Abstract patterns and representation: the re-cognition of geometric ornament

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1. Geometric decorative patterns and ornament

1.1. Introduction

As already stated in the general introduction a pattern is a regular and repetitive ordering or arrangement of elements along one or more axes. A pattern may thus consist of one kind of similar elements or of several kinds of elements but the intervals between those elements are regular and the elements are recursive. When different elements are patterned the alternation between those elements is also recursive. Regular repetition distinguishes a pattern from a set. Although in both a set and a pattern there is repetition, the repetition of a pattern is always regular; the distances between the repeated elements are equal (or proportional), the elements are of equal sort and if not, they alternate in a logical order (a, B, a, B, a, B, etc.).

Also as emphasized in the general introduction, in the context of the decorative arts the element of a pattern is referred to as the pattern's 'motif'. Any inquiry into the structure of geometric decorative patterns requires a clear distinction between the motifs being arranged, and the properties of the arrangement itself. Such an analysis is needed to determine at the end of this chapter the kind of cognitive competences required to understand and make such patterns. Therefore, geometric patterns must initially be dissected to assess at the end which of their essential parts require which cognitive competences.

For the analysis on the distinction between the motifs and the pattern I will depart from a categorization by art historian James Trilling where he emphasizes the importance of such a distinction for an understanding of the structure of ornament.[1] I will distinguish between three main categories of motifs: naturalistic, stylized and abstract; the latter including geometric motifs. I will guide the reader first into a discussion on the differences between the formal properties of naturalistic and stylized motifs and on how each type of motif specifically functions within decorative patterns. This allows the formulation of the cognitive competences required to recognize and understand the formal properties that constitute abstract geometric motifs to show that

[1] Trilling 2001, pp. 33 – 36.

abstraction, and the power to abstract, is a precondition for recognizing and making visual shapes and patterns in the first place, regardless of whether these shapes and patterns are naturalistic, stylized or abstract. This could mean that the power to refer, or to represent, is already implicitly part of abstract geometric motifs.

For a description of the different types of possible one-dimensional and two-dimensional patterns and the geometrical transformations applicable to patterns, I will draw from the anthropologist Donald Crowe, who intensively studied the structure of patterns and possible isometric symmetries on the basis of a categorization of pattern derived from crystallography.[2] Some might wonder to what extent it is possible to describe pattern as separate from the motifs patterned. It seems logical to assume that without recognizable motifs there is no pattern. However, that is only possible when assumed that pattern is also an abstraction. To be able to see patterns, therefore, concerns an ability to imagine a recursive ordering of elements extending in one or more dimensions in space along one or more axes. As an abstraction, even when stripped of the actual constitutive elements, the pattern can still be thought of as this underlying ordering. Geometric decorative patterns are the concrete and applied visual exemplifications of this abstract, regular, repetitive arrangement.

1.2. The motif as the recursive element of a decorative pattern

The elements of decorative patterns are its motifs. The *motif* of a decorative pattern is *the recurrent distinctive theme* of the pattern. In the case of geometric decorative patterns, it is obvious that the motif can be either a distinctive geometric shape or one or more groups of several geometric shapes.[3]

The distinction between the different kinds of motifs, which will now follow, is partly a modification of the categorization in Trilling's *Language of ornament*. Based on a limited number of categories I will discuss ornament in its full scope. This is necessary to place geometric motifs as a repertoire of forms in relation to other types of motifs

[2] Crowe 2004, pp. 3–17.

[3] In the decorative arts, motif or theme is often used as a synonym for pattern because the concept of pattern can also refer to the general idea of the decorative design. In this thesis pattern is used exclusivity in the sense of a regular repetitive arrangement.

and to determine whether and to what extent geometric motifs might share certain formal properties with other types, or whether and to which extent these formal properties might even be constitutive for the recognition and making of motifs in general. The latter would mean that the same cognitive competences that allow humans to recognize and make geometric motifs could also allow humans, at least partly, to recognize and make other types of ornamental motifs, e.g. the recognition and making of geometric motifs as related to other motifs might also shed light on shape recognition and sense of form in general.

Trilling distinguishes between three main categories: freeform, geometric and representational motifs, whereby the latter category is subdivided into floral and figural ornament, and ornament depicting objects.[4] Trilling's categorization has great advantages over previous taxonomies of ornament because it is not organized according to historical or culturally- determined categories but to categories based on form and content.[5] This enables an analysis of ornament from the perspective of general categories of motif, which potentially capture motifs from any tradition of ornament around the world. The disadvantage of such a generalization is that it is not sufficiently refined to deal with possible hybrid forms; motifs which are neither fully geometric nor freeform. Furthermore, the general category of geometric ornament does not account for the fact that some geometric motifs, like the meander, are culturally so widespread in comparison to others, that a distinct category would be justified.[6] However, the purpose of this chapter is not to provide a complete overview that does justice to all possible motifs applied in the decorative arts. Such studies have been

[4] Trilling 2001, p. 36.

[5] At the end of the nineteenth century design books for ornament makers were no longer solely based on examples of historical styles but increasingly on the nature of different motifs. Authors of such books often distinguished between two major categories; plastic and flat surface ornaments. The division between geometrical, natural and manmade shapes was also common whereby natural motifs were often subdivided in naturalistic and stylized motifs. Thomas 1996, p. 30.

[6] In other words, to do justice to such nuances, motifs that could be recognized as geometric should again be subdivided in different categories. Eva Wilson for instance discusses spirals and meanders as belonging to a specific category distinct from the rosette and other circular shapes although both categories could also be recognized as belonging to the broad category of geometric motifs. Wilson 1994, See for example Chapters 1 and 8. See also Flinders Petrie who made an inventory of about 3000 decorative patterns divided in 28 categories in which triangles and rhombuses form a distinct category from spirals. Petrie 1986, pp. 3–16.

increasingly published since the late eighteenth century and they have been widely studied ever since.[7]

Nor is the purpose of this chapter to describe geometric motifs in all their varieties. Instead I want to determine to what extent it is possible to distinguish geometric motifs on the basis of some of their most essential properties; to be able to determine the extent to which these properties can be connected to the cognitive competences that would allow humans to recognize and manufacture such motifs. Reasoning from this perspective, it is less important to focus on differences between geometric motifs. Instead of discussing triangles as distinct from meanders, which they obviously are, the aim is to detect those invariant properties that are shared by such motifs.

I will use Trilling's categorization only as a point of departure for the reason that contrary to what Trilling argues, I do not distinguish between representational and non-representational motifs; I view every kind of motif, regardless of its form, as endowed with the potential to be representational.[8]

The categorization I want to propose distinguishes between three general categories in ornament based on a specific kind of rendering: naturalistic, stylized and abstract.[9] Within both naturalistic and stylized ornaments three broad subcategories can be distinguished: plants and flower motifs, animals and human beings, and motifs resembling (manmade) objects (such as instruments, armoury, etc.) as well as architectural motifs (arches, joints and architraves). Principally, abstract ornament can

[7] For a brief but fairly complete overview of the main encyclopedias of ornament from the eighteenth until the early twentieth century see the Bibliography and Durant 1986, pp. 11–16.

[8] Trilling 2001, pp. 36 – 37. Because conventional and geometric patterns occur in all times and cultures around the world also cognitive scientists interested in aesthetic preferences neglect the representational aspect of such patterns and instantly assume they are based on universal principles, which they interpret as coming forth from universal preferences for beauty. See for instance Westphal-Fitch & Fitch 2013, p. 140.

