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

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4. Knowledge and the perception of patterns: the case of linear perspective

4.1. Introduction

To argue that the making and recognition of geometrical decorative patterns must be founded on a cognitive competence to represent, I want to use the theory of linear perspective. Linear perspective reveals how from the constellations of points and lines patterns emerge which have the capacity to refer to something other than itself. As one of the main theorists of linear perspective, the Florentine humanist, architect and painter Leon Battista Alberti (1404–1472) made clear how a practical geometry enables the painter to perform a certain kind of geometrical transformations on the picture plane both mentally and physically. By means of the resulting constellations of points and lines that form shapes, patterns can start to become images or representations. In the case of perspectival pictures those are the three-dimensional objects, bodies and phenomena viewers should recognize from their everyday environment.

Alberti linked the practice of making perspectival pictures to contemporary knowledge about the relationship between optics, perception and knowledge, e.g. with the practice of looking at pictures. Therefore, the theory of linear perspective can be regarded as a theory about representation as well as about perception and cognition. I want to make clear that Alberti in doing so, encountered similar conceptual problems as present day psychologists and cognitive scientists, and that the solutions he developed still matter today for this inquiry.

Some will question my choice to discuss linear perspective. I think that at least two legitimate objections can be conceived: first, linear perspective appears to be mainly concerned with the representation of space rather than with flat geometric patterns. However, since linear perspective concerns representation of three-dimensional visual shapes on a flat, two-dimensional surface, constructed by means of geometric principles, I consider the theory to be relevant for the understanding of the underlying competences of recognizing and making visual patterns in general. I will show that the ability to make two-dimensional patterns, in particular that of a simple grid underlies the representation of three-dimensional space on the flat surface. From the critical reading of those sections in Alberti's treatise that emphasize the importance of a practical geometry, it will become clear how those two-dimensional shapes and patterns are already inherently representational.

The second objection concerns the fact that linear perspective is a historical product of western art history and connected to the specific northern Italian cultural context of the fifteenth century.[1] Some will find it problematic that I use this theory to address certain aspects of pattern recognition and making representations that are claimed to be universal according to the core knowledge paradigm. But from the assumption that the cognitive competence to recognize and make representations is a universally available disposition, I can only conclude that it must underlie all systems of representation and therefore the system of linear perspective as well.

The value of the theory of linear perspective is that it shows step-by-step, literally from the first point that one puts on the picture plane, how to create shapes and surfaces by means of constructing flat-surface patterns that consist of a constellations of lines. Alberti does that from the perspective of the practice of making, and therefore he departs from the kind of knowledge that conditions the maker's competence to construct such visual patterns. Those conditions are part of what Alberti refers to as a practical knowledge of geometry. Alberti's theory is further relevant because it allows identifying the specific moments shapes and patterns become susceptible to be endowed with the potential to represent. This chapter will begin with a short introduction to explain why convincing representation was so important for fifteenth-century artists in Italy and how that relates to knowledge of geometry. The relevance for my inquiry into geometric decorative patterns is that by means of using Alberti's theory it can be made clear that the condition for something – a line or contour – to function as a sign or representation is already met at the level of abstract geometric shapes and patterns.

[1] About this context see for instance Edgerton 1975, p. 65; Panofsky 1991, pp. 50–55. & Tachau 2006, p. 354. The quick spread of the method of linear perspective across Europe was probably due to the invention of the printing press which happened around the same time. See Edgerton 1975, pp. 86, 164. & Vesely 2014, pp. 65–68.

4.2. Linear perspective, making patterns and pattern recognition

Alberti's treatise on painting (*De pictura*) was probably first written in 1435 in Latin and translated in 1436 into the Tuscan vernacular.[2] It became an important source of knowledge about the geometric operations involved in drawing and more particular in the construction of 'accurate' representations of three-dimensional space. But 'accurate' representation of space was not so much the main objective of linear perspective. The implications of linear perspective and its theoretical considerations as set out in *De pictura* stretched beyond the representation of three-dimensionality on a flat surface, which was more a means to a more important end. As Caroline van Eck makes clear, linear perspective contributed to the persuasive power of representation in an important way. Alberti's treatise served the practice of painting an *istoria*, which within the cultural context of the fifteenth century should be understood as the history as it unfolded according to the Scriptures. Besides the importance of the mathematically-ordered composition it was from the context of rhetoric equally important that the figures on the history painting expressed dignity and virtue in gesture.[3]

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[2] Sinisgalli 2011, pp. 3–14. The discussion about the priority of the Latin or Italian version is on-going. Recently Sinisgalli proposed that the treatise was written first in the vernacular language presumably for the reason it was dedicated to painters precisely. Eck & Zwijnenberg 2011, p. 11. *De Pictura* mainly revolved around the theory of linear perspective, which was a novelty for painting in the fifteenth century. Although it is not clear how, when, and why linear perspective as a method of representation commenced, it is safe to say at least Brunelleschi, Masaccio and Alberti were important pioneers for the development of the pictorial method. Brunelleschi would for instance have made two paintings of buildings in which he used linear perspective. Masaccio's *Trinità* at Florence's Santa Maria Novella church is commonly considered the oldest fresco painting survived in which linear perspective is applied. For this fresco Masaccio probably worked together with Brunelleschi. Alberti's treatise was, perhaps not surprisingly, dedicated to the Florentine architect and sculptor Filippo Brunelleschi in whom Alberti saw the hope of the resurrection of the arts in Florence.

[3] Eck 2007, pp. 20–23. See also Edgerton 1975, p. 16. Edgerton explains how the mediaeval philosopher Roger Bacon believed painters should have proficiency in geometry in order to contribute to the exegesis of the Scriptures, which essentially came down to the interpretation of the events in the Bible in a literal, allegorical, moral, as well as a mystical sense. Painters would ideally meet the first interpretation of making the spiritual literally appear, for instance by means of geometry. See further Edgerton 1975, pp. 17–18, in which Edgerton further discusses Bacon by means of a translation by Burke 1962, pp. 232–234. Bacon argued one could only achieve such literal representations when one is aware of the *Elements* of Euclid and the works of other geometricians. He argued if men would be presented the things of the world in their visual appearances in accordance to geometry, evil could be overcome by grace and beauty. Bacon thus argues the whole truth of things in the world is contained by the literal sense and by means of their geometrical properties presentable to the human eye. He even argues this comes closer to the Truth of the Scriptures of God as philosophy would be able to. See also Kemp 2006, p. 16.

Tommaso Masaccio's *Trinità* fresco at Florence's Santa Maria Novella church illustrates this; when entering the church the fresco gives the impression as if a 'real' chapel appears at the place where one actually sees the fresco. Linear perspective is applied in the fresco in such a way that the boundaries between representation and 'the real' become blurred. Hence, the notion that by mastering geometric principles underlying linear perspective, the artist potentially has a strong rhetorical tool available. Where the rhetorician must make sure that his audience will be able to imagine the acts and scenes of his speech in their mind, the viewer of a painting sees the figures acting directly in front of him.[4]

4.2.1. Practical geometry

To achieve this effect, the painter needed to be taught the basics first: practical knowledge of geometry. These basics of a practical geometry will be relevant for an understanding of how the competences underlying the making and recognizing of geometrical patterns also condition the possibility to see those patterns as representations. Therefore, I want to discuss those passages from *De pictura* in which these basics are explained.

