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DISCOVERY OF LINEAR PERSPECTIVE AND ITS LIMITATIONS

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1. Introduction

The discovery of linear perspective[1] in the Renaissance was experienced as the discovery of the objective means to represent space faithfully, or as the objective device to create a convincing pictorial space. A painter like Dürer was almost desperately in search of the new Italian discovery. This idea of faithfulness survived in Western art, even if from the 20th century on more and more painters decided not to use linear perspective.

Pictorial space does not come without its price. The more successful the painter is in creating a pictorial space with the different pictorial depth cues at this disposal,[2] the more problems arise with respect to this space. For instance, Robert Campin who painted wonderful lifelike portraits, got into serious problems when he had an angel annunciate to Mary inside a room (ca. 1425). The persons are absurdly large and the flowers threaten to drop from the table, as they were wont to do in those days.[3]

His contemporary Jan van Eyck was a master in faithful representa-

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[1] There are different kinds of perspective. For instance, the familiar *linear* or *central perspective (*with parallel lines in reality converging to vanishing points on the picture, discovered in 15th century Italy, *parallel perspective* (used in China), and *reverse perspective* (with parallel lines in real space diverging on the picture plane, occasionally used in Western medieval drawings).

[2] Next to linear perspective there are such pictorial depth cues as occlusion, the contrast between light and dark, airial perspective and relative size.

[3] Cf. Bouts' famous painting in Louvain.

tion of different kinds of materials, and his work was admired for this very reason all the way down to Italy. Moreover he could convincingly give his subjects physical bulk, that is some depth. Yet he too had problems with his pictorial space, and with what happens to things and persons in it. In the Arnolfini Marriage (1434)[4] the painter uses different vanishing points for the beams of the ceiling, for the window, and for the bed. It is unclear to us onlookers, what the size of the room is, and how everything fits into it. That does not take away the fact that Van Eyck could depict human beings as very lifelike.

So some depth causes problems. Without depth life is simpler for a painter. For instance, Stefan Lochner's flat painting 'Mary in the Rose Bower (ca. 1450)[5] is quite successful. The suggestion of a reality is not aroused. The painting is not taken as a competitor with reality. Rogier van der Weyden (ca. 1440) seems to have understood this, and so did the Master of the Bartholomew Altar (München) (ca. 1510) Their paintings usually have very little depth. The scene is enacted on a small stage in front of a cloth or a hedge.[6]

The discovery of pictorial space then introduces a serious danger. In a way it turns against the painter. The problem is, as I argue in my (2001), that with the creation of a virtual pictorial space the observer's size constancy scaling within that space is set into motion: depicted objects which have the same physical size on the canvas, and hence about the same retinal size, but which are experienced as being at different distances in pictorial space, will appear as being of different sizes. The brain calculates that the object farther in pictorial space must be larger than the object closer by, and so we see it as larger.[7] The consequence is that the painter has to reduce the object farther in pictorial space to obtain a faithful impression: the objects look equal to us in real life (due

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[4] National Gallery, London.

[5] Wallraf-Richartz Museum, Cologne.

[6] Cf. Rogier van der Weyden, *Descent of the Cross* (1440, Prado, Madrid), and Master of the Bartholomew Altar, *Descent of the Cross (1510,* Alte Pinakothek, München).

[7] In psychology books there are all kinds of pictures illustrating this. For instance, in a corridor – in which the relevant lines of linear perspective have been accentuated - we see two monsters (of equal retinal size) approaching us. The one at the far end looks much larger and more threatening.

to size constancy scaling in real space), so they should appear to us as being of an equal size in the pictorial space. The painter has to reduce the size of the object at a distance. But how much?

The history of painting demonstrated empirically that something close to linear perspective is needed for the appropriate reduction. So in a sense Filippo Brunellesschi solved the problem of reduction with the discovery of linear perspective (ca 1410-1415). Leon Battista Alberti, in his book *Dell pittura* (1436), offered the Traditional Window Argument why linear perspective is required for a faithful painting: a painting of a scene was the projection of that scene on the window pane through which the scene was allegedly seen. The painted objects follow the optical laws of projection and these correspond exactly with the laws of linear perspective. Linear perspective becomes a necessary condition for a faithful picture about spatial scenes.

However, this insight cannot be read off from reality. What we see is controlled by size constancy. That is, over a range somewhere between 3 and 30 meters,[8] we see equally-sized objects as having the same size, even if our retinal images of them have different sizes. (For objects farther that 30 meters away size constancy scaling diminishes in power, but is still active to some extent). So what we experience does not show linear perspective. To hit on the solution of linear perspective requires an empirical discovery or insight (e.g. the idea of a picture as a scene seen through window), but in the end empirical confirmation is needed.