[9] There are of course always motifs of which it is hard to determine whether they should be recognized as abstract or as a stylization. I belief there is no categorization of ornament that can overcome this. Any categorization is to a certain extent arbitrary and the criteria on the basis of which motifs are interpreted as naturalistic, stylized or abstract are always, no matter how objective they might seem, also subject to culturally- embedded conventions.

be divided into geometrical and freeform ornament but as this thesis is about geometric decorative patterns I will only discuss abstract motifs that are geometric.[10]

The category of geometric ornament cannot be subdivided in distinct subject-related categories of motifs. However, this does not mean that abstract ornament cannot refer to plants, flowers, animals, human beings, and objects, etc. I will show that geometrical motifs *can* refer to, or stand in the place of, such content. This is the main reason I reject categorizations based on a distinction between representational and non-representational. Such categorizations confuse what are basically different kinds of rendering of motifs with the potential of such motifs to represent.

1.2.1. The difference between naturalistic and stylized motifs

One might think that taking the perspective of the study object of this thesis it may seem unnecessary to discuss naturalistic and stylized motifs. Nevertheless, such a discussion is important not only to examine how the formal properties of geometric motifs relate to those of naturalistic and stylized ones, but also to determine what aspects they might have in common. This can provide an understanding about how the recognition of the formal properties of those different kinds of motifs relate to each other and about the extent to which some of the shared properties are conditional for the recognition of shape in general. This could help define the kind of cognitive competences that underlie the recognition and the making of visual shapes that can function as motifs in decorative contexts. Furthermore, the discussion of different types of motifs is needed to understand how these types of motifs, each in their distinctive ways, function in a decorative context and how these motifs are able to refer to, or make present something else. Moreover, the discussion of the types of motifs also allows distinguishing general aspects that might be conditional for the ability to

[10] I will not discuss freeform motifs, according to Trilling those arbitrary motifs, which do not have formal similarities with bodies and objects but are also not geometrical. I do acknowledge such abstract motifs exist but the drawback of a category of freeform, however, is that it can easily become a container for any ambiguous motif. This will not be helpful in distinguishing one specific freeform motif from another but most importantly: that is not the aim of this thesis. In other words: the number of categories should ideally be limited but each category should nevertheless still represent well-defined properties on the basis of which its content has been filed.

refer to, or make present, regardless of whether a motif is naturalistic, stylized or abstract.

It is important to be cautious while using the term 'naturalistic' because the term brings with it the danger of being easily misunderstood. The term literally means: 'after nature'. Sometimes it is used as a synonym for 'realistic'; a use which should be avoided, because naturalistic motifs can consist of fantasy creatures, where parts may be designed from nature but as creatures they do not exist; for example, putti do not exist but boys and wings do; a head of a putto can therefore be drawn after the head of a real boy, the wings of a putto can be drawn after the wings of real swans. Another reason for avoiding the term 'realistic' concerns the fact that in art history 'realism' denotes a period in french nineteenth-century painting and emphasizes the realism or veracity of the subjects depicted and not necessarily or exclusively the way it has been painted.[11]

Philippa Lewis and Gillian Darley describe naturalistic ornament as those ornaments, which after careful study of nature appear for example as recognizable plants, animals and birds.[12] Naturalism may therefore best be defined as that which either in its entirety or in its parts, can be drawn from observing nature, even although the result of such exercise might be a body or object that never exists in nature. The naturalistic designer may use everything provided by nature but imagination enables the designer to create the most incredible depictions.[13]

The distinction between 'naturalistic' and 'stylized' might concern the appearance of the motif, *as if* made from observation of nature, whether or not the designer truly worked after own observation.[14]

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[11] Gombrich 1951, p. 383.

[12] Lewis and Darley 1986, pp. 210–211. Historically Lewis & Darley situate the emergence of naturalistic ornament in the early Gothic period.

[13] The use of the term 'naturalistic' is also connected to specific historically and culturally-determined ways of seeing, traditions concerning the execution of certain motifs, as well as conceptions about how to give form. But the term certainly denotes an objective distinction. As will be clear motifs of natural bodies and objects can be rendered naturalistically and stylized and as such still have formal resemblances with what they depict. Abstract geometrical shapes can only be *references* to or *representations* of bodies and objects in a symbolic way. How geometric motifs are able to refer to or represent will be discussed more extensively in Chapter 3.

[14] Perhaps this was sometimes even exceptional judging by the many ornament books that were produced and which provided the ornament maker with plenty of examples of ornamental motifs which he could appropriate; any naturalistic motif can of course also be drawn from such examples in print. See for instance Niccolo Zoppino's *Esemplario di lavori* from 1530, which was a modelbook for needlework, Percier and Fontaine's *Recueil de décorations intérieurs...* from 1812, *Vorbilder für Fabrikanten*

Suggestion of depth is an important means to make a motif appear as if natural. Ornament applied to architecture seems to have depth almost by nature. However, even within this context it is possible to distinguish ornaments clearly meant to create the illusion of depth because they are meant to resemble 'living' creatures, such as in the case with heads of putti. These are distinct from figurative and bas-relief ornaments, which are not necessarily naturalistic, do not resemble living creatures, but are not flat. An example of such an ornament is the Ionian capital (Fig. 1). Both kinds of three-dimensional ornaments are however clearly distinguishable from ornaments which seem to emphasize the flatness of the architectural surface such as geometric patterned masonry or geometrical mosaic floors (Fig. 2). Furthermore ancient ornaments can be naturalistic in that they are the literal representations of constructive parts of buildings, which although initially functional, for example, as joints of distinctive parts, have lost their function and become the decorative remainders of their previous purpose when buildings were executed in different materials to those which such constructive joints owed their original function.[15]

Within ornament, the distinction between naturalistic and stylized was emphasized in the nineteenth-century debate on ornament in particular, when the illusion of the real was rejected by some because it was regarded as not adhering to what was thought of as the main function of ornament. Artist and art historian Ralph Nicholson-Wornum (1812–1877) considered naturalist designers to be concerned only with the superficial beauty of naturalistic details. He felt their designs would violate the fundamental law, which dictates that designers should follow the laws of nature and not copy nature thoughtlessly.[16] This rejection came partly from the thinking about actual function of ornament. According to Owen Jones, ornament within architecture should be supportive to construction and not be applied for its own sake; a flat surface should therefore not be decorated with motifs if that then neglected the surface's flatness. The

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und Handwerker published between 1821 and 1830 in Germany, and John Leighton's *Suggestion in design* from 1853, which title page makes clear it is aimed at artists and designers as diverse as weavers, metalworkers, potters, printers, engravers etc.. These are but a few of the many ornament books aimed at designers which were published. For a more comprehensive list see the Bibliography.

[15] Coulton 1977, p. 37.

