II (IV) ware. Sampled at low resolution.	g	22.94	2.54	0.79	0.03	0.31	5.38	0.10	19.12	0.06	0.00	0.00	0.00	0.00	0.00	-0.01
Medelhavsmuseet NM Ant 1719	CYMM	7	1	CA I	700	600	?Stylli	amphora, representational (lotus), Bichrome IV ware.	g	6.92	1.37	0.62	0.40	2.27	16.86	2.26	0.10	0.04	0.03	-0.33	1.45	0.72	-1.84	3.73
			2							7.23	1.87	0.86	0.40	1.46	19.31	3.27	0.26	0.04	0.00	0.02	0.18	-0.09	-1.27	4.43
Medelhavsmuseet MM 1997:003	CYMM	8	1	?CA I	700	600	??Kouris Valley	jug, Black on Red II (IV) ware , H35. Sampled at low resolution.	g	62.07	0.31	0.73	0.05	0.14	3.69	0.14	5.53	0.09	0.00	0.00	0.00	0.00	0.00	0.01
Medelhavsmuseet SHM 17946:038	CYMM	9	1	CA I	700	600	?Palaepaphos-Skales	bowl, Black on Red II (IV) ware, rim diam 16.5	g	16.26	2.14	0.69	0.07	0.47	3.47	0.34	8.64	0.04	0.00	-0.02	0.14	0.00	-0.01	0.09
Medelhavsmuseet NM Ant 0466	CYMM	10	1	not stated	not stated	not stated	not stated	bowl, Bichrome IV ware. Sampled at low resolution.	g	54.90	0.31	0.74	0.03	0.08	1.98	0.11	6.54	0.09	0.00	0.00	0.00	0.00	0.00	0.00
			2							38.47	1.5	0.86	0.01	0.13	5.01	0.12	9.63	0.05	0.00	0.00	0.02	0.00	0.00	0.01
Medelhavsmuseet MM Acc 0898	CYMM	11	1	CA I	700	600	not stated	bowl, Bichrome IV ware. Sampled at low resolution.	g	68.13	0.31	0.57	0.03	0.07	1.57	0.07	3.12	0.14	0.00	0.00	0.00	0.00	0.00	0.00
			2							63.63	0.31	0.53	0.04	0.10	11.96	0.09	26.72	0.14	0.00	0.00	0.00	0.00	0.00	0.00
Medelhavsmuseet MM Acc 0699	CYMM	12	1	CA I	700	600	not stated	amphora, representational (lily), Bichrome IV ware, H76	g	5.83	1.38	0.93	0.29	2.23	5.76	1.85	0.01	0.04	0.02	-0.21	1.03	20.40	-8.15	3.62
			2							5.76	2.02	0.88	0.38	1.95	3.94	1.04	0.01	0.04	0.08	-0.68	1.89	-7.80	4.96	0.96
Medelhavsmuseet MM 1956:010	CYMM	13	1	CG II	950	850	not stated	bowl, Bichrome II ware.	g	13.02	1.32	0.80	0.06	0.49	9.68	0.28	13.31	0.04	0.00	0.02	-0.15	0.00	-0.03	0.14
Medelhavsmuseet MM Acc 0443	CYMM	14	1	not stated	not stated	not stated	not stated	flask	g	15.32	2.60	0.85	0.13	0.64	9.60	0.53	31.92	0.05	0.00	0.00	0.04	0.00	-0.02	0.11
Medelhavsmuseet MM Acc 0472	CYMM	15	1	CA I	700	600	Lapithos	bowl, White Painted IV ware, rim diam 19.4	g	18.62	0.96	0.34	0.07	0.55	15.23	0.43	48.22	0.05	0.00	0.01	-0.08	0.00	-0.03	0.20
Medelhavsmuseet E. 003:276	CYMM	16	1	LC II	1450/ 1400	1200	Enkomi, tomb 3 chamber	krater, representational (plant), Mycenaean IIIA:2 ware, H39.6	g	8.08	1.02	0.67	0.39	0.24	1.22	2.53	0.81	0.05	0.00	0.00	0.03	0.12	1.41	0.34
			2							7.64	0.66	0.68	0.22	0.80	2.35	1.45	0.08	0.04	0.00	0.05	-0.12	-0.72	3.68	-2.34
Medelhavsmuseet A.J. B.A.S. 030	CYMM	17	1	not stated	not stated	not stated	Ajios Jakovos (BA sanctuary)	jug, Mycenaean style, H11	g	25.70	0.33	0.82	0.12	0.61	48.29	0.50	74.14	0.04	0.00	0.00	-0.01	0.00	-0.01	0.07
Medelhavsmuseet E. 003:044	CYMM	18	1	LC II	1450/ 1400	1200	Enkomi, Tomb 3, Chamber, Floor	carinated cup, White Painted Wheelmade III ware, diam 6.4cm	g	17.05	2.55	0.84	0.18	0.90	55.36	1.05	34.69	0.05	0.00	0.00	-0.06	0.01	-0.21	0.82

Context data										Style data														
Museum number	Museum ID	Object number	spiral numbers analysed	period*	start date	end date	place	Object notes	image source**	rotation	orientation***	curvilinearity	irregularity	path width median	path width trend error	spacing median	spacing trend error	sampling resolution	path width trend coefficients			spacing trend coefficients		
Medelhavsmuseet E. 013:211	CYMM	19	1	LC IIC-IIIA	1340	1100	Enkomi, Tomb 13, Chamber, Level 51	bowl, White Painted Wheelmade III ware, local imitation of Mycenaean pottery	g	21.02	2.55	0.84	0.09	0.48	12.06	0.31	7.94	0.04	0.00	0.00	0.03	0.00	0.00	0.01
Medelhavsmuseet E. 003:261	CYMM	20	1	LC II/LH IIIA2			Enkomi	krater, Mycenaean III ware, representational (plant), H43.8, diam 25.1	g	9.42	2.10	0.63	0.29	0.52	3.43	1.30	1.42	0.04	0.00	0.00	0.05	0.32	-0.98	1.20
			2							10.86	0.78	0.82	0.32	0.37	1.62	1.45	4.45	0.04	0.00	-0.02	0.06	0.00	0.21	-0.03
Medelhavsmuseet E. 018 Sk:046	CYMM	21	1	LC II/LH IIIB1			Enkomi, Tomb 18, side chamber	krater, representational (plant), Mycenaean IIIB ware.	g	16.96	0.50	0.88	0.25	0.28	5.18	1.58	206.65	0.05	0.00	-0.01	0.11	-0.01	0.17	-0.86
Medelhavsmuseet L. 428:080	CYMM	22	1	CG I	1050	950	Lapithos, Tomb 428, floor	jug, White Painted I ware, H12.6cm. Sampled at low resolution.	g	32.38	2.53	0.84	0.04	0.39	12.22	0.23	36.46	0.04	0.00	0.00	0.00	0.00	0.00	0.00
Medelhavsmuseet A. 023:075	CYMM	23	1	CG III-CA I	900	600	Amathus, Tomb 23, Chamber, stratum 1, floor	bottle, White Painted II ware, H11.5	g	17.60	2.50	0.87	0.05	0.44	5.46	0.21	11.43	0.05	0.00	0.00	-0.01	0.00	0.00	-0.01
Medelhavsmuseet M. 068:012	CYMM	24	1	CA I	750	600	Marion, Tomb 68, chamber, stratum 2, level 20	bowl, Black on Red II (IV) ware, diam 19.5. Sampled at low resolution.	g	50.51	2.94	0.68	0.03	0.15	4.16	0.13	7.65	0.09	0.00	0.00	0.00	0.00	0.00	0.01
Medelhavsmuseet E. 003:165	CYMM	25	1	LC II	1450/1400	1200	Enkomi, Tomb 3, chamber	pyxis, Mycenaean IIIA ware, H13.5	g	32.91	3.02	0.45	0.11	0.54	44.74	0.44	52.96	0.05	0.00	0.00	0.00	0.00	0.01	-0.04
Royal Albert Memorial Museum 917/1910	CYRAM	1	1	IA	850	600	Paphos	barrel jug, Archaic ware, Black on Red ware	i	76.62	0.12	0.50	0.09	0.13	2.47	0.14	18.40	0.14	0.00	0.00	0.00	0.00	0.00	0.00
Royal Albert Memorial Museum 31/1918/47	CYRAM	2	1	IA	850	600	Cyprus	jug (barrel), Archaic ware, Black on Red ware. Sampled at low resolution.	i	47.98	0.20	0.83	0.04	0.25	9.05	0.22	23.06	0.05	0.00	0.00	-0.01	0.00	0.00	0.00
Goldwork																								
Ashmolean Museum AN1962.244	CYASH	2	1		1450	1200	probably Enkomi	embossed funerary diadem		14.62	2.12	0.51	0.17	0.95	13.78	0.37	23.38	0.04	0.00	-0.01	0.10	0.02	-0.17	0.45
			6							17.38	1.24	0.86	0.15	1.08	29.17	0.45	14.08	0.04	0.00	-0.01	0.13	0.00	-0.04	0.16