Against this empirical, realist approach N. Goodman,[9] M. Wartofsky,[10] and post-modernists like M. Krieger[11] and N. Turner,[12] and also psychologist Margaret Hagen[13] have defended a conventionalist

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[8] The literature does not quite agree. The recent handbook article by McKee & Smallman (1998, 379) claims accurate size constancy over a distance from 3 to 36 meters, assuming that there is adequate information about depth.

[9] E.g. Goodman (1976).

[10] E.g. M.W. Wartofsky (1972), 'Pictures, Representation and the Understanding' (1972)

[11] Krieger (1984, 191): 'Western naturalism [is] just another - and different - code'.

[12] Turner (1992,149) writes: 'perspective has become the dominant *pictorial* convention of our place and time'. Cf. Turner (1996,145): 'The abstractions of projective geometry are attributed to things'

[13] Margaret Hagen (1986), *Varieties of Realism* (1986)

position. Since we can equally well represent the world in different world versions (to use Goodman's terminology), one of which includes linear perspective, the choice between these world versions is in the end based on convention. Admittedly, we experience a linear perspective painting as more faithful to appearances than a non-perspective painting, but - so the argument continues - this is so simply because linear perspective has pervaded our pictorial tradition: it is this conception, rather than the non-perspective conception, that has been inculcated in the Western tradition. That is to say, linear perspective is not an independent standard of fidelity; it is one of our conventions of which we are not aware due to our Western upbringing. Linear perspective is just a representational system to which we Western people are used and which we find natural. In a sense the way we view nature itself is biased by our linear perspective convention. We see nature as we are used to seeing it depicted on Western paintings.

In my (2001) I argue against this relativist position, using different kinds of arguments.[14] Here I will discuss two baffling cases; baffling *if* linear perspective is a kind of crucial condition for a faithful picture: (1) cases in which a picture employs linear perspective correctly, but is not experienced as a faithful picture, and (2) cases in which the pictorial space of a picture is experienced as faithful, even though the picture is not in linear perspective. I will argue that it remains the case that – in ideal circumstances – linear perspective will create a convincing pictorial space, but that painters had to learn to cope with the situation that their paintings were not looked at from the station point (the center of perspective, the point of the painter's eye).[15] To this purpose they searched for, and discovered, different constraints and tricks, all of which were objective.

I should emphasize that a faithful painting is faithful to our appearances, not necessarily to reality. That is, in claiming that some painting is faithful I do not make a "truth claim" for the painting about

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[14] One simple but powerful argument is that the far monster (compared to the monster close by) has to be reduced in size due to the size constancy operating within the linear perspective painting. So parallel perspective and reverse perspective cannot be presented as just alternative conventions. I call this the Weak Constancy Argument.

[15] The Traditional Window Argument assumes that the observer looks at the painting from the station point or center of perspective.

reality itself. I should also note that the pictorial space of a convincing painting is hardly ever confused with our experience of real space (i.e. with our visual space). Only when the picture is life-size could we take faithful pictorial space for real (visual) space.[16] We will further see that the pictorial space of a painting is highly ambiguous, in the sense that it will change when our viewpoint moves closer or farther away from the picture, or when we look with one or two eyes. Yet, and this is essential in the debate with conventionalism, the features of this virtual, pictorial space are (ontologically) objective in that they can be experimentally examined and will stay (approximately) the same over a longer period of time.[17]

2. Linear perspective and yet the picture is not faithful

Goodman makes much of cases in which a picture in linear perspective does not appear faithful even to us Western people entrenched in the tradition of linear perspective. He writes:

> the photograph of a man with his feet thrust forward looks distorted, and Pike's Peak dwindles dismally in a snapshot. As the saying goes, there is nothing like a camera to make a molehill out of a mountain. (1976, 15)

These cases do indeed point to limitations of linear perspective as a system of representation, yet it would hardly suffice as a defense of conventionalism. The easy way out for the realist is to point out that his claim is *not* that linear perspective is *sufficient* for the faithful experience of some space. He only claims that linear perspective is – at best - an (approximate) *necessary condition* for such an experience. So nothing excludes the possibility that we need more than linear perspective for the creation of a faithful, convincing pictorial space.

However, this way out is disappointing as it evades the problem.

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[16] Smith, Smith and Hubbard (1958) and Ten Doesschate (1964) gives examples. I will come back to this.