Alberti departs from the main elements of Euclidean geometry: the point, the line and the outline, which he also considered as the main elements of painting. However, Alberti clearly distinguishes the painter from the mathematician in terms of the type of knowledge each should obtain. According to Alberti, the painter needs a basic and practical knowledge of geometry.[5] For the painter, the geometric elements should have a degree of concreteness allowing the painter to conceive the elements as the basic material with which to work.

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[4] Eck 2007, p. 19.

[5] See Alberti, *De pictura*, $ 1 & 2. Towards the end of *De pictura* Alberti would himself compare his recommended practical geometry with learning to write. After all, those who learn to write first learn to recognize and write all the individual characters of the alphabet before to construct with them syllables with which subsequently meaningful expressions are construed. In the same way the painter first had to learn to draw the edges of surfaces, next the connections between the surfaces and finally the shapes of objects and bodies and their constitutive parts. See Alberti, *De pictura*, $ 55.

Alberti refers to the point as a 'signum', which denotes the concrete concept of a mark or a figure to be placed somewhere on the surface. The point as 'signum' is something that is visible to the eye, something that the painter comprehends.[6]

The point is the literal starting point of a picture. Points will form a line when arranged in a sequence without interval space (Fig. 35).[7] However, for the painter, the line is not a sequence of points but also a solid and concrete object, either straight or curved. Therefore, Alberti also defines the line as a 'signum'. In response to Alberti's conception of a line as a solid object it can be argued that even where someone does observe a sequence of points with interval spaces she or he probably still considers this sequence as a line and usually refers to such a line as a dotted line.

The example of a dotted line exemplifies the step in the thought process that leads from the conception of the point to that of the line. From a definition of line as the sequence of either uninterrupted or interrupted quantifiable points someone might even argue the point is the *only* element of geometry. However, that would be a much too theoretical conception of the point and I think that within the practical geometry such as Alberti formulates it, the point and the line are the two concrete distinguishable elements. In the case of dotted lines, humans will probably recognize those as lines on the basis of the geometrical properties of lines, namely length and direction, e.g. humans have the cognitive competence to conceive a regular series of elements (dots) as a new entity (line) and I think this is already an example of pattern recognition; after all, a dotted line could be regarded as the simplest one-dimensional pattern thinkable.

The formal properties of length and direction also enable lines to intersect when those lines are subject to the geometrical transformation of rotation. This can also be

[6] Edgerton 1975, p. 80. 'Signum' literally means a sign or a trace and in its original significance it thus already comes with the connotation of a reference to something else. See also Alberti, *De pictura*, $ 2. In his conceptualization of the point as a sign in the sense of a mark, Alberti defined the smallest possible element of what will become a concrete picture. To further defend this concrete conception of a theoretical indivisible but also infinite element Alberti wrote a short tract in which he elaborated on the conceptual difference between the mathematician's and the painter's comprehension of the 'point'. For the painter the point must be some sort of thing conceivable as being somewhere inbetween a mathematical theoretical concept and a concrete quantity definable by number. But above all, for the painter a point is a particular, material thing such as lines, edges, colours and objects observable in nature are particular things. According to Alberti these things for the sake of painting do not need to be conceptualized as abstract or infinite. See Edgerton 1975, p. 81. See for the Latin version Mancini 1890, p. 66.

[7] Alberti, *De pictura*, $ 2.

explained by the example of a grid. When a set of horizontals is rotated by one quarter turn they will become verticals. In a grid, horizontals and verticals intersect and when they do, the result is that angles emerge from the points of intersection. Angularity is a crucial property of forms and the forms detectable in the segments of a straight grid of horizontals and verticals are rectangles.

Alberti describes how, when multiple straight lines intersect, they cohere like 'threads in a cloth' and form flat surfaces (Fig. 36). Each segment in the cloth can be regarded as such a surface determined by width and length.[8] If one imagines a simple three-dimensional cube viewed from above, then the surfaces of its sides and its top can be conceptualized as emerging from a larger grid of intersecting lines (Fig. 37). Intersecting lines with different directions therefore always determine the perimeter of rectangular objects (Fig. 38). The perimeter defines the enclosure by means of which shapes as well as two-dimensional ground planes are recognizable. In the case of straight outlines, the form of a surface can take the shape of a rectangle or a triangle (Fig. 39). The nature of the angle determines the nature of the shape. If you take an irregular rectangle and make the left lower and upper right angles obtuse and the right lower and upper left acute you will end up with a parallelogram (Fig. 40). This is a two-dimensional geometrical shape that in certain pictorial contexts can represent the side of the gable roof of a house, when a left-orientated diagonal is added to the upper left side of the figure, it can represent the side of an open book, when a right-orientated diagonal is added to the lower right side of the figure, or it can, for example, represent (part of) the motif of a rhomboid patterned mosaic floor.

Geometrical shapes are thus constellations of a number of lines that intersect and form angles. The circle is the only shape constituted of a single outline that lies like an aureole around a centre although, theoretically, a circle is formed by connecting the points of the ends of all diagonal straight lines departing from that centre (Fig. 41).[9]

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[8] Alberti, *De pictura*, $ 2. In the Latin edition one reads 'Lineae plures quasi fila in tela adacta si cohaereant, superficiem ducent', which in Italian was translated as '(...)quasi come nella tela più fili accostati (...)'. Quoted from the English translation by Grayson. See Grayson 2004, p. 38.
[9] Alberti, *De pictura*, $ 2 – 3. See further Sinisgalli 2011, pp. 113–118.

By using the metaphor of a thread Alberti used a language different from that of the theoretical mathematician but in line with the everyday experiences of the painter.[10] And I also think with the everyday experience of the viewer.[11] After all as viewers, humans recognize in pictures concrete lines and concrete shapes, which depart from concrete and identifiable points. The viewer does not see theoretical abstractions about infinity: perhaps only the suggestion of an abstract idea of infinity in the case of a representation suggests such a concept.

Alberti not only used the web as a metaphor to explain how to construct shapes by means of lines on the picture plane, he also literally used a perspectival device in the form of a viewing frame, which consisted of both thick and thin horizontal and vertical threads, with which the artist could avoid complex geometric operations when constructing a perspectival image. He could place this grid between himself and the object to be represented (Fig. 42). The surface of the painting was then divided according to the same proportions as the viewing frame, allowing the painter to represent the perimeters of objects, bodies and surfaces by painstakingly copying what he saw through the grid of the perspectival device. The grid thus provided artists with the means to literally impose a web of lines on what they perceived in front of them, allowing the painter to capture the perceived proportions between objects, bodies and their parts into measurable units, and to transfer this in the same proportional relationships to the picture plane.[12]

The principle of making a grid is thus an important geometrical principle that within linear perspective served a specific purpose, but as a principle it is much older, and was already applied in many practices before that of painting perspectival images. As discussed in Chapter 1, a grid can be used to create a geometric decorative pattern. The points where the horizontal and vertical lines within a grid cross each other can be

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[10] Edgerton 1975, p. 82.