[16] Wornum 1856, pp. 10 – 11.

function of ornament would be to support the construction of architecture and objects by means of emphasizing their constructional properties.[17]

The rejection of naturalistic design caused the distinction between naturalistic and stylized ornament to become ideologically charged.[18] Whether this rejection was legitimate or not is, of course, not the concern. The aim here is to understand the kind of visual properties with which one motif distinguishes itself from another and, seen from that perspective, the nineteenth-century debate contributed to a critical assessment on how to design in relation to the function of ornaments. This will become clear when discussing the category of plant and flower motifs, which emphasizes the crucial difference between the approach of the designer working from nature, and the designer working according to certain design laws. These laws might be analogous to the ones found in nature and they are used to stylize forms derived from nature into ornamental motifs.[19] It is clear one can recognize in an Acanthus leaf designed through observation of nature, the laws of nature to which the leaf owed its shape, for instance, in a certain distribution of the nerves of the leaf. In the case the designer would stylize the leaf and design according to this distribution, the natural law that regulates the distribution of the nerves will, in this case, dictate the distribution within the stylized design but without the detail of the design necessarily being modelled on nature. Therefore, the Acanthus leaf may ultimately appear in a highly schematized fashion such as on the ruins at the ancient city of Hatra in Iraq (Fig. 3).

In summary, naturalistic motifs differ from stylized motifs in that naturalistic motifs appear as though rendered from close observation of nature. Although stylized motifs to some extent will resemble natural objects and bodies they are reduced to only the essential features of those objects and bodies to provide sufficient suggestion to provoke the image of the particular object or body in the mind of the viewer.[20]

[17] Cole & Redgrave 1853, pp. 73–74; Jones 1997, p. 20.
[18] Woud 1997, pp. 150–151.
[19] Durant 1986, p. 26.
[20] See proposition 13. Jones 1997, p. 21. See also Jones 2001, p. 23.

Motifs		
Naturalistic	*Stylized*	*Abstract*
Plants and flowers Animals and human beings Objects and architecture		Geometric Free form
Patterns		
Paratactic	*Hypotactic*	
One-dimensional Two-dimensional Three-dimensional	Two-dimensional Three-dimensional	
Transformations		
Translation Rotation Mirror-reflection Glide-reflection		

Table 1: motifs, patterns and transformations.

1.2.1.1. Plant and flower motifs

For many nineteenth-century designers, the study of plant and flower motifs from nature would emphasize principles of regular distribution of form and symmetry that

appear observable in nature.[21] These are the same abstract principles that constitute stylized plant and floral motifs, which also carefully follow the 'laws' of symmetry, the distribution of the units (such as the distribution of petals and leaves), as well as the distribution of units from the stem, etc.. The principles found in nature and botanical science had an influence on ornament makers in the sense that it encouraged them to study those principles.[22] Stylized plant and flower motifs might share its underlying principles with the practice of botany. This is reflected in William Dyce's instructions for students in how to design plant and flower ornaments. First they had to arrange the outlines of the motif in a symmetrical order and second provide this schematic outline with foliage.[23] This way of working can result in a perfect symmetrical stylized design, which at the same time can still bear naturalistic features. An example of this is observable in a design by Richard Redgrave (Fig. 4).[24]

The argument can therefore be put forward that the study of nature actually encouraged the development of stylized floral motifs and that a strict distinction between the naturalistic and the stylized does not do justice to the practice of designing ornament.

There can be many hybrid forms indeed but it is impossible to treat any type of motif in its own respect. Despite this I think the main insight the distinction between the naturalistic and the stylized points to concerns another distinction, which is the crucial one between the appearance of the motif and its underlying design principles. The plant and flower motifs on the lower register of the Ara Pacis monument in Rome illustrate this. It shows a composition of both Acanthus and vine leafs which run around the entire monument and appear as though both types of leaf spring from the same type of branches.[25] Details such as the individual Acanthus and vine leaves, grapes

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[21] See for instance A.W. Pugin's *Floriated ornament* from 1849 and Christopher Dresser's *Art of decorative design* from 1862.

[22] Durant 1986, p. 26.

[23] Durant 1986, p. 27. A general overview of William Dyce's role as an educator as Superintendent of the School of Design can be consulted in Pointon 1979, pp. 41 – 60. See also Macdonald 1970, pp. 121 – 124.

[24] Durant 1986, p. 28; Redgrave 1876, p. 167.

[25]The Acanthus leaf is one of the most frequently used plant motifs in Western and Eastern ornament traditions. It is the distinctive motif of the Corinthian capital and it has been used as a motif in ornament in Greece since the fifth-century BC. It spread across the Mediterranean by the first century BC. when Roman architects adopted the capital. See Coulton 1977, pp. 128 – 129. The Acanthus motif

and flowers, may have been rendered naturalistically in bas-relief, in a way that would never occur in nature and is entirely subordinate to the symmetrical design of the artist.

Moreover, grapes, flowers and Acanthus leaves appear on the Ara Pacis as if part of one single plant: something only possible in art. Therefore, it is a good example of the scope of the ornament maker who works from nature but combines the naturalistically-rendered motifs using his own imagination and then arranges them according to a geometrical plan.[26] Viewed from a distance one clearly sees the buds of the vegetation are arranged as to form a symmetrical composition (Fig. 5). In other words: if it were possible to remove the naturalistic appearance of the motifs, a geometrical pattern would still remain (Fig. 6).

Even although nature and its underlying laws can be a model to naturalistic as well as stylized plant and flower motifs in appearance, both categories of motifs are different. Both renderings make use of underlying laws although it does appear that in stylized motifs these laws are more clearly emphasized and perhaps as a result of stylization come explicitly to the fore.[27] Whether an artist works with 'naturalistic' or 'stylized' motifs it seems to be a matter of what a designer wants to emphasize: working 'after observation' or working 'according to the laws of'.[28] What both ways of designing seems to make clear is that they are founded on a specific way of ordering. Whether a

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has been used well into the twentieth century although it had not always been adopted in a naturalistic fashion. Lewis & Darley report that in the run up to the early Renaissance, the Acanthus leaf has been executed increasingly more naturalistically from the eleventh until the fourteenth century onwards. See Lewis & Darley 1986, pp. 20–21. In other words, the motif has its own history of design and it would be a mistake to consider the Acanthus motif as exclusively naturalistic.

[26] See for instance Grabar 1992, p. 235. Here Grabar explains how recognizable features such as birds and plants can be arranged within ornamental patterns as a means by which the ornamental pattern becomes attractive and therefore can become an intermediary between the decorated and the viewing subject.

[27] It often depends what designers interpret as 'natural'. Designers with different opinions working in different styles could at the same time claim their designs obey natural laws. It seems for instance obvious to posit design reformists like Owen Jones against some of the followers of the neo-Gothic movement. But within the neo-Gothic, designers often held contradictory views as well. A.W. Pugin for instance shared with Jones the opinion based on convention that ornament should emphasize flatness while religious designer John Ruskin rejected stylizing natural objects because in his vision stylizing would go against nature's holy character and would thus not obey natural law. See Durant 1986, p. 26; Ruskin 2004, p. 8.

[28] Because stylized ornament seems to emphasize the underlying laws of nature and not its appearance it is also often referred to as 'conventional' ornament, in the sense it obeys conventions based on certain laws. I decided to avoid that term, however, because strictly speaking any kind of motif, naturalistic and geometrical ones included, obeys certain conventions (although not necessarily conventions based on natural laws).

designer sketches a naturalistic or stylized motif, the making of the motif appears to follow a certain pattern guided by certain design principles.

1.2.1.2. Animals and human beings

With animals and human beings, the same distinction applies as with plant and flower motifs. Naturalistically-rendered animals and human beings appear as though modelled from close observation of nature while the stylized versions are reduced to the most essential features of animal and humanoid figures.