Context data										Style data														
Museum number	**Museum ID**	**Object number**	**spiral numbers analysed**	**period***	**start date**	**end date**	**place**	**Object notes**	**image source****	**rotation**	**orientation*****	**curvilinearity**	**irregularity**	**path width median**	**path width trend error**	**spacing median**	**spacing trend error**	**sampling resolution**	**path width trend coefficients**			**spacing trend coefficients**		
British Museum 1898,1201.74	CYBM	15	1	LC II	c. 1400	1200	Site A, Maroni	repoussé mouth-piece. L10	b	21.04	1.37	0.85	0.13	0.85	20.68	0.47	5.43	0.04	0.00	0.00	0.05	0.00	0.00	0.03
			2							23.98	1.41	0.85	0.17	0.95	68.19	0.39	13.96	0.04	0.00	-0.01	0.08	0.00	-0.01	0.05
British Museum 1897,0401.400.*	CYBM	16	2	from LC IB	1550	1050	Enkomi (tomb 72)	impressed mouth-piece. L9.9	b	14.35	1.21	0.51	0.10	1.10	51.25	0.53	22.88	0.04	0.00	-0.01	0.23	-0.02	0.32	-0.97
			7							12.62	0.07	0.86	0.24	0.89	42.79	0.65	5.30	0.04	0.00	0.00	0.00	0.01	-0.04	-0.02
British Museum 1897,0401.376	CYBM	17	1	from LC IB	1550	1050	Enkomi (tomb 69)	impressed mouth-piece. L9.9	b	23.80	0.85	0.87	0.23	0.78	41.74	0.29	50.54	0.04	0.00	0.00	0.02	0.00	-0.04	0.21
			12							17.00	0.16	0.84	0.12	0.62	32.01	0.99	26.39	0.04	0.00	-0.01	0.14	0.00	-0.02	0.18
British Museum 1897,0401.196	CYBM	18	1	from LC IB	1550	1050	Enkomi (tomb 56)	impressed mouth-piece. L10.1	b	19.67	1.20	0.88	0.24	0.96	15.12	0.31	25.74	0.04	0.00	-0.02	0.18	0.00	-0.01	0.06
			11							21.82	0.44	0.87	0.19	0.71	13.07	0.39	67.93	0.04	0.00	0.01	0.00	0.00	-0.07	0.34
British Museum 1897,0401.528	CYBM	19	1	from LC IB	1550	1050	Enkomi (tomb 93)	impressed and hammered mouth-piece.	b	17.72	1.51	0.88	0.13	1.14	28.71	0.32	6.84	0.04	0.00	0.00	0.08	0.00	-0.03	0.13
			2							19.82	0.23	0.92	0.14	1.25	23.23	0.28	16.02	0.04	0.00	0.00	0.10	0.00	0.01	-0.09
British Museum 1897,0401.649	CYBM	20	7	from LC IB	1550	1050	Enkomi	impressed and hammered ?mouth-piece. L10	b	15.21	0.25	0.87	0.12	0.98	15.00	0.78	14.33	0.04	0.00	0.02	-0.08	-0.01	0.14	-0.45
			11							14.41	2.23	0.87	0.11	0.69	52.57	0.82	17.93	0.04	0.00	-0.02	0.19	-0.01	0.15	-0.42
British Museum 1897,0401.471	CYBM	21	1	from LC IB	1550	1050	Enkomi (tomb 88)	impressed and hammered mouth-piece.	b	19.04	0.92	0.88	0.12	0.90	23.64	0.26	11.78	0.04	0.00	-0.01	0.04	0.00	0.02	-0.11
			7							18.85	1.98	0.92	0.11	1.04	37.65	0.17	18.17	0.04	0.00	-0.02	0.17	0.00	0.03	-0.25
British Museum 1897,0401.448	CYBM	22	7	from LC IB	1550	1050	Enkomi (tomb 79)	impressed and hammered mouth-piece.	b	17.25	2.59	0.74	0.27	0.70	17.72	0.10	65.78	0.04	0.00	-0.02	0.14	0.02	-0.16	0.20
			14							17.70	0.52	0.83	0.21	0.71	12.31	0.51	26.84	0.04	0.00	0.01	0.03	0.01	-0.09	0.23
British Museum 1900,0615.18	CYBM	23	9	from LC IB	1550	1050	Enkomi (tomb ?93)	impressed and hammered mouth-piece	b	17.96	2.51	0.53	0.18	1.07	17.49	0.20	13.93	0.04	0.00	-0.01	0.09	0.00	-0.04	0.10
			10							18.19	2.40	0.82	0.21	1.06	56.82	0.05	6.79	0.04	0.00	0.00	0.06	0.00	-0.05	0.14
British Museum 1897,0401.523	CYBM	24	7	from LC IB	1550	1050	Enkomi (tomb 93)	impressed and hammered mouth-piece	b	14.65	0.56	0.88	0.11	1.35	58.63	0.31	11.59	0.04	0.00	-0.01	0.08	0.00	0.05	-0.19
			9							15.50	0.34	0.87	0.20	1.45	69.41	0.29	12.04	0.04	0.00	-0.04	0.42	0.00	-0.04	0.09
British Museum 1897,0401.525	CYBM	25	16	from LC IB	1550	1050	Enkomi (tomb 93)	impressed and hammered mouth-piece	b	16.85	0.51	0.91	0.07	1.17	35.91	0.45	39.98	0.04	0.00	0.00	0.00	0.00	-0.03	0.22
			22							14.40	0.45	0.87	0.10	1.41	26.42	0.26	19.26	0.04	0.00	-0.06	0.39	0.00	0.03	-0.08
British Museum 1897,0401.269	CYBM	26	1	from LC IB	1550	1050	Enkomi (tomb 66)	impressed and hammered mouth-piece/diadem fragment	b	24.53	2.34	0.81	0.12	0.82	51.34	0.27	37.61	0.05	0.00	-0.01	0.17	0.00	0.01	-0.06
			2							24.67	3.05	0.82	0.13	0.79	32.38	0.30	18.94	0.05	0.00	0.00	0.01	0.00	0.00	0.09
British Museum 1897,0401.522	CYBM	27	1	from LC IB	1550	1050	Enkomi (tomb 93)	impressed and hammered mouth-piece/diadem fragment.	b	7.13	2.00	0.92	0.13	1.26	22.43	0.50	0.04	0.04	0.01	-0.14	0.68	-0.69	3.57	-1.56
			2							6.55	1.60	0.76	0.08	1.01	14.61	0.26	0.00	0.04	-0.03	0.20	-0.28	7.49	4.76	-0.34
British Museum 1897,0401.740	CYBM	28	1	from LC IB	1550	1050	Enkomi (tomb 90?)	impressed and hammered mouth-piece/diadem fragment	b	9.76	2.09	0.85	0.14	1.31	41.25	0.48	1.64	0.04	0.01	-0.11	0.54	0.12	-0.63	0.86
			2							9.83	1.74	0.90	0.09	1.52	63.68	0.95	2.71	0.04	0.00	0.03	0.09	0.05	-0.35	0.81

Context data										Style data														
Museum number	Museum ID	Object number	spiral numbers analysed	period*	start date	end date	place	Object notes	image source**	rotation	orientation***	curvilinearity	irregularity	path width median	path width trend error	spacing median	spacing trend error	sampling resolution	path width trend coefficients			spacing trend coefficients		
British Museum 1897,0401.270	CYBM	29	3	from LC IB	1550	1050	Enkomi (tomb 66)	impressed and hammered mouth-piece/diadem fragment	b	17.97	0.11	0.86	0.13	1.16	43.41	0.23	21.91	0.04	0.00	-0.01	0.07	0.00	0.07	-0.42
			4							16.84	2.92	0.90	0.11	0.98	33.87	0.41	10.25	0.04	0.00	0.01	-0.08	0.00	0.08	-0.39
British Museum 1897,0401.444	CYBM	30	1	from LC IB	1550	1050	Enkomi (tomb 79)	impressed and hammered mouth-piece/diadem fragment	b	18.92	0.00	0.35	0.18	0.99	36.86	0.39	17.90	0.04	0.00	0.00	0.00	0.00	-0.09	0.48
			4							14.63	0.33	0.79	0.13	1.04	32.75	0.34	9.36	0.04	0.00	0.01	-0.07	0.00	-0.05	0.22
British Museum 1897,0401.520	CYBM	31	3	from LC IB	1550	1050	Enkomi (tomb 93)	impressed and hammered mouth-piece/diadem fragment	b	7.50	1.84	0.85	0.16	1.19	6.82	0.81	0.12	0.04	0.00	-0.08	0.37	0.79	-1.21	0.90
			8							9.25	0.43	0.87	0.04	1.18	20.30	1.18	16.54	0.04	-0.01	0.07	-0.17	0.11	-0.96	2.20
British Museum 1897,0401.11	CYBM	32	1	from LC IB	1550	1050	Enkomi (tomb 15)	impressed and hammered mouth-piece/diadem fragment	b	24.06	1.59	0.88	0.08	0.82	19.85	0.03	15.59	0.04	0.00	0.00	0.01	0.00	0.00	-0.03
			8							23.13	2.13	0.84	0.09	0.79	29.30	0.02	23.09	0.04	0.00	-0.01	0.08	0.00	-0.02	0.09
British Museum 1897,0401.272	CYBM	33	6	from LC IB	1550	1050	Enkomi (tomb 66)	impressed and hammered mouth-piece/diadem fragment	b	23.15	2.06	0.83	0.11	0.90	50.34	0.13	24.71	0.04	0.00	-0.01	0.07	0.00	0.00	0.00
			13							23.26	1.55	0.87	0.13	0.73	29.39	0.21	23.78	0.04	0.00	0.00	-0.01	0.00	-0.02	0.08
British Museum 1897,0401.65	CYBM	34	3	from LC IB	1550	1050	Enkomi (tomb 19)	impressed and hammered mouth-piece/diadem fragment	b	24.51	1.47	0.87	0.10	0.77	38.31	0.03	32.86	0.04	0.00	0.00	0.01	0.00	0.00	-0.01
			5							21.80	0.06	0.86	0.06	0.81	53.40	0.03	6.79	0.04	0.00	0.00	0.06	0.00	0.00	-0.03
British Museum 1897,0401.64	CYBM	35	4	from LC IB	1550	1050	Enkomi (tomb 19)	impressed and hammered mouth-piece/diadem fragment	b	17.90	1.28	0.85	0.14	0.85	25.43	0.04	33.77	0.04	0.00	0.00	0.00	0.00	-0.01	-0.13
			6							24.53	1.48	0.83	0.10	0.78	26.12	0.02	20.42	0.04	0.00	-0.01	0.07	0.00	-0.01	0.07
British Museum 1897,0401.63	CYBM	36	6	from LC IB	1550	1050	Enkomi (tomb 19)	impressed and hammered mouth-piece/diadem fragment	b	22.48	0.20	0.78	0.11	0.92	46.30	0.04	8.86	0.04	0.00	-0.02	0.15	0.00	0.00	-0.05
			12							24.77	1.32	0.00	0.10	0.75	41.62	0.22	9.82	0.04	0.00	0.00	-0.03	0.00	0.01	-0.01
British Museum 1898,1201.18	CYBM	37	39	LC II/III	1400	1100	Maroni (tomb 4), Larnaka	impressed and hammered mouth-piece/diadem fragment	b	13.30	1.87	0.91	0.20	0.96	32.41	0.50	22.50	0.04	0.00	0.01	0.01	-0.01	0.26	-1.40
			77							14.51	1.76	0.83	0.21	1.76	27.99	0.49	12.88	0.04	0.00	0.03	-0.06	0.03	-0.33	0.89
British Museum 1897,0401.66	CYBM	38	8	from LC IB	1550	1051	Enkomi (tomb 19)	impressed and hammered mouth-piece/diadem fragment	b	14.37	2.14	0.88	0.16	0.89	25.96	1.08	19.36	0.04	0.00	-0.01	0.12	0.00	-0.06	0.19
			12							14.09	0.58	0.82	0.18	1.07	32.30	1.01	16.83	0.04	0.00	0.00	0.00	-0.01	0.17	-0.60