[11] Eck 2007, p. 26. See also Arnheim 1974, p. 294.

[12] Alberti, *De pictura*, $ 31. Alberti speaks about this frame as a 'velo'. Both Grayson and Sinisgalli translate this as 'veil'. Grayson 2004, pp. 65–66; Sinisgalli 2011, pp. 51–52. In Sinisgalli's version of *De pictura* there is a schematized version of the veil in which this framed veil can be recognized as a grid of lines. See Sinisgalli 2011, p. 176. In two-dimensional decorative art, a grid is often the starting point of a pattern such as I demonstrated in Chapter 1 using the examples of patterns in embroidery and the grids Owen Jones worked with in order to design geometrical ornaments. Similar grids are today still used as a tool in editing software such as Photoshop for instance. About Alberti's 'veil' see also Elkins 1994, pp. 49–52.

used as the points where certain motifs are to be placed. In this case, the grid functions as a helpful scheme for making a regular arrangement of motifs.

There is an important formal resemblance between the regularity of two-dimensional symmetries such as were described by Crowe, discussed in Chapter 1, and that of a grid. Both cases exemplify the essence of a two-dimensional regular arrangement of points, whether or not connected by (imaginary) lines. Besides being used as a scheme for placing motifs (Fig. 43), the grid can also be seen as the basic pattern for a flat surface wall or floor design. It was probably used in that way by Roman mosaic floor designers and certainly by designers in the nineteenth century such as Owen Jones who departed from grids of thicker and thinner lines in order to design geometric patterns inspired by Islamic designs (Fig. 18). In Alberti's time, the Florentine painter Masaccio used a grid to transform the figures of his painting onto the surface in proportion. Its traces are still visible in the plaster of the *Trinità* fresco at Florence's Santa Maria Novella (Fig. 44).

Although making perspectival images appears to be a complicated process, the primary conditions for making such pictures are met by the competence to understand points and lines as distinguishable visible objects, and length and direction as the formal properties of lines. Length and direction are a precondition for lines to intersect and for angles to emerge when lines are subject to the geometrical transformation of rotation. This makes possible the creation of shapes and surfaces with which objects and bodies can be represented on a two-dimensional surface.

4.2.2. How does linear perspective work?

I already referred to mosaic floors that are often based on such grids; the simplest one being the checkerboard pattern, which is a grid of horizontal and vertical lines with an alternation of black and white tiles. In *De pictura* Alberti uses the example of a checkerboard-patterned floor to explain how to represent in a convincing way on the picture plane, a flat ground plane receding in space, and how this can be used to define the ground plane of the picture. The advantage of a checkerboard-patterned floor in perspective is that it enables the painter to dimension the ground plane of his picture and place the bodies and objects in the right proportions, spatial dimensions and scale onto this plane.[13] A famous example can be found in Piero della Francesca's *The Flagellation of Christ* (Fig. 45).[14]

With his explanation on how to draw a checkerboard-pattern in perspective Alberti implicitly emphasizes the competence to imagine something that is a flat surface as tilted, i.e. Alberti explains in the terms of his practical geometry how humans are able to perform mental rotation. Seen from above, a checkerboard-pattern appears as a regular grid of lines but when walking on top of such floors someone will see how the orthogonal lines appear to run towards each other the further away they are (like a railroad track). To draw this on a flat surface someone has to be able to comprehend the rotation of a flat surface such that it appears as stretching out in space in front of the person (Fig. 46).

Alberti describes a number of geometrical principles to achieve this. One starts by determining and drawing a horizon on the picture plane. In the middle of this horizon a vanishing point is determined. A vertical line going straight through the vanishing point forms the intersection of the plane. Left and right from that intersection widths are determined (for instance corresponding to the width of a floor tile) using points from which straight lines flow to the vanishing point. Left or right from the vanishing point another point is determined which represents the point of perspective. From this point, one draws a line to the left or right corner of the floor; at the point where this line cuts the vertical intersection of the plane, the upper line of the rectangular floor is drawn. By drawing a diagonal line from the left lower corner to the right upper corner of the floor, and by drawing horizontal lines at each point where this diagonal cuts through the diagonals running towards the vanishing point, horizontal lines are drawn to create the checkerboard pattern which now appears in perspective (Fig. 47).[15]

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[13] Erwin Panofsky argued that the possibility of placing a figure for instance three tiles left from another figure made it not only possible to proportion figures to one another, but also proportion the figures in relation to the intervening space. Panofsky 1991, p. 58. See also Panofsky 1991, pp. 65–66.
[14] Field 2005, pp. 174–181.
[15] Alberti, *De pictura*, $ 19 & 20.

4.2.3. How shapes and patterns acquire the capacity to refer and represent

The result of the operation described above is a segmented geometrical trapezoid (Fig. 48). This is still a two-dimensional shape but somehow the trapezoid can now be imagined as a ground plane, like a floor, which stretches out in front of the viewer. In other words, the two-dimensional trapezoid is able to represent something which it is not. This may be due to the pattern of lines whose horizontals run towards each other at the top of the trapezoid and could therefore suggest depth as if a subject would experience when walking on a real mosaic floor. It may also be the case that the constellation of a long and short parallel within the trapezoid already implies the suggestion of depth.

Here an important consideration presents itself. In Chapter 2, I discussed how core knowledge research has shown Mundurukú children and adults are perfectly capable of distinguishing geometric shapes such as trapezoid and parallelograms.[16] But the question is whether they would also regard these shapes as receding floors or gable roofs of houses, i.e. as something which the shape itself is not. From these experiments it can be assumed that knowledge of geometry is present as a disposition. As for geometrical shapes being able to refer to, and represent something else, for instance a three-dimensional object on a two-dimensional plane, the question is how and whether geometric shapes manifest themselves as references to, and representations of, other things and concepts, also in cultures other than Western culture, such as for instance the Mundurukú culture studied by core knowledge researchers.

Seeing a trapezoid as a representation of a trapezoid appears to be based to a significant extent on context. Geometry, in the sense of operations involving points, lines and contours, itself is such a context. Humans are able to see the trapezoid as a receding floor because they understand the kind of mental rotation and geometrical operations underlying this.[17] Furthermore, in the context of drawings, paintings and ornaments, humans will probably not see the shapes within the image as constellations of lines. As a distinguishable object within the finished picture, a trapezoid-shaped floor

[16] Dehaene, Izard, Pica & Spelke 2006, p. 382.
[17] Arnheim 1974, pp. 258–259.

is usually coloured and relates to other objects and bodies within the picture to whose context it partly owes its meaning. In a painting, someone probably first recognizes a floor because of its pattern of tiles and because it supports bodies and objects. Reducing all the objects and bodies on pictures to flat geometrical shapes such as trapezoids and parallelograms is an intellectual exercise, which is probably lost on the average viewer.