From the Renaissance onwards, naturalistic ornamental motifs with animals, human beings and mythological figures were increasingly applied in palaces, houses, churches and public buildings. Winged putti are one of the most recurrent figures in Western European ornament and their presence within large decorative programs was inspired by the winged children such as were depicted in Greek and Roman antiquity.[29]

Stylized animal and human-being motifs were applied in many different cultures around the world and this mode of representation dates back at least a few millennia.[30] Illustrative of this are those examples found on ancient Greek vases. On one bowl, which is now at the art historical museum in Vienna, a row of water birds is visible. Each bird has the same stylized shape (Fig. 7). The shape is flat, executed in black profile only, and bears no further details of the birds other than its silhouette. On a dipylon amphora at the Rijksmuseum of antiquities in Leiden, a band with a procession of chariots is visible. Horses, chariots and warriors are clearly stylized and, as with the water birds, executed in profile (Fig. 8). A dipylon krater from the Metropolitan Museum of Art in New York has similar bands containing chariots, horses and human beings; a band with a funeral procession contains figures whose torsos have the shape of a reverse triangle. The alignment of all these torsos is a geometric pattern (Fig. 9). These stylized examples come from a style period in ancient Greek pottery referred to as geometric. It is this period in Greek antiquity, which shows an interesting transition

[29] Dempsey 2001, pp. 1–6.
[30] Onians 2006, pp. 407–408.

from the use of pure abstract geometrical motifs towards a style characterized by an alternation of geometric motifs with highly stylized figures.[31]

1.2.1.3. Objects and architecture

The most peculiar and conceptually most difficult and arbitrary category is perhaps that of naturalistic motifs derived from manmade objects and architectural details. The shape of a vase used as a motif within a decorative pattern is of course in itself derived from a form that does not exist in nature and to a certain extent might be considered as abstract. The same occurs with ornamental motifs of architectural details. As briefly discussed above, such motifs are often the remnants of architectural details, which originally had a structural function. For example, the triglyphs, which appear above the columns of Greek temples, are thought to be the remnants of the ends of wooden beams of earlier temple forms.[32]

The volute is another example of such an architectural detail and as part of the Ionic capital its shape probably had a decorative function from the beginning. From the front, each Ionic capital shows two volutes symmetrically ordered above the column. The shape of the volute is a spiral, sometimes decorated with a rosette at the centre. In some cases, leaves spring from the spiral, which could indicate the form might have been derived from the stem tendrils of vines and other climbing plants.[33] From the

[31] Coldstream 2003, pp. 117–118, 170–171, 208–209.

[32] Coulton 1977, pp. 36 – 37. Vitruvius argued that carpenters used to close the spaces between the crossbeams of a temple and subsequently cut off the protruding heads. To mask the cutting edge of the beams from the viewer's eye small wooden bars were placed on the head end of the beams. Vitruvius thus assumed that from the position of the crossbeams emerged the arrangement of alternating triglyphs with their in-between spaces, referred to as metopes, which in turn were often painted or provided with ornament. Vitruvius, *De architectura* book IV, 2 – 4. Whether triglyphs are really the literal remnants of the wooden crossbeam construction remains open for debate. Other scholars have argued that schemas comparable with the triglyph and metope alteration already occur on Greek pottery and that painted slabs from Assyrian temples might have been a source for Greek temples as well as the alternation of grooves and decorated flat surfaces, which frequently appear on Egyptian sarcophagi. These examples could indicate that the metope and triglyph might have had a decorative function from the beginning. See Coldstream 2003, plate 10 & 15 e–m; Coulton 1977, p. 41; Montet 1942, p. 116 fig. 24.

[33] See for instance Vitruvius, *De architectura*, book III.

other end, it looks like a piece of cloth, which has been tied at the centre and is looser at the end (Fig. 10).[34]

Spiral-shaped ornaments had already been common on Greek pottery in the centuries prior to when the Ionian order would have emerged. The British Museum holds a jug from the Cyclades, which has a spout in the form of a griffin and contains a band of triangular ornament on its belly. At the top of each triangle, two symmetrically-arranged spirals are observable. The spirals are each other's mirror image and seem to be the curly offshoots of a stylization of what appears to be a bundle of crops framing the black triangular silhouette. It is not hard to imagine the frontal view of an Ionian capital in this ornament (Fig. 11). This motif even goes back to the second millennium before Christ. On another spouted jug from the Cyclades, which is on display at the British Museum, a geometrical ornament is visible, which also displays mirrored spirals bringing to mind the Ionian volutes (Fig. 12). From Rhodes comes a storage jar, also visible at the British Museum, containing a total of eight bands of overlapping spirals in relief (Fig. 13).

With the examples of the spirals in mind one could rightfully argue that architectural motifs like volutes are anything but naturalistic and to a certain extent this is true. However, this category in fact expresses what is basically a double effect. As with the presumed origin of the volute, spirals were used in many other decorative settings, as the previous examples make clear. The volute would later evolve to become an individual ornamental form once it was used detached from the Ionian capital.

Architectural details such as volutes have been used frequently as decorative elements in painted decorations and in prints, for example, on title pages of books. From this context it will become clear why such motifs can still be grouped under the category of naturalistic motifs even although their original use in architecture is actually a case of stylization. The categorization as naturalistic is based on how the ornament maker has treated architectural elements such as scrolls, columns, volutes, pediments, and lists etc.. When the ornament maker applies these elements after observation, creating the illusion of depth for example, the illusion that they are part, or parts of, actual architectural constructions, the elements could be regarded as naturalistic, such

[34] Coulton 1977, p. 126.

as is the case in a cartouche from the title page of the *Livre d'ornements* by Juste-Aurèle Meissonnier (Fig. 14).

The peculiarity of this category of motifs concerns the fact that when a motif such as a volute when applied as ornament in architecture is actually an abstraction, presumably a stylization of spiral-like forms from nature, but drawn after observation and applied as an ornament in drawing, print or on paintings, it can be regarded as naturalistic. The same applies to objects and perhaps this makes it even clearer. Each manmade object is an abstract form, a stylization, because as such not present in some way in nature. But each object can be drawn from observation and thus be expressed and applied naturalistically, for example, in the ornament by Hans Vredeman de Vries containing musical instruments as motif (Fig. 15).

What is brought to the surface by the distinction between the naturalistic and the stylized within this category is the question of *how* bodies and objects are actually represented, regardless of whether that body or object is natural in origin or manmade. Thus, the volute of the Ionian capital probably originated from a stylization of spiral-like forms of nature, which were initially applied as motifs on Greek vases. Alternatively, an ornament maker could also theoretically make an ornamental spiral-like motif stylized after the volute of the Ionian capital, or like Meissonnier, draw an Ionian column after close observation, for instance, at a ruin in Rome and use the naturalistic rendering of the capital and its volutes as an ornamental motif on the title page of a book.

What is emphasized in the examples within this category is that these are abstractions. Humans abstract from their surroundings certain shapes and use these shapes in a specific context where these shapes fulfil a specific function. This can be the beginning of the further development of a shape into a theme that becomes a frequently used distinctive motif within different decorative contexts, such as clearly shown in the example of the Ionian volute. What happens is that the shape, as a distinct product of human abstraction, becomes the source of other abstractions. Viewed from that perspective one can indeed argue that there is an evolution of motifs which is particular to the arts.