Context data										Style data														
Museum number	Museum ID	Object number	spiral numbers analysed	period*	start date	end date	place	Object notes	image source**	rotation	orientation***	curvilinearity	irregularity	path width median	path width trend error	spacing median	spacing trend error	sampling resolution	path width trend coefficients			spacing trend coefficients		
British Museum 1897,0401.651	CYBM	39	3	from LC IB	1550	1051	Enkomi (tomb unknown)	impressed and hammered mouth-piece/diadem fragment	b	15.56	0.00	0.89	0.16	0.94	53.88	0.05	10.59	0.04	0.00	-0.04	0.22	0.01	-0.08	0.19
			4							13.51	0.09	0.84	0.00	0.75	57.75	0.45	8.57	0.04	0.00	-0.05	0.34	0.00	0.01	-0.07
British Museum 1900,0615.9	CYBM	40	1	from LC IB	1550	1051	Enkomi (tomb 93 probably)	impressed and hammered mouth-piece/diadem fragment	b	23.67	1.73	0.87	0.13	0.76	20.74	0.23	25.15	0.04	0.00	0.00	0.02	0.00	-0.01	0.08
			8							23.37	2.54	0.92	0.10	0.84	22.12	0.19	11.37	0.04	0.00	0.00	-0.04	0.00	-0.01	0.06
British Museum 1897,0401.517	CYBM	41	2	from LC IB	1550	1051	Enkomi (tomb 93)	impressed and hammered mouth-piece/diadem fragment	b	10.64	0.84	0.66	0.37	0.81	16.50	1.56	2.25	0.05	0.00	-0.02	0.16	0.11	-0.19	-0.82
			6							10.03	0.11	0.81	0.40	1.12	48.76	2.88	6.98	0.04	0.00	-0.02	0.21	-0.12	0.62	0.73
British Museum 1897,0401.518	CYBM	42	7	from LC IB	1550	1051	Enkomi (tomb 93)	impressed and hammered mouth-piece/diadem fragment	b	19.46	1.01	0.83	0.13	1.36	64.65	0.03	2.62	0.04	0.00	-0.01	0.16	0.00	0.00	0.00
			10							17.72	0.43	0.86	0.13	1.39	102.22	0.00	0.91	0.04	0.00	-0.01	0.25	0.00	0.00	-0.01
Fitzwilliam Museum GR.155b.1909	CYFM	1	18	LH IIIA-B	1400	1201	Cyprus	diadem		10.73	2.86	0.83	0.18	0.90	6.89	0.74	2.92	0.04	0.00	-0.02	0.15	0.05	-0.17	-0.20
			22							12.43	2.68	0.52	0.10	0.80	6.84	0.75	4.37	0.04	0.00	-0.01	0.11	0.03	-0.25	0.68
Medelhavsmuseet E. 011:198	CYMM	26	1	LC II	1450/ 1400	1200	Enkomi, Tomb 11, chamber, floor	mouth-piece	g	18.38	2.96	0.85	0.14	1.09	23.38	0.24	26.84	0.04	0.00	0.00	-0.01	0.00	-0.01	0.10
			3							18.29	3.11	0.88	0.14	1.03	41.71	0.32	6.29	0.04	0.00	0.00	0.06	0.00	0.01	-0.07
Medelhavsmuseet E. 011:036	CYMM	27	11	LC II	1450/ 1400	1200	Enkomi, Tomb 11, chamber, level 96	diadem	g	18.80	1.60	0.87	0.15	1.14	44.00	0.29	29.72	0.04	0.00	0.01	-0.02	0.00	0.00	-0.08
			16							18.34	2.76	0.82	0.13	1.23	34.24	0.17	6.93	0.04	0.00	0.00	-0.02	0.00	-0.01	0.04
Medelhavsmuseet BEK 1963.30	CYMM	28	4	CA	not stated	not stated	not stated	diadem	g	11.29	2.96	0.86	0.20	1.23	44.95	1.00	6.88	0.04	0.00	0.04	-0.19	0.03	-0.14	0.15
			13							15.53	0.12	0.79	0.33	0.47	10.80	0.79	14.53	0.05	0.00	0.00	0.03	0.01	-0.10	0.19

*LC – Late Cypriot, LH – Late Helladic, CG – Cypro-Geometric, CA – Cypro-Archaic, IA – Iron Age

** image source codes refer to those used on the List of Figures

*** underlining indicates orientation estimated from clustering

Table A2.6 Context and style data for the endogenous visual phenomena examples

Context data							Style data														
Source	Page/figure	Object number	spiral numbers	cause	drawn during/ after experience	Object notes	**rotation**	**orientation**	**curvilinearity**	**irregularity**	**path width median**	**path width trend error**	**spacing median**	**spacing trend error**	**sampling resolution**	**path width trend coefficients**			**spacing trend coefficients**		
Horowitz 1964	p.516, fig 2b	FC1	1	schizophrenia, hallucinations exacerbated by medication,	probably after	interpreted as a pebble dropped in a pond may have been redrawn from the original drawing	34.12	0.68	0.35	0.03	0.37	6.23	0.18	72.82	0.05	0.00	0.00	0.01	0.00	0.00	-0.01
Horowitz 1964	p.516, fig 2b	FC1	2	spirals not apparently seen prior to medication	probably after	interpreted as 'hate' may have been redrawn from the original drawing	10.30	0.41	0.79	0.12	0.62	1.75	0.44	12.25	0.04	0.00	0.00	-0.02	0.06	-0.43	0.76
Horowitz 1964	p.517, fig 4	FC2	1	schizoid hallucinations for several weeks after taking LSD	after	interpreted as a dragon subject was an artist	13.14	1.64	0.89	0.13	0.38	1.49	1.01	50.79	0.04	0.00	0.00	0.00	0.00	-0.09	0.56
Maclay and Guttmann 1941	p.133, fig. 4	FC3	1	mescaline	unknown	subject was an artist	24.15	0.35	0.92	0.16	0.60	16.20	1.15	232.72	0.04	0.00	0.00	0.06	0.00	0.05	-0.16
Siegel and Jarvik (1975)	p.135, fig.19	FC4	1	ketamine	unknown	described as multicoloured patterns' but presented within a representational scene of houses and sea flashback image, presented as a rotating image	6.77	0.29	0.82	0.48	0.70	7.07	4.27	0.04	0.04	0.01	-0.19	0.75	0.60	-1.17	5.91
Siegel and Jarvik (1975)	p.135, fig.20	FC5	1	LSD/ schizophrenia	unknown	flashback image, diagnosed as schizophrenic	39.84	1.25	0.80	0.08	0.08	2.48	0.66	66.57	0.05	0.00	0.00	0.00	0.00	0.00	-0.01
Siegel and Jarvik	p.136, fig.21	FC6	1	schizophrenia	unknown		30.01	0.08	0.89	0.07	0.59	35.72	0.44	53.09	0.04	0.00	0.00	-0.02	0.00	0.00	0.07
Becker (2005)	p.202	FC7	1	light flicker 11Hz	after	response to a concentric circle stimulus card	16.60	2.46	0.87	0.16	0.15	1.74	1.93	79.24	0.04	0.00	0.00	0.00	0.02	-0.38	1.59
Becker (2005)	p.202	FC7	2	light flicker 12Hz	after	response to a concentric circle stimulus card	14.74	2.71	0.39	0.02	0.15	2.61	0.96	60.07	0.04	0.00	0.00	-0.01	0.00	0.01	0.09
Becker (2005)	p.202	FC7	3	light flicker 12Hz	after	response to a concentric circle stimulus card	21.38	1.31	0.48	0.12	0.24	4.26	1.53	158.68	0.04	0.00	0.00	-0.03	0.00	-0.08	0.39
Becker (2005)	p.203	FC7	4	light flicker 13Hz	after	response to a concentric circle stimulus card	21.91	2.08	0.88	0.10	0.26	6.30	0.55	28.54	0.04	0.00	0.01	-0.05	0.00	-0.02	0.17

Context data							Style data														
Source	Page/figure	Object number	spiral numbers	cause	drawn during/ after experience	Object notes	**rotation**	**orientation**	**curvilinearity**	**irregularity**	**path width median**	**path width trend error**	**spacing median**	**spacing trend error**	**sampling resolution**	**path width trend coefficients**			**spacing trend coefficients**		
Becker (2005)	p.205	FC7	5	light flicker 16Hz	after	response to a concentric circle stimulus card	19.54	0.39	0.86	0.04	0.20	3.68	1.19	46.45	0.05	0.00	0.00	0.00	0.00	0.05	-0.11
Becker (2005)	p.206	FC7	6	light flicker 18Hz	after	response to a concentric circle stimulus card	19.92	1.79	0.42	0.14	0.36	5.62	1.17	187.99	0.04	0.00	0.01	-0.10	0.00	-0.04	0.29
Becker (2005)	p.206	FC7	7	light flicker 19Hz	after	response to a concentric circle stimulus card	8.98	2.87	0.47	0.15	0.15	1.20	1.74	159.65	0.05	0.00	-0.01	0.02	-0.01	0.02	0.22
Becker (2005)	p.212	FC7	8	light flicker 14Hz	after	response to a line stimulus card	20.72	0.63	0.92	0.14	0.30	8.04	1.06	12.03	0.04	0.00	0.00	-0.02	0.00	-0.02	0.15
Becker (2005)	p.217	FC7	9	light flicker 13Hz	after	response to a point stimulus card	25.79	1.05	0.86	0.03	0.13	4.30	0.89	223.90	0.04	0.00	0.00	-0.02	0.00	-0.02	0.13
Becker (2005)	p.221	FC7	10	light flicker 12Hz	after	response to a radial pattern stimulus card	19.24	1.92	0.82	0.14	0.21	6.09	1.15	53.61	0.05	0.00	0.00	0.02	0.00	-0.08	0.38
Becker (2005)	p.233	FC7	13	light flicker 11Hz	after	response to a wave stimulus card	18.15	2.87	0.85	0.09	0.15	1.81	1.34	136.55	0.04	0.00	0.00	-0.01	-0.01	0.12	-0.61
Becker (2005)	p.235	FC7	14	light flicker 15Hz	after	response to a wave stimulus card	15.54	3.04	0.87	0.06	0.36	25.56	1.42	203.53	0.04	0.00	0.00	-0.08	-0.01	0.08	-0.01
Becker (2005)	p.238	FC7	15	light flicker 14Hz	after	response to a zig-zag stimulus card	27.15	2.91	0.85	0.11	0.32	5.14	0.84	60.45	0.04	0.00	0.00	-0.02	0.00	0.00	-0.05
Becker (2005)	p.223	FC8	1	light flicker 16Hz	after	asked to look for radial patterns	8.24	1.90	0.82	0.15	1.54	33.98	1.79	3.47	0.04	0.00	0.00	0.29	0.62	-2.82	3.94
Becker (2005)	p.229	FC8	2	light flicker 12Hz	after	asked to look for radial patterns	23.71	1.13	0.84	0.13	0.08	1.84	1.58	301.49	0.05	0.00	0.00	-0.01	0.00	0.01	0.17
Becker (2005)	p.230	FC8	3	light flicker 15Hz	after	asked to look for spirals	17.43	0.82	0.82	0.15	1.43	58.20	0.12	15.21	0.04	0.00	0.01	0.09	0.00	-0.01	-0.03
Becker (2005)	p.230	FC8	4	light flicker 15Hz	after	asked to look for spirals	9.07	1.80	0.89	0.16	1.55	29.33	1.51	9.13	0.04	0.01	-0.15	0.87	0.34	-1.22	0.53