[17] Koenderink measured and remeasured the properties of some people's pictorial space and found them (about) the same after a couple of weeks. (Private communication).

What we need is an explanation why there are these limitations that Goodman's examples point to. Further, we need to examine whether such an explanation supports a conventional approach or a realist approach. Does it point to further objective constraints for a faithful experience of pictorial space? Or are the constraints conventional?

It is in this fashion that I will look at a number of examples which demonstrate the discrepancy that Goodman makes so much of.

2.1 The photograph of a man with his feet thrust forward looks distorted

To meet

> Goodman's objection regarding the possible looming of proximate objects (87)

Topper (1996) notes that the phenomenal size of proximate objects is not always realized. He quotes Gombrich with approval:

> in real-life situations we rarely have occasion to attend to such occlusions. If a small object cuts out a large part of our field of vision, we simply shift our head and are rid of the obstruction. (87)

However, the relevant question here is why we experience the picture of the feet as "unnatural", while our own hands which often occupy a large size of our visual field and loom large in front of our eyes (e.g. when writing or typing), do not make us tremble with fear about the large monsters so close to our throat.[18] The phenomenal size of our hands is enormous, yet we are not disturbed by them. And it is irrelevant that we 'rarely have occasion to attend' to them. For we can consciously attend to our hands and keep them quite close to our eyes, and yet they do not turn into huge monsters. So what is the explanation of this discrepancy?

To get a start, consider Vermeer's painting *The Soldier and the*

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[18] Turner (1992,144) makes the Goodmanian point: 'If [a chair such that we sit in] is projected from nearby and the projection is viewed in the ordinary way, with both eyes open and in motion, distortion will be considerable and obvious'.

Laughing Girl.[19] According to many commentators this wonderful painting suffers from the same problem as the feet thrust forward on the photograph. The soldier seems too large, or the girls seem too small. Why does this seem so to many spectators?

The answer seems to be that the soldier and the girl are so close together that – in Rock's terms - the proximal mode of perceptual experience takes over. Let me explain. According to Rock's theory of the double stance,[20] we should distinguish between the default mode, the *constancy mode* in which we see objects corresponding to their real sizes, and the *proximal mode* in which we see the object according to their projective sizes, i.e. according to the proportion of the retinal images.

> We cannot properly describe sensory experiences without including reference to the proximal mode of perception. Consider [a] railroad track. How shall we describe its appearance? Are the tracks parallel or do they seem to converge toward the horizon? The fact is that both descriptions are true, a fact that has been referred to as a paradox of converging parallels. If we stress constancy of size, ... we cannot explain the vivid impression of convergence that every observer will tell you he has'. (347/8)

Perception is thus flexible to a degree. Rock adds that 'due to the dual aspect of perception, a potential conflict is always present' (350).

> We do *perceive* the circle at a slant as circular but we are *also* aware that its projected extensity relations are "elliptical". The point is that we would be seriously distorting the phenomenal facts if we chose to speak *only* of the constancy aspect of perception (348).[21]

And it is this conflict that accounts for the less than complete constancy in many cases in real space perception. We are somewhat troubled by the proximal mode. By means of some practice we can even intentionally move into the proximal mode, and learn to see things according to their

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[19] The Frick Collection, New York.

[20] See Rock (1975).

[21] This example concerns shape rather than size constancy.

retinal sizes.[22]

How does this double-stance theory apply to the perception of paintings? Assuming that size constancy scaling will work somewhat less effectively in pictorial space, we may expect an even greater flexibility due to greater ease with which the proximity mode will impose itself upon us in pictorial space. This can be instructively seen from the relative effortlessness with which we can outwit the constancy mode in the well-known picture of the two monsters (or the three men) in a corridor, when we concentrate on two monsters while neglecting their environment. That is, if we succeed in eliminating the depth cues, we can evoke the proximal mode. This is an intentional effort on our part. By painting the soldier and the girl so close together on the painting's surface Vermeer evokes the proximal mode in us unintentionally. The nearness of the soldier and the girl leads to an uncomfortably strong influence of the proximal mode.[23] And thus we have an explanation why the girl is often experienced as too small.

We may expand this explanation by drawing another aspect into the discussion, viz. the usual comment on Vermeer's painting that the station point is too close for comfort. The near station point results in huge differences in pictorial size of approximately equally-sized objects, and it is just a fact of human (two-eyed) perception that our constancy scaling in pictorial space cannot cope with this huge difference. Thus it would be the combined working of the close station point with its strong decrease in size and the effectiveness of the proximal mode in that situation (or the weakness of size constancy in that situation) which explains the dissatisfaction with the experienced (pictorial) size of the soldier. Our hands are safe, though, as they are in real space, and size constancy scaling can apparently overcome their large proximal size.