The latter exercise is more of interest to the mathematicians, philosophers, and perceptual psychologists and, of course, artists. What an artist probably does is to abstract simple geometric shapes from the complex visual shapes perceived in everyday experience. By means of geometrical principles these can be transformed into the concrete geometric shapes on the flat surface, which by means of, for instance colouring and the suggestion of texture can start to represent the complex shapes of bodies and objects from everyday experience. I think representation should therefore be understood as a process, which starts by abstracting certain formally invariant visual properties and principles from the visual impressions humans receive from the environment. This will then enable the creation of a repertoire of forms with which the experienced world can be recreated and represented within a different medium and a different visual language. As part of that repertoire of forms geometric shapes can function as icons, indices and symbols, i.e. as signs that refer to, or make something present other than the sign and picture itself.

In a way that is practical and comprehensible for the painter, Alberti gives an account of how that process of abstracting and recreation actually works. Alberti's description of the geometrical principles makes clear how from points and lines the artist is able to construct shapes and segments of shapes (as abstractions of what the artist perceives) that have the potential of representation.

4.3. Two-dimensional grid patterns from the perspective of other practices: floors and maps.

The geometrical principles Alberti describes and with which the painter creates bodies, objects and surfaces on the picture plane to a significant degree, also underlie other practices than painting, for instance designing and making mosaic floors, patterned cloths, as well as objects and buildings. The example of drawing a receding checkerboard floor on a two-dimensional surface points to the basic operation from which the mosaic maker and the tile worker also probably started, when designing the layout of a floor: namely the design of a basic grid.

The art critic and perceptual psychologist Rudolf Arnheim argued that with a basic grid of horizontal and vertical lines the formal conditions are met to generate the kind of properties that constituted the early two-dimensional arts and would eventually constitute linear perspective. When one or more sets of parallel lines are added to this grid, the framework emerges on which isometric perspective is based and which allows a whole new quantity of possible relations and angles. Its oblique lines form a first condition for the possibility to suggest depth since it makes the creation of shapes like a parallelogram possible, which humans, at least in some cultural contexts, tend to see as a plane receding in space.[18]

Arnheim showed that the competence to make a grid of horizontal and vertical lines, and the addition of diagonals, were necessary conditions for linear perspective to be developed, i.e. the competence to make patterns with lines underlies both linear perspective and geometric patterns (Fig. 49).

4.3.1. Designing and constructing floor patterns

Indeed, there is archaeological evidence that Roman mosaic makers used isometric grids. They carved the grid into the upper foundational layer of the floor where the pieces of glass, tesserae or marble could be inserted later. In Chapter 1, I referred to evidence indicating this practice found on pieces of floor from Roman villas, for instance on a floor in the Villa Adriana in Stabiae from the mid-first century AD (Fig. 50).[19]

There have also been attempts to reconstruct how the knowledge to execute complex pattern designs for mosaic floors and walls would have been made

[18] Arnheim shows that the concept of determining a vanishing point in which parallel lines that can run from all directions commence, finally allows for the possibility of an infinite number of angles. Arnheim 1974, pp. 298–299. See also Vesely 2014, p. 61.
[19] Dunbabin 1999, pp. 281–286.

transferable to workers. The assumption is that designers would have provided them with instructive diagrams that guided in executing a limited number of relatively easy geometrical operations to construct intricate patterns. The point of departure would have been a simple basic grid. However, there is no concrete evidence that such diagrams were really used by the Romans. But it seems plausible, because in the reconstruction it appeared possible to draw complex patterns like the ones found on ancient floors in a few relative easy steps, and because the piece of floor from the Villa Adriana does seem to suggest such a step-by-step method.[20]

Alberti's example of a receding floor is a tilted two-dimensional grid, whose lines extend into three-dimensional space towards the vanishing point. If humans are able to construct simple checkerboard patterns by means of creating an abstract definite surface such as a two-dimensional grid of horizontal and vertical lines, then from experience, when walking across them and looking upon them from above, they would have known checkerboard patterns recede into space when laid-out as a floor.[21] However, they did not immediately have the means available with which to represent this on a picture. Linear perspective would provide those means in the form of a set of geometrical rules.

4.3.2. The practice of surveying and the making of maps

Making floor patterns is also a way to define dimensions, and divide the spatial surface into segments. The geometric designs of mediaeval Italian church floors for instance often functioned as a demarcation of certain pathways along which processions had to move towards the altar and as markings of specific places on the route where prayers had to be said.[22] In this demarcation of routes and areas the origin to which geometry owes its name is still recognizable: the measuring of land. For the development of representational systems such as linear perspective, with which space, volumes and

[20] Parzysz 2009, pp. 273– 288.

[21] The principle of a spatial layout in the form of a grid might even constitute the mental representations of space at the level of the human brain. Neuroscientists observed grid-like representations activated in the human brain of participants during navigation tasks. See Bellmund, Deuker, Schröder & Doeller 2016, pp. 1–21.

[22] Claussen 2002, pp. 319–324.

coordinates of bodies and objects could be represented on the flat surface, the practice of surveying has been fundamental. It is no accident that Brunelleschi, one of the first practitioners of linear perspective as codified by Alberti, was a surveyor in his early career. In this context, it is interesting to note that in map- making some of the principles were used that had already been applied in the decorative arts. The art historian Samuel Edgerton points to the important fifteenth-century re-publication of Ptolemy's *Geographia* in Italy: a work which until that century had remained unknown in the West.[23]

In the thirteenth and fourteenth centuries portolan maps were used. These maps usually depicted the coastline and the most important harbours. By means of a compass rose the cardinal points were marked on the map as well as the half and quarter winds, which corresponded to the other twelve points of the rose. This way, the navigator was able to locate on the map the Rhomb line nearest and parallel to the desired course. Edgerton explains how some maps used a scale in which distances were indicated in the form of a grid imposed on the map. This grid should be seen as a kind of geometrical skeleton, which according to him, forms the link between cartography and paintings based on linear perspective. However, although portolan maps were accurate in terms of showing direction, they were not when it came to distance. To explain this Edgerton makes a comparison with the representation of spatial proportions as depicted in Giotto's frescoes. In these frescoes, it is already clear from what angle objects and architectural settings are seen. It is also clear which objects are in front of others but there is not yet any clue of how far apart buildings, objects and figures are, neither are there clues about the depth of the spatial environment depicted. Edgerton concludes that like portolan maps, Giotto's frescoes provided the viewer with 'a good approximation of angle and direction but not of distance.' (Fig. 51) [24]