Context data							Style data														
Source	Page/figure	Object number	spiral numbers	cause	drawn during/ after experience	Object notes	**rotation**	**orientation**	**curvilinearity**	**irregularity**	**path width median**	**path width trend error**	**spacing median**	**spacing trend error**	**sampling resolution**	**path width trend coefficients**			**spacing trend coefficients**		
Becker (2005)	p.231	FC8	5	light flicker 16Hz	after	asked to look for spirals	13.79	2.88	0.87	0.11	2.27	524.79	0.04	1.95	0.03	0.00	-0.04	0.41	0.00	-0.02	0.08
Becker (2005)	p.231	FC8	6	light flicker 17Hz	after	asked to look for spirals	18.78	1.86	0.81	0.14	1.32	110.24	0.02	6.17	0.04	0.00	-0.03	0.19	0.00	0.00	-0.01
Becker (2005)	p.231	FC8	7	light flicker 17Hz	after	asked to look for spirals	7.22	2.30	0.82	0.21	2.91	109.95	0.01	4.78	0.04	0.00	-0.21	1.27	0.01	-0.08	0.19
Becker (2005)	p.232	FC8	8	light flicker 18Hz	after	asked to look for spirals	10.25	2.89	0.89	0.24	2.58	78.68	0.07	0.56	0.04	0.02	-0.30	1.46	0.01	-0.04	0.09
Becker (2005)	p.232	FC8	9	light flicker 18Hz	after	asked to look for spirals	16.12	0.41	0.43	0.19	1.98	118.76	0.31	12.82	0.04	0.00	-0.02	0.32	0.00	0.05	-0.14
Becker (2005)	p.232	FC8	10	light flicker 19Hz	after	asked to look for spirals	11.68	1.15	0.83	0.33	2.34	61.96	0.00	0.05	0.03	0.01	-0.27	1.44	0.00	-0.01	0.00
Becker (2005)	p.229	FC9	1	light flicker 12Hz	after	response to a spiral stimulus card	14.95	0.89	0.45	0.13	1.07	147.14	0.75	43.93	0.04	0.00	0.00	-0.02	0.00	0.02	-0.12
Becker (2005)	p.229	FC9	2	light flicker 13Hz	after	response to a spiral stimulus card	19.85	0.96	0.84	0.12	0.15	3.27	1.56	279.41	0.04	0.00	0.00	0.03	-0.01	0.16	-0.65
Becker (2005)	p.231	FC9	3	light flicker 16Hz	after	response to a spiral stimulus card	19.08	1.31	0.90	0.06	0.08	2.38	1.27	94.52	0.04	0.00	0.00	0.01	-0.01	0.12	-0.35
Becker (2005)	p.232	FC9	4	light flicker 18Hz	after	response to a spiral stimulus card	16.61	2.28	0.84	0.13	2.01	403.18	0.15	0.52	0.04	0.00	0.00	0.09	0.00	0.00	-0.02
Becker (2005)	p.232	FC9	5	light flicker 18Hz	after	response to a spiral stimulus card	19.75	0.60	0.85	0.08	0.09	3.41	1.12	281.26	0.05	0.00	0.00	-0.02	0.00	0.02	-0.22
Becker (2005)	p.232	FC9	6	light flicker 19Hz	after	response to a spiral stimulus card	18.73	2.41	0.89	0.10	0.19	3.27	1.34	308.41	0.04	0.00	0.00	0.00	0.01	-0.17	0.57
Becker (2005)	p.239	FC9	7	light flicker 16Hz	after	response to a zig-zag stimulus card	6.94	2.42	0.82	0.14	1.28	86.34	0.50	0.04	0.04	0.02	-0.22	0.70	-4.21	4.01	-1.80
Becker (2005)	p.230	FC10	1	light flicker 15Hz	after	asked to look for spirals	14.61	1.24	0.83	0.08	0.20	2.66	2.14	45.26	0.04	0.00	0.01	-0.06	-0.02	0.13	0.02
Becker (2005)	p.230	FC11	1	light flicker 15Hz	after	asked to look for spirals	9.12	2.16	0.92	0.28	2.36	91.42	0.31	5.22	0.03	0.01	-0.17	1.02	0.47	-1.49	0.70
Becker (2005)	p.231	FC11	2	light flicker 16Hz	after	asked to look for spirals	15.65	1.95	0.90	0.08	0.23	3.55	1.15	161.36	0.04	0.00	0.00	-0.02	0.02	-0.23	0.67
Becker (2005)	p.231	FC11	3	light flicker 17Hz	after	asked to look for spirals	27.42	0.74	0.45	0.10	0.05	1.10	1.11	515.99	0.04	0.00	0.00	0.00	0.00	-0.04	0.34

Context data							Style data														
Source	Page/figure	Object number	spiral numbers	cause	drawn during/ after experience	Object notes	**rotation**	**orientation**	**curvilinearity**	**irregularity**	**path width median**	**path width trend error**	**spacing median**	**spacing trend error**	**sampling resolution**	**path width trend coefficients**			**spacing trend coefficients**		
Becker (2005)	p.231	FC11	4	light flicker 17Hz	after	asked to look for spirals	8.40	0.53	0.96	0.40	1.91	90.58	1.20	1.00	0.03	-0.02	0.12	0.04	0.05	0.73	-0.17
Becker (2005)	p.232	FC11	5	light flicker 19Hz	after	asked to look for spirals	9.96	0.40	0.67	0.29	1.22	26.19	2.07	12.60	0.04	0.00	0.00	0.01	-0.03	0.19	0.09
Becker (2005)	p.230	FC12	1	light flicker 15Hz	after	response to a spiral stimulus card	8.92	0.06	0.43	0.11	0.15	1.72	4.11	2.64	0.04	0.00	-0.02	0.06	-0.34	1.09	-0.51
Becker (2005)	p.230	FC12	2	light flicker 15Hz	after	response to a spiral stimulus card	9.07	2.15	0.87	0.04	0.18	2.16	1.07	1.71	0.04	0.00	-0.03	0.11	0.02	-0.24	0.37
Becker (2005)	p.231	FC12	3	light flicker 16Hz	after	response to a spiral stimulus card	19.73	0.82	0.82	0.17	0.10	1.53	1.70	99.79	0.04	0.00	0.00	0.01	0.00	-0.07	0.47
Becker (2005)	p.231	FC12	4	light flicker 17Hz	after	response to a spiral stimulus card	6.45	0.66	0.87	0.53	0.16	0.46	6.34	0.01	0.04	0.01	-0.06	0.13	-174.60	37.70	1.03
Becker (2005)	p.232	FC12	5	light flicker 18Hz	after	response to a spiral stimulus card	7.22	0.56	0.91	0.25	0.40	1.73	5.01	0.53	0.04	0.00	-0.01	-0.05	2.50	-4.85	2.69
Becker (2005)	p.232	FC12	6	light flicker 18Hz	after	response to a spiral stimulus card	9.03	1.07	0.43	0.11	0.18	1.48	3.72	2.23	0.04	0.00	-0.02	0.06	-0.37	1.43	-1.34
Becker (2005)	p.232	FC12	7	light flicker 19Hz	after	response to a spiral stimulus card	8.96	0.25	0.83	0.11	0.16	1.10	3.48	1.00	0.04	0.00	0.00	0.01	-0.29	1.13	-1.12
Ermentrout & Cowan (1979)	fig.1c	FC13	1	theoretical model	n/a		5.92	3.01	0.84	0.42	0.70	2.38	5.19	n/a	0.04	0.00	0.01	0.02	0.00	0.00	0.00
Tass (1997)	fig.6c	FC14	1	theoretical model	n/a		6.91	2.05	0.85	0.87	1.95	1.55	9.31	n/a	0.04	0.01	-0.10	0.78	0.00	0.00	0.00
Tass (1997)	fig.6d	FC14	2	theoretical model	n/a		4.70	1.56	0.85	0.67	2.83	9.48	9.17	n/a	0.05	0.14	-0.76	2.17	0.00	0.00	0.00
Tass (1997)	fig.11, col.1	FC15	2	theoretical model	n/a		10.79	1.64	0.80	0.78	9.28	6.80	14.31	n/a	0.06	0.00	-0.03	1.85	0.00	0.00	0.00
Tass (1997)	fig.11, col.4	FC16	3	theoretical model	n/a		4.86	0.90	0.89	0.70	2.60	22.92	6.68	n/a	0.04	-0.04	0.27	0.37	0.00	0.00	0.00
Tass (1997)	fig.24 c1,r3	FC18	2	theoretical model	n/a	series of plots includes spiraloids	8.49	2.96	0.84	0.56	2.62	7.29	4.48	0.99	0.05	-0.01	0.08	0.33	0.04	-0.22	2.40
Tass (1997)	fig.24 c2,r3	FC18	3	theoretical model	n/a		7.72	0.16	0.87	0.53	2.95	16.41	3.71	10.08	0.04	-0.05	0.55	-0.78	-0.37	1.63	0.37
Tass (1997)	fig.24 c4,r2	FC18	4	theoretical model	n/a		7.18	0.30	0.92	0.68	2.86	14.72	5.71	3.26	0.04	-0.01	0.11	0.34	-0.28	0.63	3.27
Tass (1997)	fig.24 c4,r4	FC18	5	theoretical model	n/a		7.77	1.65	0.93	0.53	2.90	37.94	5.26	9.71	0.04	-0.02	0.16	0.43	0.79	-2.69	4.57