Leonardo da Vinci already noticed the problem, and drew the proper

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[22] Painters can do it fairly easily, but we normal mortals can also try. It is important to get rid of the impression of depth.

[23] A real-size reproduction has been in my living room for quite some time. By moving to the proximal stance, by concentrating on the adjacent figures and neglecting depth, the girl can be made to look too small. When concentrating on the constancy mode, for example by looking at the picture with one eye which gives more depth to the painting, the girl looks just perfect. So it seems that when looking with two eyes, the proximal mode gets in the way.

consequence: the painter should avoid a close station point. The distance of the station point to the painting should be at least twice or three times the largest diameter of the picture.

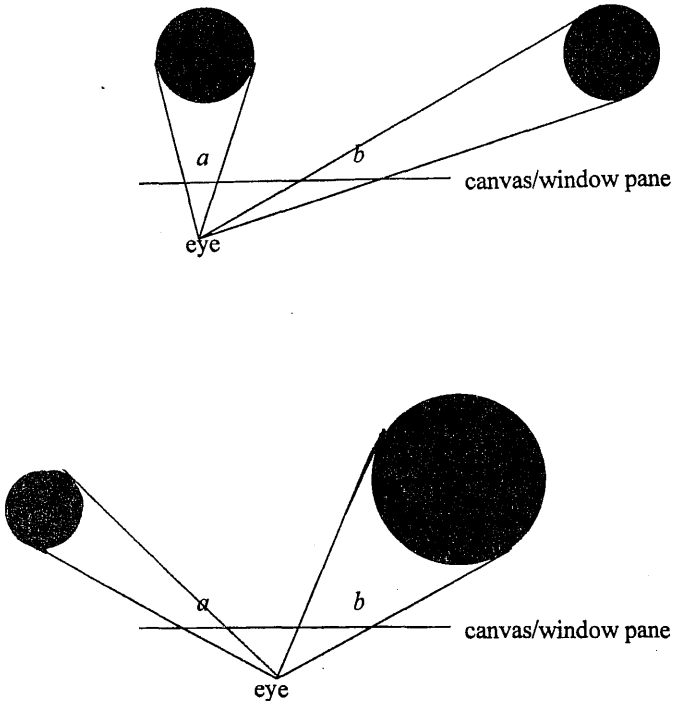
So the problem with the discrepancy of Goodman's feet-example does not turn linear perspective into a cultural convention. It points to an objective fact about human perception, viz. that, especially when the station point is relatively close, the proximal mode is much more powerful in pictorial space than in real (visual) space (or in other words, that size constancy scaling is much less powerful within the pictorial space than in the real visual space). The consequence is that a painting with a close station point with strongly convergent sizes, is apt to cause problems of faithfulness for the observer. The practical solution for the painter is: avoid such a close station point. This advice is based not on conventions but on facts related to vision.

It is surely the case that regular exposure to pictures from a near station point gets us accustomed to such pictures. We are not shocked or surprised any more. Like painters we have learned not to take photographs from too close by. We try to avoid such a close station point because, e.g., the resulting legs are not like the legs we are used to see. That is, we have got used to such pictures but the pictures do not please us, as they do not faithfully present our appearances. These legs are really not like our legs!

2.2 Wide angle leads to distortions

Another distortion caused by negligent use of linear perspective, shows up when the width of the picture from the station point is larger than 45^0. The reason for the problem is again objective: when we look at two pillars, one close by, the other one at some distance, we see their sizes according to their angles, and as the further pillar has a smaller angle, we would have seen it as smaller if size constancy had not interfered. (That is, the smaller visual angle is compensated by size constancy). When we depict the scene as if looking through a window (i.e. according to linear perspective), the projection of the near pillar on the window pane (segment *a*) is much smaller than the projection of the far pillar (segment *b*). When looking with one eye from the station point, there is no

problem.[24] However, when we look from a somewhat different spot, - and rarely do we view a painting from its station point -, then the size of the pillar at a distance may well disturb us. Projecting back the pillar from *b* to its place in pictorial space gives us the impression of an enormous pillar.[25]



[24] Turning the head does not make any difference as long as the eye remains in the station point. (Goodman is wrong here). We still see with the same angle. The longer *b* is just the result of the projection of the far pillar on the window pane.