According to the classic cartography of Ptolemy the earth as a whole had to be divided in longitudes and latitudes in order to determine the parts of the whole and their mutual relations. Edgerton sees an analogy with the classical conception of art in which the whole should express the sum of its parts. To support this argument he

[23] Edgerton 1975, p. 93.
[24] Edgerton 1975, p. 95.

points out that Ptolemy's *Geographia* was re-introduced in Florence at the dawn of the fifteenth century on the eve of the city's artistic florescence in which these classical ideals of harmony, symmetry and perspicuity would again become the standard. The integration of direction and distance proved to be very useful for painting and Edgerton argues that Ptolemy in his time was already fully aware of the implications of cartography for painting, which he made explicit in the *Geographia*. Ptolemy conceived the aim of cartography to be concerned with the parts of the whole, not in isolation but how those parts proportionally relate to the whole. Indeed like the painter who not only paints an ear or an eye but concerns himself with these details as proportionally related parts of the larger object of a head. The cartographer and the painter thus work according to a similar process of relating and connecting different elements and, in order to accomplish this successfully, they should first concern themselves with the bigger picture. Only in this way are they able to place the details of the whole in the correct proportion to one another.[25]

What Edgerton points to and what makes his comparison between maps and the arts so significant, is the integration of a geometrical property of lines, namely that of direction, with that of number, namely distance. The ratio between the distances on maps and the actual distance a sailor had to sail is a matter of scale. The principle of making maps thus relies on the principle of employing a grid of lines to define a surface into segments, which in its whole and its parts can be quantified. The quantification of a grid is a precondition for scaling, that is, it makes possible that the grid can be related to a surface other than the grid (a piece of land, sea, a floor) and can become a representation of that surface with a very particular purpose; in the case of maps the ability to accurately navigate the surface represented by the map.

But according to Edgerton Ptolemaic maps as opposed to portolan maps were, remarkably enough, not used to navigate the seas initially. Again, there is a similarity with linear perspective, now in the sense that, regardless of their potential practical uses, both ways of geometric projection were contemplated intellectually as a means to

[25] Edgerton 1975, p. 111. Anyone who has ever drawn a portrait has probably experienced it is not sufficient just to start by drawing an eye and going from there. If one wants to be able to create a convincing portrait one should begin by determining the circumference of the head, which will enable one successively to determine the relative points in order to place the eyes, the nose and mouth and so forth.

impose mathematical order on reality. It enabled the Florentines to gather accurate geographical knowledge of the world within a system that appealed to the same aesthetic harmony as in linear perspective. Edgerton argues:

> "The power to render an abstract image of space in our minds, regulated by an inflexible coordinate framework of horizontals and verticals, is what makes any grid system of measurement so instantly meaningful. No matter how the grid-squared surface is shrunk, enlarged, twisted, warped, curved, or peeled from a sphere and flattened out, the human observer never loses his sense of how the parts of the surface articulate. The continuity of the whole picture remains clear so long as he can relate it to at least one undistorted, modular grid square.'[26]

The ability to create and recognize the cohesive proportions between the elements of a pattern may be regarded as an important step towards the insight that the relations between apparently non-connected elements in space can also be proportional, in other words: things becoming larger and those becoming smaller when one moves in space also become larger and smaller in relation to each other and in relation to the space.[27]

For the creation of floors, maps, and as the basis of linear perspective, the integration of direction and distance within a grid as the precondition for exact proportion and scale has been fundamental. But before that integration occurred, the principle of making a grid of lines was already applied in the arts and has been applied continuously throughout art history in what could be defined as a looser form of making grids; cross-hatching. This enables the artist to create a web of lines, not only to indicate surface, but also, by means of drawing a more open or closed web of lines, suggests volume and tone of objects and bodies (Fig. 52).[28] The example of making maps shows that the possibility to scale a constellation of lines significantly increased the possibilities of the grid to accurately define a space.

The idea of a surface as a web of lines comes from Alberti, and he draws a comparison with weaving, which I consider very important. Alberti's definition of

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[26] Edgerton argues the use of the grid was certainly not new but had already been proved to be fundamental for town planning, construction, and the division of farmland. Edgerton 1975, p. 114–115.
[27] Panofsky 1991, pp. 50–52.
[28] Kemp 2006, pp. 109–115. The illusion of volume can be further strengthened when hatchings bend along with the curvature of the outline of the hatched body.

surface as a constellation of different lines 'quasi fila in tela', might point to the basic grid as a common principle, which formed the basis of the measurement of land, as well as of flat-surface ornament and painting but probably also that of architecture and the textile arts.

4.4. Linear perspective, cognition and perception

Points and lines are thus the building blocks for making two-dimensional patterns such as the grid, which can be used to represent a surface. Direction is an important geometrical property of lines. By means of the geometrical transformation of rotation the direction of lines can be manipulated and as a result multiple lines can intersect and form the outlines of shapes; a row of horizontals that intersect with a row of verticals form a grid, which can also be regarded as a squared surface. Once direction and distance are integrated, shapes, patterns and their internal proportions can be quantified and therefore scaled whilst keeping the same proportions. This makes possible the creation of geographical maps, but also that of the representation of three-dimensional space on a flat surface. These skills require certain kinds of knowledge but are also dependent on the working of the human perceptual system. In Chapter 3, I showed how complex the relationship between visual perception, cognition, and the visual representations humans make in the form of pictures, patterns and maps actually is. In the next section I will discuss how the method of linear perspective, such as put in practice, already exemplified these issues. The method of linear perspective depended on the acquisition of knowledge from other disciplines than painting, such as optics and geometry. The capacity of a perspectival picture to become a representation appears to be conditioned by abstract geometric principles. This again, stresses the arbitrary distinction between so-called representational pictures and abstract patterns that would be non-representational.

4.4.1. Optics, geometry and the vanishing point

Although not the only one, Alberti was as far as is known, the first author who described the geometrical principles behind linear perspective in relation to contemporary knowledge on optics, and whose reflections on the emergence of linear perspective have survived in written form.[29] It is important to note that until the fifteenth century the term 'perspectiva' denoted the mathematical theory behind optics and not the representation of three-dimensional space on a flat surface. Edgerton claims Alberti never used the term. Mediaeval views on optics founded on geometrical principles probably had an influence on painting in the late thirteenth, and already during the fourteenth century. It may have had an influence on Alberti's thought since optics was probably taught at the University of Bologna where Alberti studied.[30]

The theory of optics Alberti knew dictated that light reflected by objects and perceived by subjects should be conceived of as rays, connected to both the eye and the object (or vice versa) and which captured the light transmitted by objects. Alberti distinguished in *De pictura* three kinds of rays: first, extreme rays that capture the extremes of surfaces and that would allow humans to determine the length and the width of surfaces, the distance between the highest and the lowest part, or between surfaces that are further away or closer nearby; second, median rays that capture the whole inner surface and its properties such as colour and texture, and third the centric ray as the 'prince of rays'. The centric ray stands perpendicular to the surface creating two equal adjacent angles at both sides (Fig. 53). If one would imagine a pyramid with an equilateral rectangle as its ground plane then the centric ray runs perpendicular to the top.[31] Alberti imagined the bundle of rays effectively as a pyramid. This bundle