1.2.2. Abstract geometrical motifs

Both the making of naturalistic and stylized motifs thus appears to be a matter of abstraction. Even though an artist might have drawn a shape from nature, the artist can never capture all the features of an object or a body. No matter how naturalistic a drawing of a tree might be, reduced to a shape it will be an abstraction even although it resembles the shape of the actual tree. The next level of abstraction could be a further stylization of that tree shape as reduced to its most essential formal features. The ultimate abstraction may be the reduction of the shape into a constellation of points and lines that no longer shows any formal resemblance with respect to its original model.

The category of abstract geometric motifs includes shapes such as squares, circles, spirals, triangles, trapezoids etc., as well as combinations and variations of such forms. [35] It might be argued that a circle is a stylization of the sun or the moon, or that squares and triangles are naturalistic depictions of the form of crystals. With regard to the latter, however, the question is whether humans were already aware of the existence of geometrical shapes in the form of crystals in the natural world in those times when humans started to apply geometric shapes on objects and artefacts. If not, there might be an argument for the assumption that geometric motifs are the product of a mind capable of thinking in forms that are independent of those the subject might encounter in his/her surroundings. That assumption would make these forms abstract in the sense they are not depictions or stylizations after the maker's observation of natural forms. Ultimately, the problem is that nothing is certain with regard to this matter; it is simply unknown.[36]

[35] The anthropologists Dorothy Washburn and David Crowe refer to geometric motifs as 'finite designs'. They do so from the perspective that individual motifs as well as one-dimensional and two-dimensional patterns are all designs but that the distinguishing feature of patterns is translation (meaning patterns are recursive). From their perspective, individual geometric motifs are thus designs without translation. They describe two types of 'finite designs': designs that have rotational symmetry but no mirror-symmetry, such as for instance star-like motifs, a triskelion, or a swastika, and motifs that have both rotational as well as mirror-symmetry such as for instance triangles, rectangles and polygons. Once the 'finite design' is repeated, pattern emerges. Washburn & Crowe 1988, p. 57.

[36] On the age of the earliest incised geometrical patterns see for instance Mendoza Straffon 2014, pp. 58–59.

Practice shows, however, that one can arrive at a geometric shape as the ultimate abstraction of a body and object as well as the other way around, where one uses a geometric shape as the abstract building block for making more complex shapes, for example, to resemble bodies and objects. Viewed from the latter perspective a further discussion on the constitutive properties of geometric motifs, i.e. the building blocks of those motifs, may shed light on how humans use constellations of points and lines to create shapes, which can vary from relatively simple to highly complex. Therefore, the category of geometric motifs, which appears to involve motifs that are pure form in itself, sheds light on the cognitive competences needed at least to recognize and make shapes. Since abstract shapes such as geometric motifs appear to have only a limited degree of formal resemblance with objects and bodies, the identification of their constitutive formal properties should also allow light to be shed on which of those properties, and to what extent and how, might endow abstract shapes with the potential to refer to, or make present something else (like an object or a body).

1.2.2.1. The building block of geometric motifs

If one would imagine one of the most basic geometric forms known, for instance, a triangle then this can be made in two ways: first as a solid form with a certain colour, for example, as a solid red triangle, or as an 'empty' form where only its outline is visible (Fig. 16). This distinction might seem obvious but is nevertheless fundamental for this study. In human perception the objects and bodies from the environment, as well as their distinctive parts, appear as distinguishable surfaces, because each surface, as a result of their material and chemical structure, as well as their spatial position, reflects light in a distinctive way. Humans experience this as differences in colour, hue, and saturation. Hence, where the one surface is tangent to one or more other surfaces, humans experience the outline or in other words, the contour of the surface. The fact humans can distinguish between a solid and an open form shows that humans are able to abstract the outline of the form as distinguishable from the whole.[37] In the visual

[37] Brincat & Connor 2004, p. 883; Goodale & Milner 1992, p. 23; Hegdé & Van Essen 2000, p. 1; Hubel 1988, p. 86; Livingstone & Hubel 1988, pp. 740–749.

arts, contour also denotes this outline of bodies and objects.[38] When humans perceive an object they are able to understand its contour as an abstraction of the outlines of the surface of the object but always with the actual surface in view. When humans represent an object in a drawing, it is the contour line which constitutes the form. In other words, in perception, without an object, without a surface, there is no contour; in drawing, without contour, there is no surface, hence there are no objects.

It can be argued that the human capacity to perceive the extremities of objects, as a distinguishable property of their appearance, is a precondition for the comprehension of the abstract concept of contour. However, when someone draws the contour of an object, for instance, the triangle from the example above, this contour will only emerge after drawing a few lines at least (unless someone is able to instantly draw a closed form in one stroke). Therefore, in representations such as drawings, lines are the basis of contours and must therefore be a distinguishable feature of manmade contours.

Line can be defined as 'a thread-like mark. (...) long in proportion to its breadth'.[39] This definition makes clear that a line has a certain thickness and in a certain sense can be conceived as an extremely elongated rectangle. Only in theory, a line, for instance as the division between two surfaces, can be thought of as endlessly thin. As a concept, line thus appears to be an abstraction of the contours perceived between surfaces of objects and bodies. Both the concept of contour and that of line are abstractions, which could have originated in the human mind, as the result of how the mind processes and abstracts the distinct properties of the visual impressions of surfaces of bodies and objects, as well as those of elongated bodies and objects, such as how they appear to the subject through the senses.[40]

The above means that underlying the abstractions of naturalistic, stylized and abstract shapes is again an abstraction: the abstraction of line. One could, therefore, argue that line is an *abstraction of* the contours perceived of objects and bodies and not

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[38] "contour, n.". OED Online. December 2016. Oxford University Press. http://www.oed.com/view/Entry/40304?rskey=LW1H1T&result=1&isAdvanced=false (accessed January 23, 2017).
[39] "line, n.2". OED Online. December 2016. Oxford University Press. http://www.oed.com/view/Entry/108603 (accessed January 23, 2017).
[40] Dehaene 2009, pp. 137–142

an abstract concept present in the mind a-priori. Still, this cannot be stated with such certainty.

In Immanuel Kant's formulation of transcendental aesthetics, objects take shape within their appearance in space. Space, according to Kant, is no more than the form of human sensuousness and, as such, the precondition for having sense experiences in the first place. From this perspective one could argue that 'line' as an abstraction *is* a-priori present as the multiplicity of space in one dimension.[41] The capacity to identify contour, and abstract from it the concept of line, is only possible because as the form of our sensuousness, in the first place, space is the precondition for the appearance of objects and bodies (and their contour).

Conversely, the view that line is an abstraction of contours of natural bodies and objects and that the ability to recognize line as a distinctive feature has been gradually acquired in response to sensory experience appears to be supported by recent research from the neurosciences.[42] The human brain dedicates specific attention to junctions where contour lines of different natural objects overlap because such junctions provide significant information about the environment. Contours of objects that overlap each other form distinctive shapes, for example, a t-shape. Such shapes could have been imprinted upon the mind in the course of evolution and may have been the foundation for manmade shapes such as those humans use in decorations and written language.[43]

Both views are not mutually exclusive. It is quite possible that the ability to perceive contour has gradually evolved and that, from that ability, originates the capacity to think of line as an abstraction, which in turn at some point during evolution may have started to determine the way humans visually perceive the world, enabling humans to transform the abstraction of line into a concrete element with which to make signs and pictures that could represent that world.[44] In any case, what counts for the maker and the viewer of geometric ornament, is that the ability to recognize contour in the natural environment, and the ability to abstract those contours to the

[41] Kant, *Prologomena zu einer jeder künftigen Metaphysik die als Wissenschaft wird auftreten können, von Immanuel Kant.*, 268 – 269.
[42] Dehaene 2009, p. 137.
[43] Dehaene 2009, p. 137.
[44] Onians 2006, p. 20.

concept of 'line', seems to be a necessary pre-condition in the ability to recognize and make shapes.