Context data							Style data														
Source	Page/figure	Object number	spiral numbers	cause	drawn during/ after experience	Object notes	**rotation**	**orientation**	**curvilinearity**	**irregularity**	**path width median**	**path width trend error**	**spacing median**	**spacing trend error**	**sampling resolution**	**path width trend coefficients**			**spacing trend coefficients**		
Tass (1997)	fig.26 c1,r1	FC19	1	theoretical model	n/a	series of plots includes spiraloids	7.35	1.87	0.83	0.64	2.94	1.35	5.08	1.21	0.06	-0.01	0.12	0.43	-0.89	1.81	2.32
Tass (1997)	fig.26 c1,r3	FC19	2	theoretical model	n/a		6.99	0.31	0.84	0.62	2.72	0.96	4.98	0.96	0.05	-0.01	0.10	0.40	-0.42	0.83	2.26
Tass (1997)	fig.26 c2,r1	FC19	3	theoretical model	n/a		7.50	1.75	0.89	0.58	2.45	12.42	4.93	3.31	0.05	-0.02	0.25	-0.03	-1.55	4.64	-0.64
Tass (1997)	fig.26 c2,r3	FC19	4	theoretical model	n/a		7.01	0.34	0.81	0.61	2.75	15.02	4.69	0.29	0.05	0.02	-0.23	1.17	1.68	-3.51	3.97
Tass (1997)	fig.26 c4,r2	FC19	5	theoretical model	n/a		6.09	0.28	0.91	0.59	3.06	2.11	4.62	0.13	0.04	0.00	-0.01	0.97	-0.89	-0.82	4.64
Tass (1997)	fig.28 c1,r1	FC20	1	theoretical model	n/a		7.25	1.83	0.83	0.67	2.52	1.54	4.80	2.04	0.05	-0.01	0.17	0.14	-0.10	0.79	1.34
Tass (1997)	fig.28 c1,r2	FC20	2	theoretical model	n/a		7.06	2.58	0.74	0.66	3.03	5.65	5.02	0.39	0.04	-0.02	0.20	0.26	-0.07	0.20	2.58
Tass (1997)	fig.28 c1,r3	FC20	3	theoretical model	n/a		6.77	0.24	0.85	0.68	2.74	1.24	4.48	0.23	0.04	0.02	-0.24	1.24	-0.27	0.99	1.48
Tass (1997)	fig.28 c1,r4	FC20	4	theoretical model	n/a		6.87	0.91	0.40	0.61	2.46	3.39	4.12	1.94	0.04	-0.01	0.11	0.34	0.23	-0.41	1.93
Tass (1997)	fig.28 c2,r2	FC20	6	theoretical model	n/a		7.70	2.10	0.45	0.63	2.21	5.61	4.93	3.97	0.04	0.02	-0.17	0.90	0.44	-1.41	4.14
Tass (1997)	fig.28 c2,r4	FC20	8	theoretical model	n/a		7.67	0.27	0.89	0.61	2.57	15.21	5.51	2.80	0.05	-0.01	0.16	0.20	-0.34	1.10	2.57
Tass (1997)	fig.28 c4,r3	FC20	9	theoretical model	n/a		7.31	0.91	0.78	0.69	2.65	14.38	4.99	5.06	0.04	-0.02	0.17	0.21	-0.09	0.40	2.59

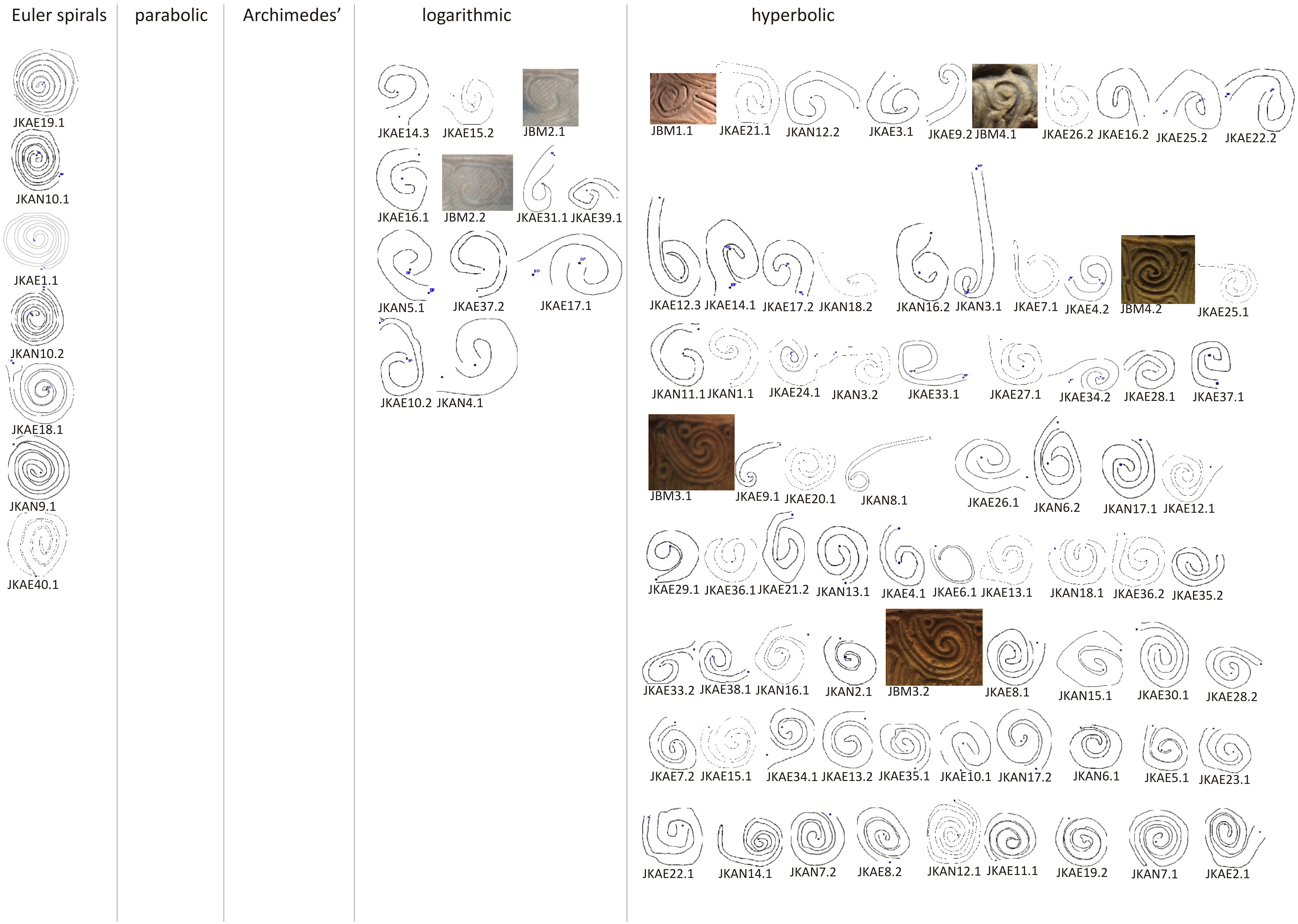


Table A2.7 Classification of Jōmon period spirals according to correlation with mathematical spiral types.

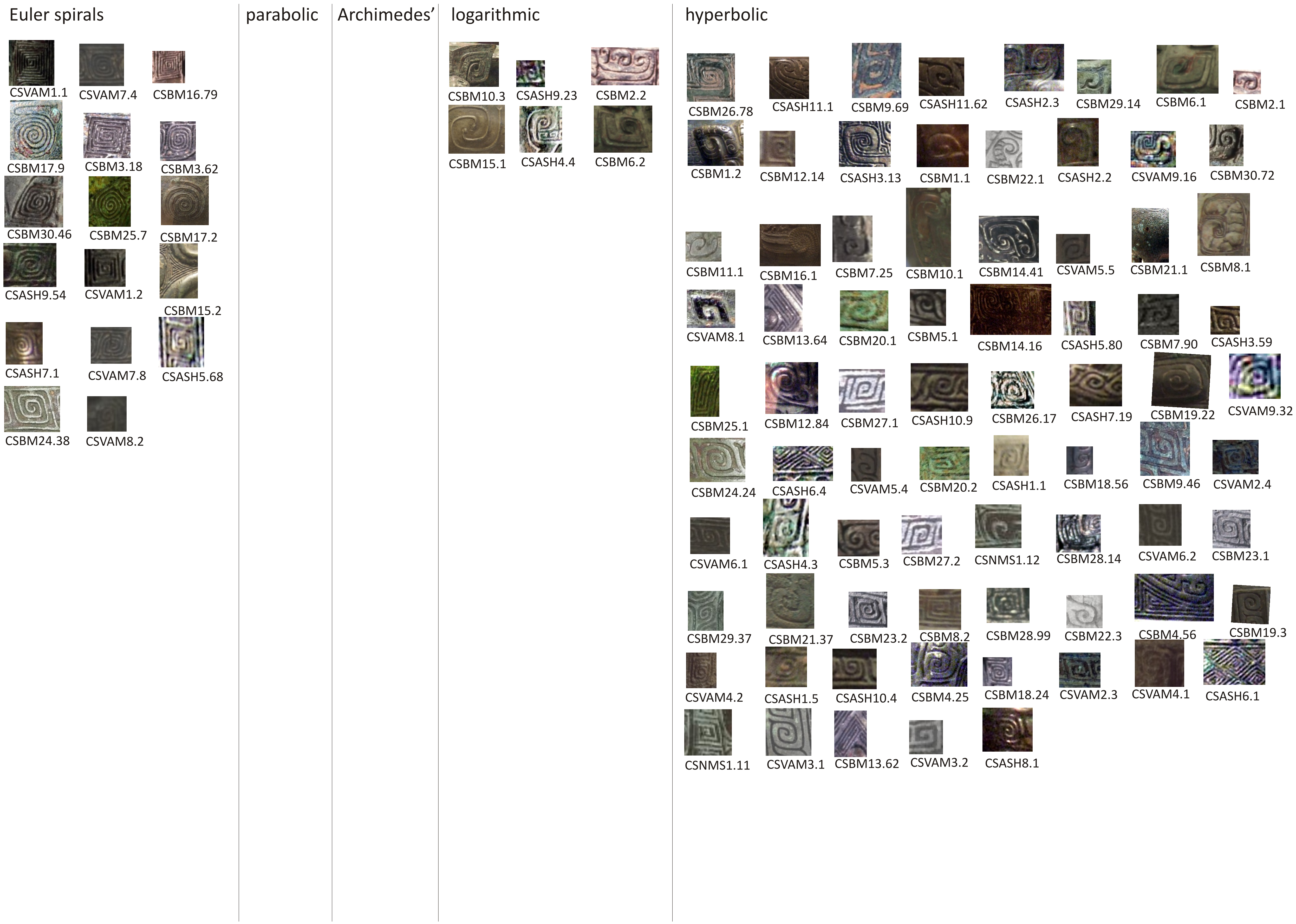


Table A2.8 Classification of Shang/Western Zhou Dynasty spirals according to correlation with mathematical spiral types.