[25] Due to technical problems (or more fairly, due to my incompetence) the picture is not completely accurate, but it is - I hope – good enough to given an idea what happens when the observer leaves the station point.

Piero della Francesca already knew about this problem.[26] So did Leonardo da Vinci. Ten Doesschate (1964) states that 'the trouble starts as soon as the eccentricity gets about 30^0 or 40^0 '(43), while Dubery *et al* (1983) in their handbook *Perspective and other drawing systems* already warn against a width larger that 25^0.

So there is a problem here, and painters had to find a practical solution. Linear perspective gave painters the depth they desired, but it brought along some complications which had to be overcome. Painters came up with different solutions. The easiest one was to follow Leonardo's advice, who counseled against too wide an angle. But this was not always feasible.[27]

Saenredam did not make life easy for himself.

> [By disposing of] the bird's eye view - formerly so frequently used in both landscape painting and paintings of church interiors - in favor of placing the horizon at the approximate eye level of the figures who people his church interior[28]

he was almost forced to use too wide an angle. (He actually used an angle of vision up to 160^0). He developed two practical solutions: (1) cut off the far pillar at the edge of the painting, so that its projected size (on the canvas/window pane) does not stand out, and (2) use two vanishing points, to imitate the fact that in the real church we could not possibly see the whole space in a single glance. In front of the wide painting we can now inspect the two spaces, safely separated by a row of big pillars in the middle.

How did Saenredam know that these solutions would work? Well he did not, his solutions are just the result of an empirical trial and error to see what works (that is, of discovery). In real life most of the pillars appear the same size to us, due to size constancy, in spite of the fact that their angular sizes are quite different. So the issue is: what will cause a similar experience in the spectator of the painting? The painter faces conflicting demands: he needs linear perspective for a convincing

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[26] Ten Doesschate (1964), 42.

[27] I discuss Raphael's famous solution in *The School of Athens* later on.

[28] Ruurs (1987), 36.

pictorial depth, and for the reduction of size constancy within the pictorial space. But he should also worry about the bulky pillars at the edge of the painting, as soon as the spectator's eye is not at the station point. He cannot know in advance what will do the trick. [29]

I conclude that the wide angle discrepancy with its possible distortions is due to a conflict between objective factors, it is not due to conventions which trouble us because of their entrenchment. Saenredam discovered (or borrowed) objective tricks to circumvent a wrong appearance. Linear perspective has limitations as a system of representation for us humans but these are not conventional limitations.

2.3 Hagen's experiments: adults do only experience minimally converging cubes as natural, among all possible diverging cubes painted according to linear perspective.

In her *Varieties of Realism: Geometries of Representational Arts* (1986) Margaret A. Hagen points to a restriction of linear perspective which may be more threatening to the realist position defended here. She presented to students a number of pictures which were all drawn according to linear perspective, but which differed in degree of convergence.[30] She found that, in 75% of the time, the students (looking at the pictures with one eye from the station point) chose pictures with no convergence or only a minimal convergence (between 1.0 and 0.8 convergence). So even though according to linear perspective all cubes should look equally faithful, there was a clear preference for the minimally convergent cubes. Hagen concludes:

> It is not enough that a perspective construction for a picture be

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[29] Another example of clever hiding of the problems can be found in Vermeer's *Music Lesson*: here a rug covers the square floor tiles at the bottom of picture. These tiles would look distorted without such a rug.

[30] The pictures of the cubes varied from the non-convergent cube familiar from geometry books (with an equally-sized front and back, and parallel sides on the picture plane corresponding to parallel sides in reality) to extremely convergent cubes with huge fronts and tiny backsides with strongly converging sides. All pictures were projections of a real cube according to linear perspective. The differences were due to the place of the center of perspective (the station point).

> projectively correct; it must also be generated within certain *cultural conventional constraints* in order to look good to members of the culture. (90) (A.A.D.: my italics)

And in line with Goodman's claim about the inculcation (entrenchment) of linear perspective, she points out that very young children did not have this bias.