[29] Eck & Zwijnenberg 1996, pp. 18–20.
[30] Edgerton 1975, p. 60. See also Vesely 2014, pp. 50–55. And if so, Alberti would in Bologna probably have been confronted with the ideas on geometry and perception in the *Opus majus* of the mediaeval philosopher Roger Bacon. Sources from painting that were available to Alberti were Giotto's fresco programs at the Scrovegni Chapel in Padua and the Basilica di San Francesco in Assisi, which document the first serious attempts to create a spatial organization within the pictures of the frescoes in order to give the viewer the impression as if the events visible in the pictures were set in a world similar to the one the viewer occupied. See Lindberg 1976, pp. 147–148.
[31] Lindberg 1976, p. 149. Although Alberti's linear perspective concerns optics and vision, Lindberg argues that Alberti did not take a critical position with respect to the question from which direction the rays emerged, whether they came from the object or from the eyes. Neither did he take any position

would converge at a single point (the eye), like the axes of an actual pyramid converge in a single point at its top. The picture plane of a painting could be conceived as an intersection at some point in this pyramid shape. The distance between the subject, the imaginable intersection, and the perceived objects within the visual field determines the relative proportions of all the objects within the depiction of the visual field (Fig. 54).[32] The distance of the objects in relation to the subject and the imaginable picture plane determines the actual size of the object in the picture. The position of the object in relation to the subject and the picture determines the angle of view.[33]

The point of convergence in the human eye corresponds to the vanishing point on the picture plane and it is by means of drawing lines towards that vanishing point that an artist is able to distort the actual geometric properties of objects and bodies and depict them as if they are in three-dimensional space (Fig. 55). Lindberg argues that Alberti's vanishing point operation, such as described in the example of the receding floor may have been influenced by Euclid's eleventh proposition from the Optics, in which Euclid proposed that objects captured by higher rays in the visual field will also appear higher to the viewer (Fig. 56).[34] This phenomenon was undoubtedly familiar from visual experience but to represent this in such a way that a viewer also experiences the illusion of depth watching a picture required the kind of practical knowledge of geometry that Alberti described.

Representing three-dimensional bodies, objects and phenomena on the picture plane, however, does not necessarily depend on creating the illusion of depth. Art history provides many examples that show how shapes that do not create that illusion can indicate three-dimensional objects and bodies, or can make objects and bodies

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about whether the image becomes manifest in the optic nerve or on the lens of the eye, which in those days were believed to be the location of the image's manifestation. Alberti's theory of linear perspective simply required the conception of the visual pyramid and with it, the part of optics concerned with the geometrical principles behind vision. The physics and physiology of vision were for Alberti's theory of linear perspective from the context of the purpose to develop a practical geometry for the painter not important. The dispute about whether rays emerged from the eyes or commenced in the eyes has a long history. Avicenna (980–1037) agreed with Galen upon the importance of the lens of the eye but disagreed with Galen's explanation that visual perception is made possible as a result of rays emitting from the eye. According to Avicenna the eye receives and its lens should therefore rather be understood as a kind of mirror. See Edgerton 1976, pp. 72–73.

[32] Alberti, *De pictura*, $ 5–8.

[33] Sinisgalli 2011, p. 126.

[34] Lindberg 1976, pp. 152–153. See the English translation of Euclid's *Optica* by Burton 1945, p. 359.

present in a symbolic way, such as a flat triangle can refer to, or make present in the mind of the viewer, a mountain.[35] Therefore, linear perspective is anything but the 'accurate' way of representing the three-dimensional environment on the flat surface but *a* way to do that, namely a way that by means of geometry exploits the psychological phenomenon of the illusion of depth.

The development of that particular way is connected to a specific sociocultural demand. Biblical scenes were from the fourteenth century onwards increasingly staged within contemporary interiors or landscapes. As a result, artists had to find ways in which to represent receding planes such as those one would encounter in buildings in which those scenes were set. Tiled floors are an example of such planes. From the fifteenth century onwards linear perspective became a tool enabling painters to create compositions in which the architectural bodies of the picture could be ordered and put in place in such a way they could contain all the figures and objects as if it were a 'real' three-dimensional space.[36] The latter probably functioned as a means to almost literally draw the viewers into the scene depicted, by which to enhance its power of persuasion.

This effect is visible when comparing an artwork from the fourteenth with one from the fifteenth century. On Pietro Lorenzetti's (ca. 1280–1348) 1342 triptych *Natività della Vergine* one sees a complete interior in which Mary's birth is staged. The tile floor of the room in which Saint Anne has given birth to Mary recedes to the back, but although the illusion of space is very advanced for its time, it has not yet fully matured (Fig. 57).[37] A century later Donatello (1386–1466) sculpted the relief *Feast of*

[35] See for instance Klee 2016, pp. 17–33.
[36] Alberti, *De pictura*, $ 21. See also Eck 2007, p. 24.
[37] Hyman 2003, p. 91. Two pillars divide the triptych in three panels. The left panel shows a hallway in which Joachim is waiting for the news of the birth. From this hallway opens a view into a courtyard that contains a gothic structure. The hallway has a simple tiled floor from which the lines recede to the back. The two other panels show the room of Saint Anne. The tile floor of this room is in particular visible on the right panel but it is clear that the receding lines of the tiles of this floor appear to be too steep; they do not seem to correspond to the receding lines of the checkerboard motif of Anne's blanket, which appear to recede more naturally. As a result of the depiction of the washing of Mary in the foreground of the middle panel, the floor on this part of the painting is not easy to see but on closer observation it does show that the recession of the lines does not really correspond to the floor on the right panel, although both ought to represent an on-going floor in the same room. It is easy to determine the idea was not that the viewer looks at two different scenes from the event nevertheless occurring in the same room. Although the pillar divided the setting of the room over two panels, Lorenzetti clearly painted a continuous picture of the room. This is indicated by the vertical figure behind the pillar, whose dress runs continuously from the middle to the right panel. Presumably Lorenzetti already had an idea of how lines recede towards the back, and already the means of

Herod, made in 1425, as part of the bronze doors of the baptistery of Siena Cathedral. In this depiction the representation of a receding tile floor has been executed in accordance with the perspective of the entire picture (Fig. 58).[38]

4.4.2. Perception and representation

Alberti certainly connected to what may be called a fifteenth century 'psychology of perception' albeit implicitly because linear perspective rests on a crucial assumption; an assumption the viewer must comprehend cognitively.[39] This concerns the concepts of proportion and scale. I discussed above how the concepts of proportion and scale were fundamental for making geographical maps. To explain their relevance for painting Alberti referred to a philosophical thought experiment in which the physical world with all her inhabitants and objects would be reduced to half its size. Alberti wanted to make clear that in the hypothetical case this shrinking would occur and all the objects and bodies would maintain their relative positions to one another. People would probably not even notice the world had shrunk.[40]

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organizing the architectural stage in which the event in his picture is set. In the *Annunciation* of 1344 the visible receding contour lines of the floor for the first time orient to a single point. See also Panofsky 1991, pp. 57–59. Panofsky argues even though this fresco still has a traditional golden background, the mathematical precision with which the floor has been depicted for the first time suggests this floor forms the ground of a space and as such could be imagined as extending infinitely to all sides beyond the borders of the picture. But the concept of infinite space was not fully comprehended yet. Panofsky argues it cannot be determined whether the lines of the floor coming from outside the picture, which for instance are partly obstructed by figures and objects in the picture, also point to the single point. It would take up until the fifteenth century before space was conceived as something, which preconditions the possible presence of figures and bodies within it and therefore as something to be defined first.