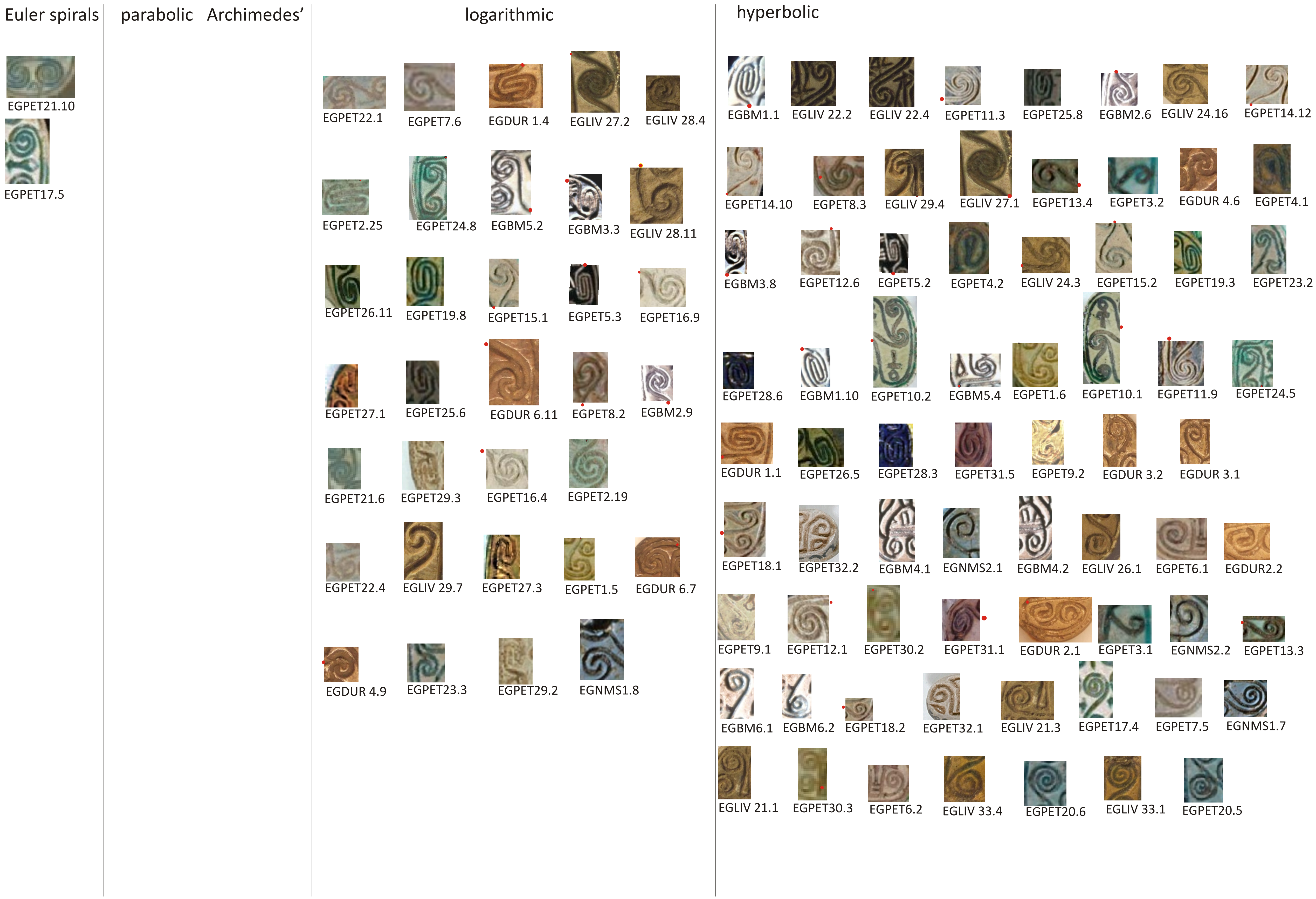


Table A2.9 Classification of Egyptian scarab spirals according to correlation with mathematical spiral types.

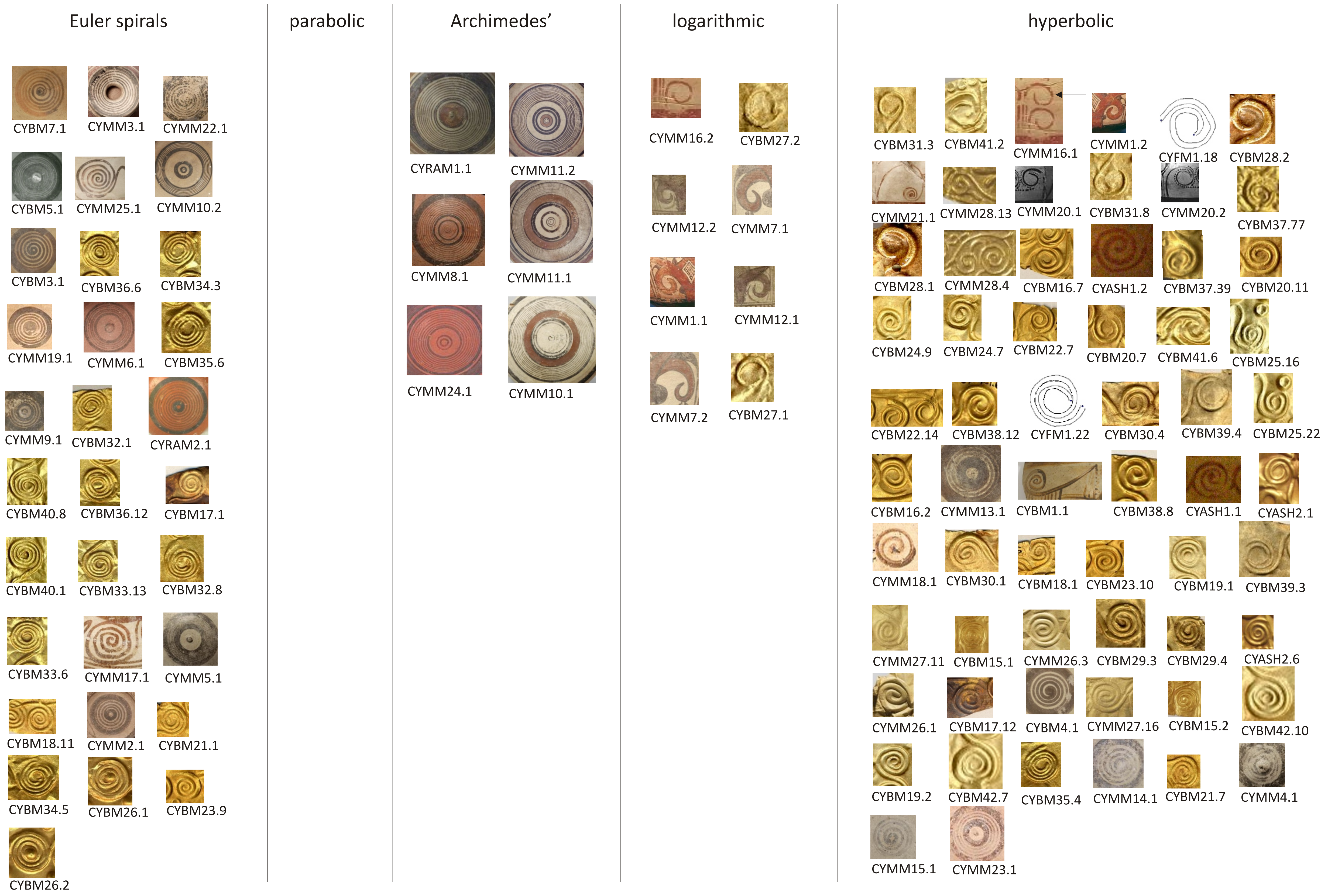


Table A2.10 Classification of Bronze Age Cypriot spirals according to correlation with mathematical spiral types.

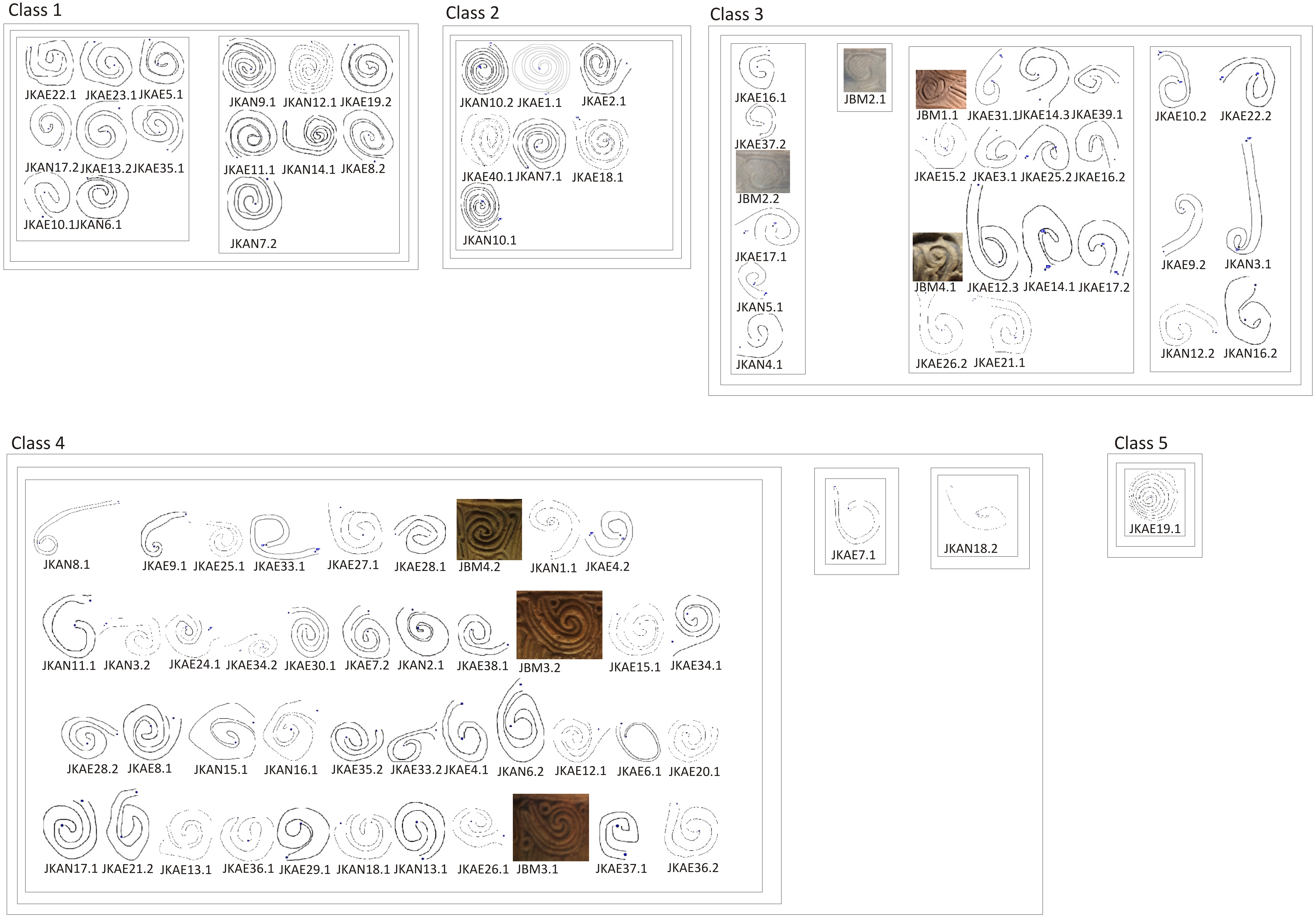


Table A2.11 Clustering of Jōmon Period spirals. Increasing numbers of frames show more distant clustering.