> The very young children functioned not according to a *culturally* determined criterion of correctness [as adults apparently do], but to an *environmentally* determined one'. (93)

In brief,

> the Western post-Renaissance system, so often hailed as the only truly visually valid system of depiction, is itself clearly a cultural acquisition. (94)

But does this follow from the data? The data tell us that 75% of the adults prefer drawings of minimally convergent cubes - among all possible cubes drawn in linear perspective - as the most natural, and that children do not have this preference. Whatever the conventional elements here, this result does not undermine the realist claim that for a picture to present a faithful pictorial space, it has to employ linear perspective. So at most the data support the conclusion that it is conventional which of the possible linear perspective cubes are experienced as natural. So let us see what support there is for this conclusion, and let us ask why the adults did have their preference for minimal convergence. There are some features of the experiment which have to be taken into account and which cast doubt on Hagen's (purely) conventional explanation:
(1) one should note that the kind of pictures that Hagen's subjects had to evaluate, were pictures of bare cubes in an empty space, or rather in no space. One may well wonder whether the subjects would have had the same preference for minimally convergent houses in landscape or townscape paintings. This should be examined before we draw conventionalist consequences from Hagen's data.
(2) it is further the case that highly convergent cubes and houses are more difficult to recognize because we usually do get less information about the cube or building. This objective fact may well be part of the explanation

for the preference of minimally converging cubes. And again no dramatic consequences follow.
(3) the prototype of a cube will probably be a cube with little convergence. We have to be careful here less we argue in a circle. But since a prototype should present its information clearly, it is plausible that a minimally convergent cube is our prototype. But if such a non-convergent cube is our prototype, it should strongly influence our feeling of naturalness in case we see a bare cube. And again it is not conventional but some objective feature which makes us prefer minimally converging cubes. Moreover, this prototype background does not imply anything about the implicit cubes which appear in landscapes or town-scapes.
(4) we should realize that among the convergent cubes with more than 80% convergence, there are many with quite a close station point. And we have seen in the thrust feet-case that with such a station point size constancy does not operate strongly (enough) in the pictorial space. Given the bare cube in no or little space, we should not then be surprised that size constancy operates even less. But in that case a bare convergent cube will present to us the same problem as the feet thrust forward. And we have already found that the problems in the situation were independent of convention.

But what about the children? Why do they not show this preference? I suggest that the answer is that the size constancy within paintings and pictures does not yet operate in children. There is experimental evidence that this is so. Olson, Yonas, Cooper (1980) found that infants do not have pictorial size constancy and that it seems to develop around the age of six.[31]

However, in arguing thus do I not get from the frying-pan into the fire. "Apparently children need 6 years of *conventional* inculcation before they develop full-scale size constancy within pictorial space". The answer is that, however children get their pictorial size constancy, conventional inculcation cannot be the cause, as in the time of the discovery of linear perspective adult Italians - without years of conventional inculcation - had

[31] Seven-months old infants already have (some) size constancy in real space. The data are not uncontroversial.

no problem in recognizing the faithfulness of linear perspective paintings.[32] For this recognition to occur, the person need to have an effective size constancy scaling operation in pictorial space, and since the early 14th century Italian had not been exposed to linear perspective in his youth, we can reject the hypothesis that the appearance of size constancy scaling in children of about six is due to conventional exposure. The early 14th century Italian managed to have the proper size constancy within pictorial space without inculcation at all.[33]

I conclude that Hagen's research results, however interesting in themselves, do not present a problem to the realist case. They demonstrate the same feature as the feet thrust out. A close station point in pictorial space is something we humans cannot deal with effectively. Apparently our size constancy scaling is not strong enough in that domain.

Interestingly enough, this conclusion is supported by other evidence which Hagen's research brought forth. Hagen mentions another restriction on a natural experience of the bare cube:

> for a pictured object to appear natural and realistic to a Western adult, it must be photographed, painted, or drawn at a distance at least ten times as great as its rough front-to-back dimension. (92)

But this is just to say that the subject will reject a close station point. Hagen concludes that this is a Western convention. However, my argument brings us to another conclusion: the close station point is excluded because of some objective limitation of the size constancy scaling within pictorial space, - whatever the cause for this.

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[32] The locomotor hypothesis states that 7-months old infants developed size constancy (in real space) because they crawled. However, also the non-crawlers developed size constancy at that age. So we need the evolutionary explanation that at about 7 months infants size constancy develops to make sure that infants who start to crawl at that age, do get into serious harm. (As this is an evolutionary explanation the intentionality can be written out of the explanation). The point is that some capacities might develop for innate reasons. (Cf. the capacity to talk).

[33] The same is true for Dürer, 18th century Japanese and Chinese, and many others.