1.3. The regular arrangement

Now that the different categories of motifs have been distinguished, the focus of attention in the forthcoming section will shift to the recursive nature of geometric decorative patterns, i.e. the repetition of the motif(s). I want to distinguish two ways in which motifs can be ordered in a decorative pattern: as a regular sequence of motifs and, as a regular but layered sequence of motifs. The repetition of the pattern can principally unfold in space in three dimensions but, as this thesis is about geometric decorative patterns, the discussion will be limited to the one-dimensional band pattern and the two-dimensional flat surface patterns.[45] Next, I will show that there are a few crucial geometric transformations that can be applied to patterns.

Repetition is the defining transformation while rotation is a transformation that, in addition to repetition, allows for an increase in the number of possible variations of the pattern. The aim of this inventory is to arrive at a definition of repetition, rotation and dimension as the main geometrical features of decorative patterns. This will finally enable formulation of those cognitive competences required to understand those features.

Before continuing a discussion of that part of geometric decorative patterns concerning the arrangement of motifs, I want to make a few more remarks about how shape recognition relates to the arrangement of a pattern. The distinction between the motifs and the pattern is necessary to understand the structure of patterns and to show that a pattern is the abstract ordering that, in its appearance, may also contain stylized and naturalistic motifs. This means that regardless of whether ornaments concerns patterns with motifs in the form of geometric shapes, stylized flowers or angels, pattern recognition is always active.

[45] A three-dimensional cube sculpture such as those of Sol LeWitt is an example of a three-dimensional pattern.

At the same time, the distinction might suggest that both pattern and shape recognition are two distinct, individual, mental activities. However, this is by no means certain. The recognition of shape does not appear to be an isolated capacity. Humans recognize shapes in relation to other shapes; they recognize the parts of the shape in relation to the other parts. Three non-parallel lines orientated towards each other from a certain angle may constitute a triangle. Consequently, three angles can be identified.

With reference to the previously discussed example of the triangle being one of the most basic geometric motifs, the recognition of its shape does not only involve the capacity to recognize a line, but also the capacity to individuate distinct lines in a certain spatial relationship to one another. Dehaene explains that one object makes a dot, while two objects make a line, and three objects make a triangle.[46] He argues that this capacity to individuate distinct objects is innate and enables humans to accurately extract the number of small quantities.[47] At the beginning of the chapter, it was stated that a pattern consists of an ordering of a recurrent motif and is different from a set of elements: a set is not evenly ordered and can consist of different dissimilar elements. However, the competence to distinguish between individual objects underlies both the recognition of patterns as well as sets. To be able to recognize a pattern, humans need to recognize the proportional relationships between its constitutive elements and they need to be able to recognize shapes. Shape recognition itself appears to depend on the capacity to individuate. It could therefore be argued that some aspects of pattern recognition also apply to shape recognition. The perception of patterns therefore seems to be layered. The capacity to individuate objects enables the subject to recognize the different components of a shape, and also enables the subject to recognize the shape as an individual object amongst other individual objects, which in turn as a group can also be individuated in relation to another group, and so on.[48]

At this point, the distinction between motifs and patterns reveals another shortcoming. It may suggest that the making of geometric decorative patterns comes down to the arrangement of geometric motifs on an imaginable grid. Indeed, this is a frequently used method. One can easily imagine a rectangular grid where if motifs are

[46] Dehaene 1997, p. 68.
[47] Dehaene 1997, p. 241.
[48] See for instance Diamond & Carey 1990, pp. 345–368.

placed at certain points a regular decorative pattern results, as is the case with many wallpaper ornaments designed by Owen Jones (Fig. 17). However, from the practice of designing geometric decorative patterns, it becomes clear that it is not merely a matter of placing motifs on a grid but that a grid is often a tool by means of which the designer generates geometrical motifs.[49] The simplest grid consists of horizontal and vertical lines to which another layer of complexity can be added by drawing diagonal lines resulting in a two-dimensional pattern of mirrored triangles (Fig. 18 and 19). Owen Jones' drawings show that he used this method frequently although in his drawings of the Alhambra designs as well as drawings for many of his own designs, Owen Jones departed from a grid, which left him with a lattice of cells which could then be filled in with colours to make the design.[50] In many other, and earlier contexts, the grid was probably a frequently used tool for generating decorative patterns. A piece of floor from the Roman Villa Arianna at Stabiae shows that a grid was incised into the layer beneath the floor which contained the actual mosaic. The grid probably marked the general design of the pattern and might have been an aid for the workers who laid out the pieces of marble, glass or stone.[51]

Whether the ornament maker arranges geometric motifs using guidelines that are unseen in the final design, such as on the wallpaper designs, or whether the design of the ornament maker emerges from the grid of straight lines from which geometric shapes emerge, the concept of line is fundamental for all this activity, as well as the concept of a point, i.e. the particular location at which lines intersect or at which a motif can be positioned. Again, to be able to conceptualize a point, the subject by definition conceptualizes a point in relation to other possible points. This is actually

[49] Durant 1986, p. 64.

[50] http://collections.vam.ac.uk/item/O74625/designs-for-tiles-in-islamic-drawing-jones-owen/ Consulted June 20, 2017. Washburn & Crowe argue that every two-dimensional pattern can be conceived as a lattice of points in which a primitive cell can be identified for instance in the shape of a parallelogram or a square on which the pattern is based and whose transformations cover the whole plane. Washburn & Crowe 1988, pp. 59 – 60.

[51] Dunbabin 1999, p. 283 see image no. 293. The earliest geometric flat surface ornament applied in the form of patterned floors have been found in Gordion in Asia Minor and date from the late eighth century BC. In Greece patterned floors were made from the sixth century BC. onwards. It is uncertain whether designs from Asia Minor and Assyria influenced Greek designs. Maybe the emergence of patterned floors in Greece should be considered as an independent development. The elaborate Hellenistic designs became popular in Italy as well as a more simple ornamental design that started to flourish at the end of the Republican period. See Dunbabin 1999, pp. 5, 53.

fostered by the same cognitive capacity to which Dehaene referred: the capacity to individuate.[52]

Whether one creates a pattern by arranging a series of motifs on a grid of guidelines, which will be subsequently withdrawn from the design, or whether one makes a pattern by drawing sequences of lines at whose intersections geometrical motifs such as stars or triangles emerge, the following is at least required when making such a pattern: one needs an understanding of the concept of line and one needs to be able to individuate line as a distinguishable element to be spatially related to the other distinguishable elements of the pattern, whether the line is only a guideline or actually forms part of the design. However, for the sake of the conceptual distinction between the motif and the pattern, one should imagine the motif in its pure concreteness, for example, in the form of a rosette, a star, and a flower, etc.: as the specific distinguishable and recurrent element in the decorative pattern.