[38] Panofsky 1991, pp. 60–62.

[39] Alberti's treatise implicitly calls into question how knowledge, perception and representation are related. In other words: it can be argued that Alberti was interested in similar problems as present day cognitive psychologists. Although the problems might be similar, the solutions to the problems of course are not. Edgerton explains how mediaeval philosophy such as that of Grosseteste and Bacon was still highly influential during the fifteenth century. In mediaeval philosophy the ultimate source of knowledge of the material world is light, which is explained as governed by the mathematical rules of geometry. And through this knowledge of the material world light is ultimately also the source of spiritual truth. The logic of mathematics and the Divine Grace of God were regarded as fully compatible. By means of the same logic God makes his creation cognizable for men and allows them by means of this knowledge to become receptive of the creation's deeper significance. Edgerton argues that Italian painters were aware of such notions in particular. See Edgerton 1975, p. 20.

[40] Alberti, *De pictura*, pp. 52–53. See also Arnheim 1974, p. 290.

Edgerton makes clear how the theory of linear perspective starts from this necessary assumption, and that it was also at the basis of optical theory. By implication, Alberti's treatise on linear perspective turns out to be not just a treatise on how the painter can represent 'what' the eye sees, but also on 'how' the eye sees it, at least according to conceptions of optics and perception that were common during the fifteenth century.[41] However, from a purely physiological perspective, Alberti could already have acknowledged that human beings see the world with two eyes and, therefore, single vanishing points and fixed points of viewing at least pose a problem to the theory of linear perspective, even though humans in daily life do not experience sight as constructed of two images. Most humans experience a fairly constant and consistent visual reality.[42]

Leonardo da Vinci would identify binocular vision as a problem for the theory of linear perspective.[43] Moreover, as Leonardo's own works illustrate other means of suggesting depth in painting such as atmospheric and colour perspective, are equally effective and could also be used in combination with linear perspective.[44] He therefore, both in theory as well as in the practice of painting, emphasized the use of light and shadow effects, together with the position of the viewer and the angle of viewing, as means to create the illusion of depth (Fig. 59).[45]

All this goes to show that the ways in which humans make images that function as representations within representational systems such as linear perspective, relate to and rely on visual perception, but they do not necessarily work according to the same principles.[46] A representational system such as linear perspective follows its own laws and principles by means of which it is possible to suggest depth on a flat surface and thereby create the impression that the picture resemblance 'reality'. In that respect one could say that linear perspective affects human perception. The study of

[41] Edgerton 1975, p. 88.
[42] Noë 2012, pp. 55–58; Nordhjem 2017, pp. 85–101.
[43] Veltman 1986, pp. 321–325.
[44] Elkins 1994, pp. 68–69.
[45] Veltman 1986, pp. 326, 337.
[46] Art historian Gombrich was already sceptical about making such inferences. Gombrich 1986, pp. 330–332. However, pictures somehow do 'exploit' human depth perception. That is why humans experience depth in a 3D movie although this is not the same kind of depth experience as in everyday life (often such movies produce a kind of exaggerated experience of depth).

representational systems like linear perspective rather shows how humans use certain abstractions from visual perception (such as the concept of line) as the building blocks with which to create pictorial signs that can refer to, make present and distribute knowledge about the world (in the broadest sense: mythical, scientific, metaphorical etc.).[47] This means that the fact the human perceptual system allows to abstract from visual impressions features such as line, is a condition for the competence in order to recognize and make visual shapes that can refer to, or make present something else.

4.4.3. Brunelleschi's experiment

Alberti showed step-by-step how the artist by means of a practical geometry could make a perspectival picture. I have shown how his treatise also enables one to determine under which conditions shapes and patterns can become representations. Although Alberti was the first to write a theoretical treatise on linear perspective he was not the first to exploit the method in practice. I have already referred to Masaccio's *Trinità*, which is one of the earlier perspectival paintings still visible *in situ* at Florence's Santa Maria Novella (Fig. 60). But the earliest experiments with linear perspective in painting can be ascribed to the Florentine architect Filippo Brunelleschi (1337–1446).

The paintings on which he applied the method are lost, but from the literature in which these experiments were described one can still get an idea of what he must have depicted. But perhaps even more important: it shows how Brunelleschi wanted his paintings to be viewed. This tells a lot about the effect linear perspective would have on human perception. Therefore I want to discuss his most famous example because it can indeed be read as a psychological experiment on perception.[48]

It concerns a painting of the Baptistery in Florence, which Brunelleschi painted from a fixed point of view using the method of linear perspective. When he finished the painting he pierced it with a peephole. The idea behind it was that the viewer would

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[47] That does not mean that systems of representation and projection are based on convention exclusively. Heelan for instance argues that the possibilities and limitations of any projective and representational system will always depend by definition both on the neurophysiological and intentional condition of the perceiving subject, as well as on the properties of objects and bodies in the world as how they appear to the subject. Heelan 1983, pp. 105–106.

[48] Manetti 1970, pp. 42–45.

look from the back of the painting through the peephole at a mirror, which the viewer had to hold in his other hand and which allowed the viewer to see the painting he held reflected in the mirror (Fig. 61).[49] The result of this unwieldy method with a mirror was such that the viewer was now fixed with respect to the painting in a similar position to the one from which the painter had painted it. In order to have its full effect, Brunelleschi's perspectival painting required such a fixed viewpoint.[50] When this viewer was placed on the same spot from where Brunelleschi painted the Baptistery, the condition was met to convince the viewer of the accuracy with which the Baptistery was painted and thus the success of Brunelleschi's painting method. After all, from this point of viewing, the viewer could compare the painting and the Baptistery in an instance (Fig. 62).