2.4 Pike's Peak dwindles on photograph

Goodman presents another, elegant case of "unfaithfulness" of linear perspective:

> Pike's Peak dwindles dismally in a snapshot. As the saying goes, there is nothing like a camera to make a molehill out of a mountain. (15)

Goodman is quite right. Amateur pictures of mountains usually are a great disappointment. Hagen provides a simple conventionalist explanation:

> We are not used to seeing molehill-sized mountains in pictures because Westerns artists correct it according to the Western station-point convention and has done so for 500 years. (139)

Is the conventionalist implication that, if Western artists had drawn more molehill-sized hills, we would have not have been disappointed by our present-day holiday snapshots? But isn't it is more likely that we would have been disappointed both by the paintings and the snapshots? For the mountains would have lost all their impressiveness. So let us consider some reasons *why* the holiday snapshot is so disappointing.

The *prima facie* reason is that the real mountain is huge, as we know, and on the picture the mountain is physically small, and as it is the size that has impressed us, the photograph is bound to disappoint us. However plausible, it cannot be the only reason, as mountains on photographs taken with zoom lenses are still very small compared to the real thing, and yet are much less disappointing. So let us see what happens when we take a picture with a zoom lens.

By using a zoom lens we artificially diminish the depth of the painting. We can see this effect clearly when we look at a tv-programme made with the assistance of a zoom lens: it seems that the zebras are only a few steps removed from the lions, and that in a baseball game the catcher is dangerously close to the hitter. By diminishing the experienced depth the mountain becomes more impressive, not simply because the actual picture of mountain will become bigger, but also because size constancy scaling will be somewhat more effective since the depth

diminishes considerably.[34]

Returning to the disappointing picture taking with the normal lens, we may tentatively conclude that the (large) difference in effectiveness between size constancy scaling in real visual space and size constancy scaling in pictorial space, especially for objects at a large distance, substantially contributes to our disappointment. We may test this analysis by looking at the holiday snapshot from much closer by. In that case we imitate the effect of the zoom lens artificially. (By diminishing the distance of the station point to 50%, you decrease the depth of the painting by 50%). Also in that situation the picture looks better (less disappointing) and the reasons are the same: the mountain-on-the-picture is bigger and the pictorial size constancy has increased in effectiveness.

So we find that choosing a closer station point will give us a more convincing, faithful picture of the mountain, not because painters conventionally chose that station point when drawing mountains, but because a closer station point improves the strength of pictorial size constancy. It is this objective fact which, once discovered, made painters chose the closer station point, just as they avoided too close a station point for an objective reason. So there may not only be a prohibition against too close a station point, too far a station point fares no better for the painter if he is interested in an impressive background. But again this prohibition is not a conventional choice but something required by the objective situation (our perceptual apparatus and the laws of optics) if the painter aims at a faithful appearance.

2.5 Depth in linear perspective pictures cannot be faithful as we see less depth in such a picture than in real (visual) space

There are some further complications with real visual depth and pictorial depth which may seem to undermine the realist claim of faithfulness. Sheena Rogers (1995), in her state of art survey of perceiving pictorial space, writes:

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[34] The literature mentions that size constancy is (fairly) perfect between 3 and 30 meters. At a distance farther than 30 meters the effectiveness of size constancy scaling diminishes gradually. So by decreasing the distance we increase the effectiveness of the size constancy scaling.

> depth and distance in real scenes are themselves usually underestimated (123) ... [there is especially] a compression of depth extents relative to frontal extents and that compression increases as distance increases. (124)

And Atsuki Higashiyama (1996) seconds this:

> extent seen in depth tends to be perceptually contracted relative to that in the frontal plane (268)

Rogers adds that, even if this underestimation is taken into account,

> most researchers have found that perceived pictorial depth is underestimated relative to perceived real depth, even when the geometric array from the picture is isomorphic with that from the real scene. Hagen et al. for example found that depicted distances of 10 to 50 inch between objects standing on a chequered ground were underestimated by an average of 50% (monocular viewing). (127)

However, this claim about perceived pictorial depth conflicts with careful experiments by Smith and Smith (1961) and Ten Doesschate (1951).[35] These experiments may perhaps be trusted better as they depended on acting on the perceived pictorial space, thus cancelling the tricky factor of estimation. Smith & Smith (1961) found that with life size pictures of a corridor (with strong features of linear perspective, viewed with one eye) throwing a ball at a target was only slightly less accurate than on the basis of a perception of the real corridor.