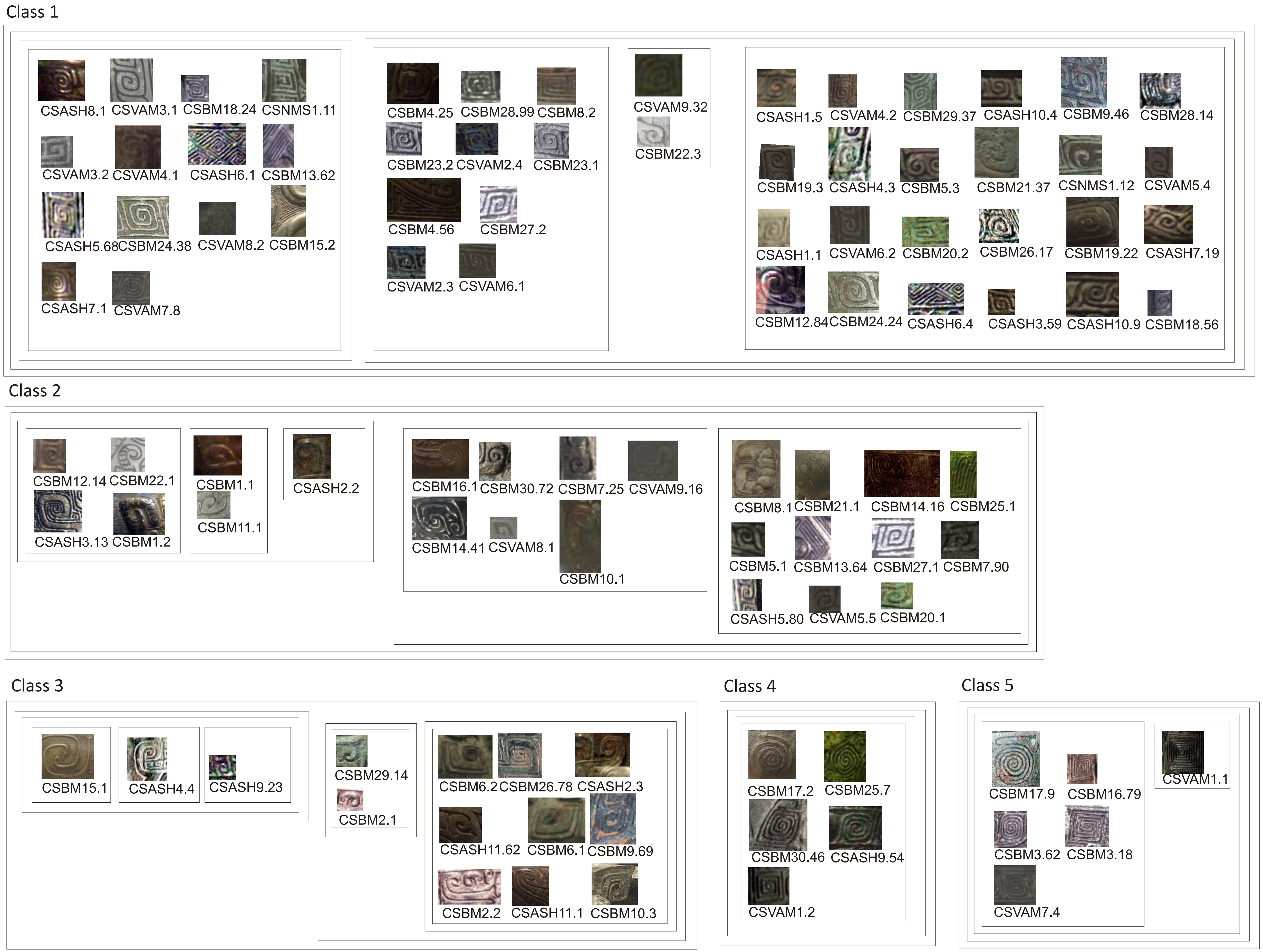


Table A2.12 Clustering of Shang and Western Zhou Dynasty spirals. Increasing numbers of frames show more distant clustering.

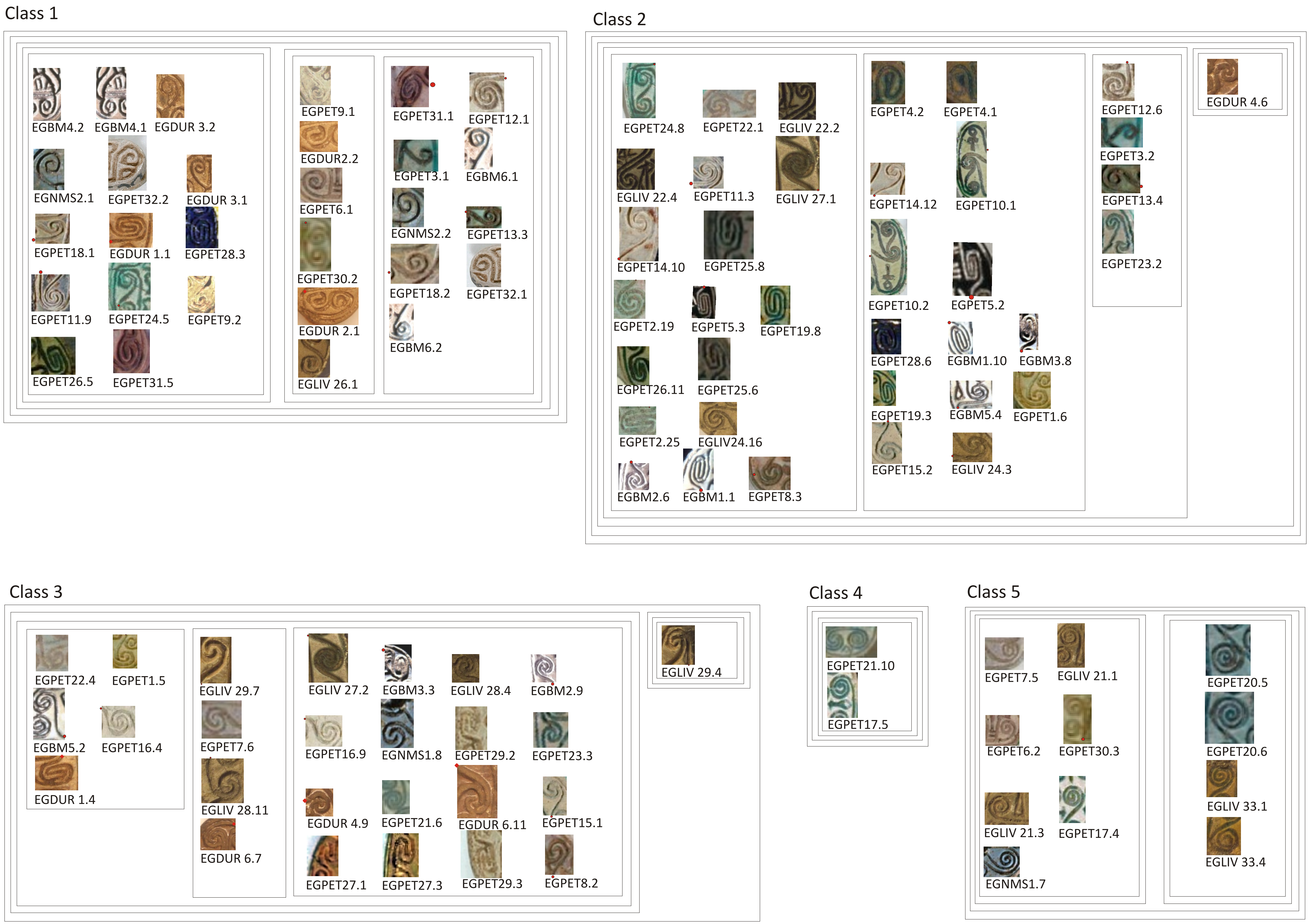
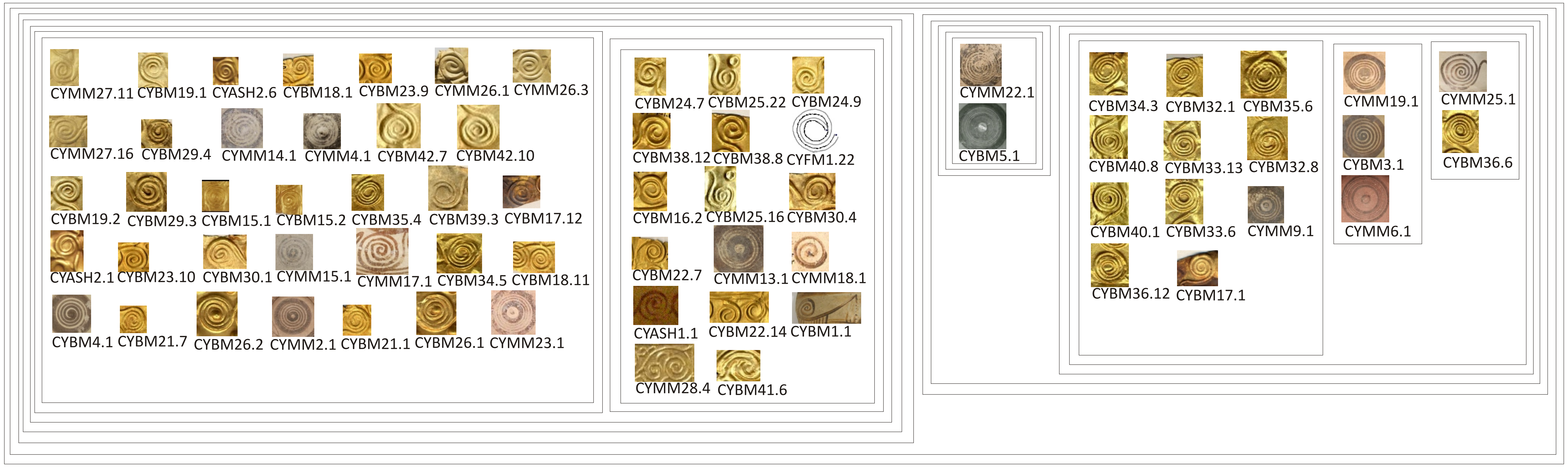


Table A2.13 Clustering of the Egyptian scarab spirals. Increasing numbers of frames show more distant clustering.