Even though the painting in Brunelleschi's experiment appeared to have the desired effect on the viewer, Edgerton suggests that Brunelleschi used the mirror to conceal the relative flatness of his painting. He argues Brunelleschi might have been aware of a phenomenon described by modern perception psychology; the effect of illusionary depth is stronger once the viewer is no longer conscious of the fact he is looking at a painted surface. The trick with the mirror would have distracted the viewer from the medium to such an extent the viewer could adopt the picture as 'real'.[51]

With regard to linear perspective I think it is legitimate to argue that the illusion of depth is the persuasive effect elicited by a perspectival picture as a result of the geometrical distortions of object and bodies depicted on the flat surface. Experiencing the above effects does not just depend on the viewer's knowledge or cognitive competences to recognize visual patterns. They are also psychological phenomena resulting from how the human visual perceptual apparatus 'interprets' certain formal properties of images.[52] I do think this is one of the reasons though that most people

[49] Lindberg 1976, p. 149.
[50] Manetti 1970, p. 44.
[51] Edgerton 1975, p. 152.
[52] I think these examples show that the cognitive competences that underlie the recognition and making of visual patterns as representations of, should be distinguished from the psychological effects that visual patterns are able to elicit. Linear perspective shows that those effects do seem to contribute although to the subject's assessment of a picture as a representation. Oddly enough perhaps because the effect initially tends to make the viewer forget about the picture being a representation. Knowledge and effect might therefore work together to enable the subject to finally judge a picture for what it really is.

tend to consider naturalistic images as representations. After all, by means of likeness and illusion the naturalistic image seems to present something to the eye in an instant very explicitly, whether it is a building, a space, or a person.

At first sight, abstract patterns appear to lack formal resemblances with the objects and bodies, which humans encounter in everyday life, or they resemble them only in a very limited way (such as the triangle within the context of a map as a reference to a mountain shares with the mountain the formal property of being wide at the bottom and narrow at the top). I think that is also the reason why many are therefore inclined to think that abstract figures and patterns do not refer to, or represent, anything.

4.5. Conclusion

The purpose of this chapter was to develop, by means of Alberti's practical geometry, a plausible account of how abstract shapes and patterns can become signs, images or representations. With regard to the underlying competences needed to recognize and make representations the critical reading of *De pictura* made clear that both the recognition and making of geometrical decorative patterns as well as the recognition and making of images representing three-dimensional objects and bodies in space, are founded on the same geometrical construction principles and use the same building blocks.

The universal value of Alberti's treatise lies in its applied use of geometry, through which he demonstrates how a space can be defined graphically by means of points and lines. Alberti identified the point and the line as the building blocks of the painter, repetition and rotation as the main operations to which they can be subjected, constellations of lines in the form of shapes and surfaces as its main result. Because the point already allows differentiation between one and another, humans are now also able to apply these concepts to the lines created. Thus, humans can understand the possibility of constructing, by means of these building blocks, simple constellations of lines such as geometrical shapes and patterns, which become identifiable and recognizable as a new entity.

The recognition and making of geometric decorative patterns as well as that of perspectival pictures are at least in their first stages founded on the same fundamental principles of pattern-recognition. Linear perspectival representations are indebted to geometric patterns. That is, abstract patterns are the foundation of naturalistic images. A basic grid should be regarded as a geometrical pattern, based on the definition of a pattern as a recursive ordering of different elements, in the case of a grid an ordering of lines.

The principles on which linear perspective as a representational system is based have emerged from the human practice of applying forms and patterns to surfaces of objects by means of points and lines, as well as by defining the outlines of plots of land; practices which precede its codification as geometrical theory. Cross-hatchings, for instance, can be regarded as the not yet proportionally organized predecessors of the geometrically constructed grid. They were and are still applied in cultures worldwide as surface decoration on vases.

In drawing, cross-hatching is applied as a means to define surfaces and to suggest shadow, depth and tone. Such patterns formed the precondition for a systematic conception of space, as being comprised of a number of quantifiable and proportionally interrelated segments. The practice of making maps shows that humans have first had to integrate certain cognitive concepts over the course of time in order to arrive at such a conception. It emphasizes the making of geographical maps as the result of a successful integration of the geometrical concepts of angle and direction with that of number (Fig. 63).

De pictura thus already shows what cognitive psychologists empirically want to prove today. Pattern recognition relies on the utilization of numerical and geometrical cognition, which is probably present in humans as a universal disposition. The research conducted with the Mundurukú showed that without having had formal training in geometry they were able to comprehend concepts such as angle and length by means of which they recognized geometrical shapes such as triangles, rectangles, parallelograms and trapezoids. This knowledge thus enables the comprehension of the building blocks of geometric patterns, their formal properties and to a certain extent, the geometrical transformations to which they can be subjected. As the basis of linear perspectival paintings perspectival line drawings are essentially very complex patterns of points and lines, but the rudimentary principles enabling the suggestion of complex three-dimensional objects do not differ from the ones enabling the creation of both complex as well as simple two-dimensional shapes. This means it can also be assumed that the cognitive competences underlying the making of the simplest two-dimensional patterns is in the end a precondition for the competence to make more complex patterns.

The concrete externalization of this competence is also something present around the world. It can take the form of perspectival pictures, cross-hatchings on vases, geometrical shapes on baskets, or maze patterns on mosaic floors. It can exploit the medium of painting, sculpture, textiles or any other medium. It can be classified as ornament, as art, as scientific drawing, etc. As concrete externalization the nature of all these different possible products, in the sense of their formal properties in relation to their function and to what they are able to make present by means of reference or representation, is determined by and embedded within a specific culturally shaped context.

Alberti also implicitly showed that the constellations of lines in the forms of shapes and patterns at some point acquire this capacity to represent. Somehow humans start to consider shapes and patterns as standing for, referring to, or denoting something else. Partly this is due to the formal properties of shapes, which in the case of abstract shapes often only very rudimentary, show similarities to the formal properties of the objects and bodies to which they refer such as, for instance, in the case of a trapezoid as a representation of a receding floor. Partly, this is also due to the arrangement of the pattern and shape itself. The example of maps shows how from a certain purpose within a certain context a geometric ordering can make present something which it is not; a piece of land, or a sea.

But it could also be the case that regardless of context and function humans will tend to judge an ordering as intentional and will therefore assign any kind of pattern to a maker. From that perspective, Alberti's comparison between drawing a surface and weaving a web of lines, can be interpreted as a conception about making patterns as both an intellectual and artistic exercise as well as coming forth from the physical manipulation of concrete materials. The relationship between weaving a surface by means of threads and making two-dimensional patterns such as grids for decorative purposes could be fundamental indeed. I will discuss that relationship in more detail in the next chapter where I will also show how that relationship enables one to connect the underlying cognitive competences for recognizing and making geometric decorative patterns to physical labour and cultural context. Therefore, I will discuss the nineteenth-century German architect and architecture historian Gottfried Semper who was one of the first to show that making patterns result from the reciprocal relationship between mind, material, technique and the body. He considered the practice of textiles as an example of one of the first practices in which this relationship became explicit. In weaving, the use of a rudimentary concept of line, in the form of a thread or a fibre, instantly resulted in patterns. Semper shows how the woven cloth became the literal surfaces of constructions in early settlements and how their patterns not only remained references to a maker and an intention but also in the course of cultural development started to become representations in many other ways.