1.3.1. Two types of repetition

Now that the distinction between motif and pattern is clear, a number of significant properties of patterns will be emphasized. Trilling distinguishes four ways in which motifs can form a pattern. The simplest one he refers to as a unitary pattern, which is a pattern that consists solely of one single motif (Fig. 20). This idea of a pattern cannot be connected to the definition of pattern that is used in this thesis which defines pattern as a regular and repetitive ordering or arrangement of elements along one or more axes; after all there is no repetition in a unitary pattern and thus no extension along an axis. Moreover, Trilling's notion of a unitary pattern does not distinguish between the pattern and the motif. In the interest of clear definitions, I will not, therefore, refer to a single motif as a pattern. The second kind of pattern Trilling distinguishes is the additive pattern in which different individual shapes are aligned along one or more visual axes. In this case, however, there is no regular repetition of one or more motifs and therefore an additive pattern would be a series instead of a pattern. This means that from the perspective of the definition of pattern as a regular

[52] Dehaene 1997, pp. 68, 241.

and repetitive ordering or arrangement of elements along one or more axes used, only two kinds of patterns Trilling distinguishes remain: patterns in which one or more motifs are repeated (Fig. 21), which I will refer to as *paratactic*, and patterns in which the repetition of motifs is layered and characterized by a certain complexity, to which I will refer as *hypotactic*. In hypotactic patterns the subject may for instance discover a hierarchical order of groups of motifs where some appear more important than others. Sometimes, a group of motifs can in turn be considered as a distinct motif itself, which within the whole design is again distinguishable as a recurrent feature (Fig. 22).[53]

1.3.1.1. Paratactic

The term paratactic I have derived from linguistics.[54] With regard to patterns, the term can be understood as denoting those patterns in which one or more motifs are arranged without any hierarchy between them. There is simply order.

This might apply to an arrangement of different motifs where no motif is more important or more emphasized than another. Band patterns on ancient Greek vases are examples of paratactic patterns, for example, the bands of repetitive spirals on the storage jar from Rhodes at the British Museum. Another example of a paratactic pattern is the pattern of flower motifs on a wallpaper design by Owen Jones.

On a steatite disc belonging to the Eastern Zhou period in China and which presumably dates from the fourth or third century BC, a plain circular motif can be identified (Fig. 23). It might have been carved or could have been punched into the soft stone. It is clearly visible that the motif has been applied at the intersections of diagonal lines. Despite the simplicity of the design, the lines and motifs have been arranged with extreme accuracy. Along the outer and inner edge of the disc a fine line is visible which appears to frame the pattern. Decorative discs like these were found in tombs and therefore likely played a role within funeral rituals and the afterlife.[55] This is an illustrative example of the most elementary way to create a pattern. The points at which

[53] Trilling 2001, pp. 46–51.
[54] Dirven and Verspoor 1999, p. 231.
[55] Rawson 1998, p. 127. See also Rawson in Loewe & Shaugnessy 1999, pp. 430–431.

the motif can be placed emerges from the grid which in turn emerges from drawing lines at straight or oblique angles to each other.

1.3.1.2. Hypotactic (layered)

Most patterns, however, have several layers of complexity in which a hierarchy of main and subordinate motifs is to be discovered. This is visible in the tile pattern from Turkey which dates from circa 1580 and is now on display in the Victoria and Albert Museum in London (Fig. 22). The complete pattern is spread across four tiles and could be repeated endlessly. It shows the principle of a motif, which in turn is part of a larger motif, which in turn again is part of an even larger motif etc. In the pattern, a clear hierarchy is recognizable consisting of smaller flower and plant motifs, which are part of the central red leaf motif.[56]

Geometric patterns not only give an insight into the complexity of designing such layered patterns but also into the role of geometric principles within a design, even although the geometric operations in some patterns are not clearly deducible from the ornament. The flower and plant motifs in the previous example can be said to be designed after nature or at least to have been stylized using examples from nature. However, their arrangement within the pattern has probably been determined using a grid of guidelines enabling the designer to place each motif on its distinctive position within the larger whole.

Within the geometric patterns such as they appear on the floors and walls of Islamic and Moorish architecture and Byzantine and Romanesque churches, for example, the motifs appear as a result of geometric operations. As previously outlined, the addition of diagonals to grids of only horizontal and vertical lines increases the complexity of the grid and allows more variations with regard to possible designs. It is therefore probable that grids were used to construct complex and hierarchical patterns. Even although no study drawings of ancient floors have survived it is, however, possible to reconstruct the ancient patterns and to show that ancient mosaic makers must have indeed used grids. The French mathematician Bernard Parzysz has shown

[56] Ayers et al. 1983, pp. 120–121.

how this is possible with a method similar to how Owen Jones probably worked when drawing his designs or when he copied the Alhambra patterns; namely by drawing a simple grid of horizontal and vertical lines, adding vertical lines and so on, thereby executing several geometrical operations step-by-step to create an ostensibly complex pattern.[57]

1.3.2. Two types of symmetries

The two types of repetition identified as paratactic and hypotactic can be subjected to a number of different types of isometric symmetries. Before describing these symmetries it is important to first reflect on the different definitions. I will use the description of the different types of symmetries by anthropologist Donald W. Crowe. Crowe's descriptions explicitly denote a definition of symmetry as the possible motions within the planar field, in geometry referred to as isometrics. He argues this definition of symmetry should be distinguished from the conventional meaning of symmetry, which denotes the similarity of form at both parts along the form's central axes. Most examples of motifs discussed in this chapter, and which could be called symmetrical in the conventional sense, would in plane symmetry therefore be referred to as reflection or mirror symmetry as in such motifs the two halves of the shape of the motif are each other's mirror image. But the symmetries discussed by Crowe, however, concern the operations on the patterns as a whole. Crowe therefore defines symmetry as: '(...) a *distance-preserving* (sic) transformation of the plane onto itself'.[58]

The best way to understand this is to imagine a simple pattern in which the motifs are positioned towards one another at an equal distance. Crowe explains four possible transformations which affect the motifs within the entire pattern: the simplest transformation has been discussed already. It concerns the repetition of the motif in a certain direction with certain intervals that make up a pattern in the first place. Crowe refers to this transformation as *translation*. Every pattern thus has translational symmetry by definition and this translation can unfold in a paratactic order or be arranged within

[57] Parzysz 2009, pp. 273–288.
[58] Crowe 2004, pp. 3–4.

a hypotactic pattern (within a hierarchy). Next Crowe discusses *rotation*, which can be identified as the transformation in which the motion of the motif takes place around a certain point and with a certain angle; he further identifies *mirror-reflection*, which comes closest to the conventional meaning of symmetry and in which the two halves of a motif are each other's mirror image, divided by a central axes, Finally, *glide reflection* is a variation of mirror reflection in which the two halves are each other's imaginary mirror image but relatively positioned offset from each other (Fig. 24). The theorem that Crowe adheres to holds that any kind of motion of the plane, no matter how complicated, belongs to any one of these four possible motions.[59]

The identification of the four possible transformations allows an understanding of how these transformations can be applied to different types of patterns. Different types of patterns can be identified according to their dimensions; one-dimensional patterns have a repetition of the motif in one particular direction such as the band patterns from vases or from the hems on textiles; in two-dimensional patterns the repetition takes place in two directions such as on the flat surface ornaments applied on floors, walls and the surfaces of objects. Technically, three-dimensional patterns can also be identified in which the repetition unfolds in three directions as in designed objects such as buildings, sculptures and objects. However, the latter category is not of concern in this thesis and therefore I will limit myself to the discussion of one- and two-dimensional patterns. The four transformations are applicable to patterns of both dimensions but obviously these transformations will result in seemingly more complex patterns in the two-dimensional. [60] To identify the possible combinations of transformations in one- and two-dimensional patterns, Crowe appropriates a system of notation partly taken from crystallography where each possible transformation is signalled by a letter.[61]

[59] Crowe 2004, pp. 4–6.
[60] Crowe 2004, pp. 7–8.
[61] Kadesch 1998, pp. 125 – 132. Pólya 1924, pp. 278–282. Washburn & Crowe 1988, pp. 3–6.