Class 1



Class 2

Class 3

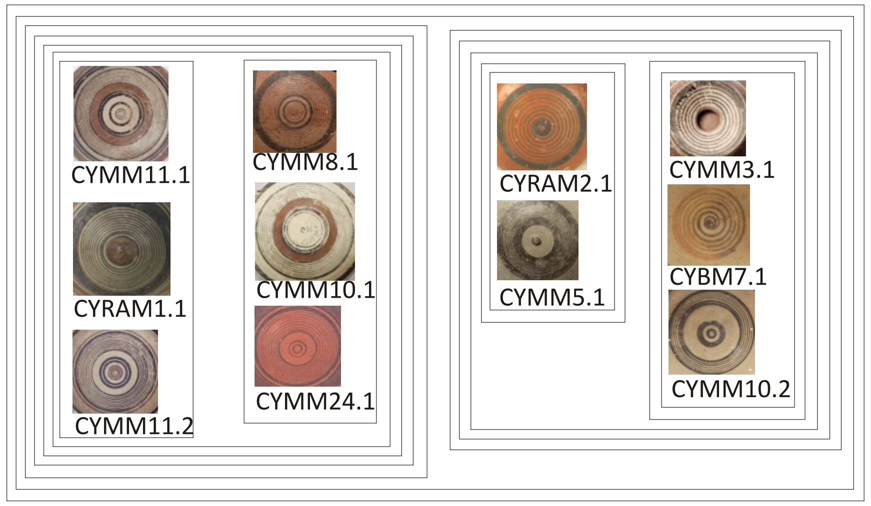


Table A2.14 Clustering of the Bronze Age Cypriot spirals. Increasing numbers of frames show more distant clustering.

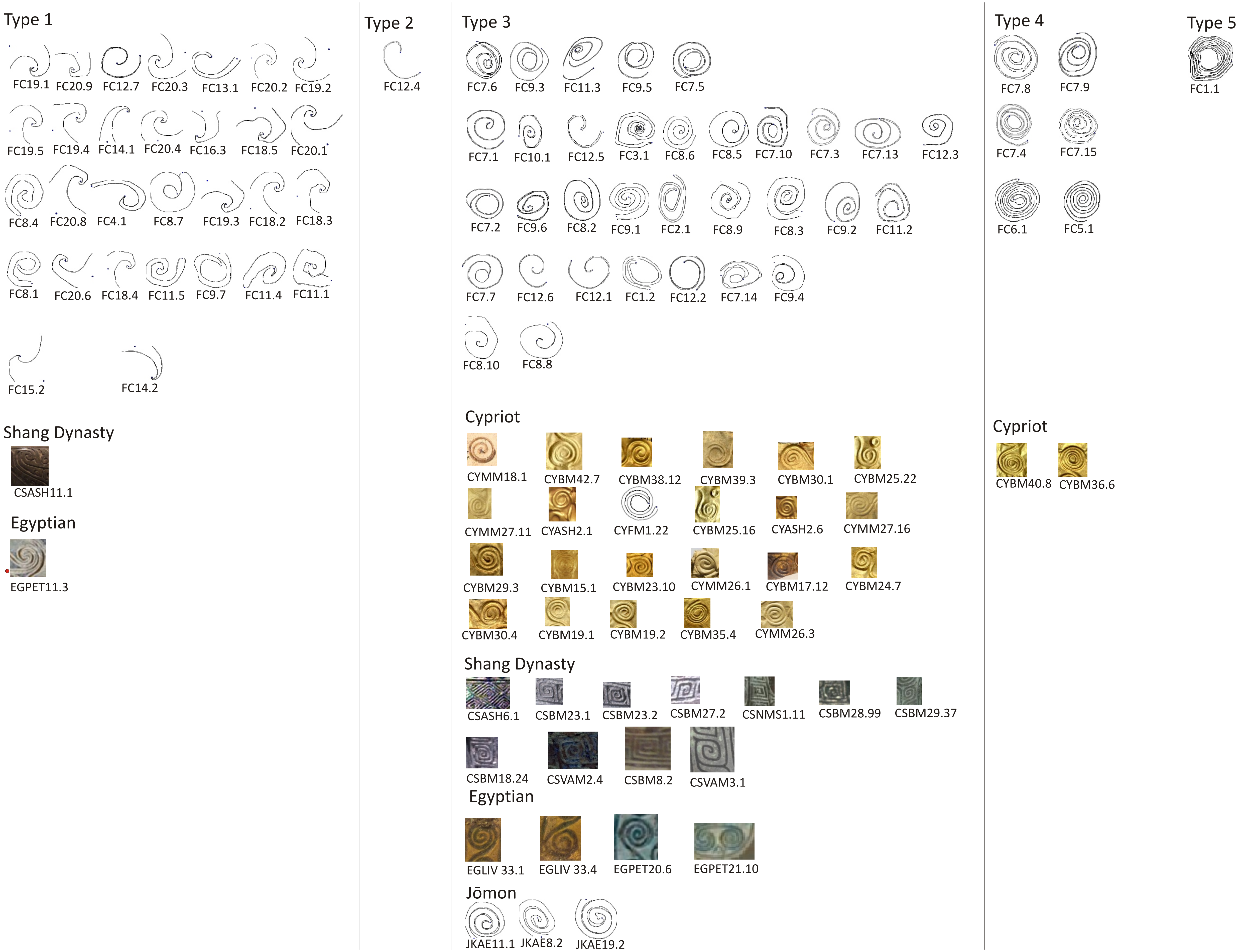


Figure A2.15 EVP type groups and corresponding decorative spirals.

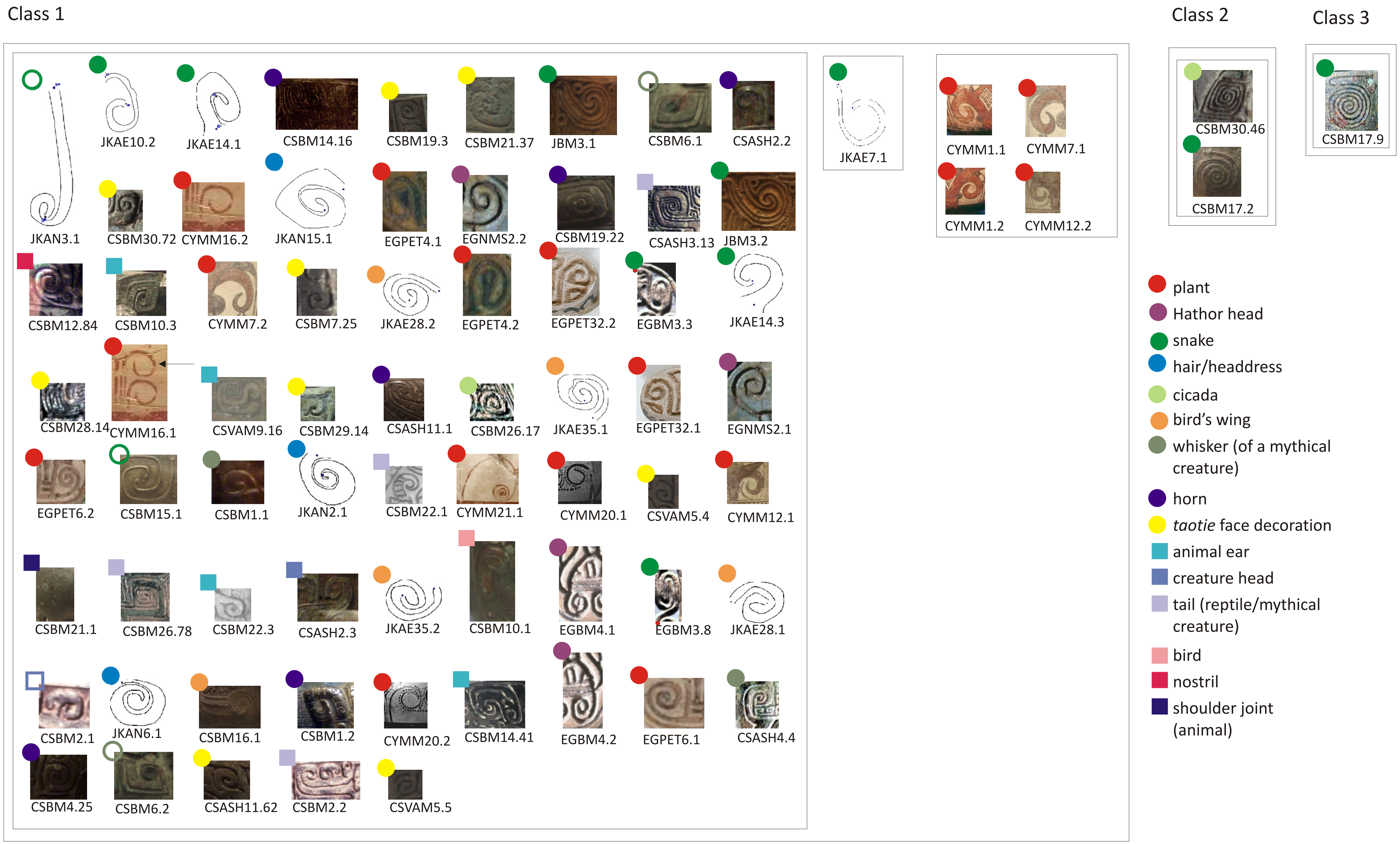


Table A2.16 Clustering of spirals by representational meaning. Unfilled representational type markers indicate an uncertain attribution.