1.3.2.1. One-dimensional (band patterns)

As determined, one-dimensional patterns are band patterns and as ornament they are applied for example on objects such as vases, on textiles, but also as lists in architecture, for instance at the border of a wall and ceiling. There are four possible transformations of which translation is applied by definition. The presence or absence of any of the three other transformations, in addition to translation, makes it possible to express each pattern as though it were a formula. Each formula is made-up of four symbols: the first symbol is *p*, which signals translation and because there is always translation in a one-dimensional pattern every pattern starts with *p*; the second is *m* in which case vertical reflection is applied to the pattern and *l* if vertical reflection is not applied; the third is *m* if horizontal reflection is applied, *a* if glide reflection is applied and *l* if otherwise; finally either the symbol *2* denotes a half turn (rotation) or *l* if other. In the case of one-dimensional patterns there is only one way of rotation distinguishable which is the half turn (90 degrees). A quarter turn would provide vertical reflection, while a three-quarter turn would provide horizontal reflection, each already distinguishable by *m*. Summarized: the simplest pattern in which there is only repetition would have the formula; plll. To determine a pattern's isometric symmetry Crowe provides a flowchart with which the type of one-dimensional isometric symmetry of the pattern can be determined; i.e. which formula it has. Because every one-dimensional pattern has translation by definition the flowchart does not ask whether there is translation or not but starts with the question 'is there vertical reflection?'. Where there is vertical reflection it asks whether there is also horizontal reflection; if not whether there is a half-turn or not. If, for instance, the answer would be yes, one would end up with the formula *pma2*. By using this flowchart, seven possible one-dimensional patterns are identifiable (Fig. 25).[62] This means that every band pattern in ornament would meet the requirements of one of these seven symmetries.

[62] Crowe 2004, pp. 8–12.

1.3.2.2. Two-dimensional (flat surface)

By using a similar kind of flowchart, it is also possible to identify the two-dimensional patterns. Crowe makes clear patterns that allow translations in more than one direction obey the geometrical restriction that only four types of rotation are possible, namely by 60, 90, 120 or 180 degrees. By means of the flowchart, one starts with determining the presence of the type of rotation applied to the pattern, which may be none, or one of the four mentioned above. The second determination revolves around the presence of reflection or no reflection, which already results in three possible patterns that have one-quarter turn, a half turn, or three-quarter turn rotation, but no reflection, and results in one pattern, which has rotation by half a turn, as well as reflection. Subsequently, determinations follow regarding the presence of reflection and glide reflection, as well as with regard to the position of the rotation centres. Ultimately, 17 two-dimensional patterns are possible.[63] As discussed above, many designers of flat-surface ornament start by making a simple grid. Each of the 17 two-dimensional patterns correspond to one of five possible grids. For instance, a simple square grid allows the designers to create patterns of the type p4 (translation, half-a-turn rotation) and the types p4m (translation, half-a-turn rotation, mirroring) and p4g (translation, half-a-turn rotation, glide reflection) (Fig. 26).[64]

1.4. Conclusion: cognitive requirements for the recognition of decorative patterns

In this chapter, the minimal conditions and requirements for an ordering to be defined as a pattern have been identified: a *pattern* is a repetitive regular arrangement of one or more kinds of elements along one or more axes. Geometrical patterns are repetitive regular arrangements of one or more geometric motifs, i.e. kinds of geometric shapes. Two types of patterns were identified: one- and two-dimensional paratactic patterns, as well as two-dimensional hypotactic patterns. Four geometrical transformations can be

[63] Crowe 2004, pp. 12–17.
[64] Schattschneider 1978, pp. 441–444.

applied to the motifs of the entire pattern. These transformations include repetition, rotation, mirror-reflection, and glide-reflection.

This should now enable the formulation of the kind of cognitive competences required to understand and make such patterns. First, with regard to what has been discussed, I want to return to the definition of a decorative pattern. From the perspective of an understanding of the structure of decorative patterns, one should distinguish between the pattern and the motif. Each pattern can consist of either one or multiple motifs. The pattern concerns the ordering of motifs while the motif is obviously that which is ordered within the pattern, or the distinguishable feature that emerges from the pattern as a result of geometrical operations. In other words: a pattern within ornament could be considered as the orderly repetition of one or more motifs along one or more axes. Geometric motifs are distinguishable from other motifs as those motifs made up of straight and curved lines and whose shapes do not seem to have formal resemblances with natural bodies and objects. They are also not stylizations of natural bodies and objects but do nevertheless seem to be constitutive for such stylizations. Geometrical motifs are abstract motifs and their apparent lack of a clear resemblance to natural objects and their emphasis on the concept of form itself, show one of the extremely important properties of geometric motifs: the potential to denote any kind of significance in a symbolic way. This makes them exceptional compared to those motifs that in appearance *do* resemble natural bodies and objects. Therefore, the practice of making and recognizing geometric shapes might also reveal how representation works. It can show how a simple constellation of lines is able to bear content and thus able to make something present: a feature of geometric shapes and patterns that will be discussed extensively in Chapter 3.

From a cognitive perspective the observations about the formal properties of geometric motifs mean that to recognize geometrical motifs as such, and to be able to distinguish them from others, requires the competence to recognize shapes. Shapes consist of lines. They consist of colour in the case where a shape is solid. In the latter case, contour can be abstracted from the solid shape. To be able to recognize *shape* humans thus need the cognitive competence to recognize contour.

A pattern is repetitive by definition; a pattern is a translation of one or more motifs in one or more directions. This means that to be able to recognize and make patterns humans need a cognitive competence that allows them to distinguish one visual feature from another, i.e. they need the competence to individuate and understand the *number* of individual elements within the pattern. In addition, humans need to understand that a pattern unfolds in a direction along one or more axes, i.e. either in one or two dimensions. Humans therefore need a cognitive competence allowing them to understand *geometric* properties such as length and direction.

Besides repetition, the motif of a pattern can be subjected to rotation and reflection. To understand rotation and reflection, humans should be able to identify uniform shapes, also in the case where these shapes are in different positions in space or when different uniform shapes are different in size; in other words, humans should be able to identify uniform shapes on the basis of their invariant properties while, at the same time, the subject needs a concept of space and the competence to imagine individual bodies and objects occupying relative positions within that space. Moreover, the recognition of rotation and reflection requires a cognitive competence allowing humans to make a mental rotation of shapes to be able to judge uniform shapes with different spatial orientations as belonging to the same kind of shape.

The cognitive competence to recognize patterns thus assumes a number of underlying competences at the very least, namely the competence to recognize *shape*, the competence to individuate one from another (*number*), as well as the competence to recognize the regular arrangement of elements along a straight or curved axes (whether imaginary or not) in one or more dimensions, i.e. the recognition of spatial dimensions such as length and direction (*geometry*). In the next chapter these competences will be further scrutinized from a cognitive perspective.