Ten Doesschate (1951) asked his subjects to look through a door in a wall with two eyes at an actual tiled room, while one eye also saw a

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[35] Koenderink has done the best modern experiments in this field. He avoided any estimation. He found that with respect to real visual depth, two-eyed vision led to the experience of a greater depth than the actual depth. With respect to pictorial depth he especially emphasized the huge difference between single-eyed vision and two eyed-vision (in one subject the experienced pictorial depth was twice as deep with one-eyed vision than with two-eyed vision) In all cases 'Large - individual - differences in the depth scale are routinely encountered' (1997, 813). However, his experiments about pictorial depth perception operated on the basis of light gradients only, and avoided all use of linear perspective (apart from foreshortening). So it is not quite clear that the outcome also tells us something about pictorial depth perception of pictures which uses linear perspective.

life size photograph of the extension of the room on the wall next to the door. Ten Doesschate found that the subjects saw the same depth and the same floor with both eyes.

> the imaginary space [i.e. the pictorial space] seemed to coincide with the room and the image of the tiled pavement seemed to be at a level with the floor of the room. It is probable that visual space and imaginary space are conform.(1964, 66) [36]

So it seems that in the case of a life-size linear perspective picture viewed from the proper place (i.e. its station point), we experience about the same depth as in real life. It should be noted that the distances at stake were not great and that there was probably no noticeable compression of space perception in the real space.

What is important in all this is that, for the different subjects with their different pictorial depths, all those depths looked quite faithful. It is an interesting empirical fact that linear perspective creates a convincing pictorial space even if the depth experienced may be very different depending on the place from which the subject looks, and even if it is to some extent also dependent on the actual observer.

It is also important that in Koenderink's experiments the subjects all produced similar results, even if they disagreed about the amount of depth, and that they reproduced the same results a couple of weeks later. So pictorial space is not a fluke, but a mental state that has its own features and that obeys special laws. It is this objectivity that my argument depends on: linear perspective in a painting apparently has the consequence that our psychological machinery produces an experience of some pictorial space which we experience as faithful.

The point is all cases must be: linear perspective is a wonderful means to create appearance like pictures,[37] but it has its objective

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[36] Van Doesschate refers to a paper of his in *Ophtalmologica*, 1951, 122, no. 1, p. 46.

[37] In my (2001) I examine what reasons we have for thinking that it is due to linear perspective that we experience a faithful pictorial depth.

limitations.[38] These constraints are objective as well, and we can take account of them so that our picture is more appearance like again than without.

2.6 Hudson's (1960) experiment: the space in a picture in linear perspective was differently seen by Bantu and Western subjects

In the sixties Hudson performed experiments to find out the cultural determination in viewing depth in pictures. To this purpose he exposed Bantu subjects and Western subjects to a picture in linear perspective. His findings were that most of the Western subjects had no trouble understanding the drawing, while most of the Bantu subjects understood the picture differently. They missed the (Western) depth implicit in the drawing. It seemed a clear experimental demonstration of the conventionality of drawings in linear perspective.

However, these data seem suspect as Italian people in the 15th century had no trouble admiring the then new linear perspective painting, and the same is true for non-Western people like the Japanese and the Chinese who in the 18th century were full of admiration for the depth and faithfulness of Western paintings.[39] This gets further support from Leach's discovery that the Hudson drawing was not in proper perspective. In his (1975) experiment he found that, when the picture was redrawn correctly according to linear perspective, the Bantu subjects had no problems, and that the substantial minority of the Western subjects which had had the same problem, did not show up either.

Why did the Bantu subjects fail first? Because they were actually tested on their knowledge and familiarity with some Western representational system which was related to linear perspective, but was not the real thing. Hudson's experiment tells us something about understanding some artificial representational system, not about experiencing a linear perspective drawing as faithful.

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[38] The limitation may not be noticed. As the observer does not know how deep the real space was, he can be quite pleasantly surprised by the immense depth of the virtual space of the painting, even if that perceived virtual space would not have been as deep as the perceived real space.

[39] The Chinese admired the skill only.

Concerning the six cases of discrepancy I conclude that in none of the cases we have been forced to reject the objective working of linear perspective, or to accept a conventional analysis. We have seen that pictures in linear perspective have their shortcomings, and that painters, facing these problems, have discovered all kinds of objective methods (tricks) to diminish the impact of these problems.[40]

3. No linear perspective and yet the picture is faithful

Goodman and Hagen also use the opposite discrepancy to argue for the conventionality of linear perspective paintings, viz. cases in which the painting does not use linear perspective and yet is convincing and faithful. Let us look at the cases.

3.1 Goodman's converging telephone poles

Goodman argues that according to the laws of geometric optics each pair of telephone poles along train rails converges just as the rails do. Yet according to the laws of perspective a pair of poles should not converge, even if the rails on the picture should converge: the poles should be drawn vertically (non-converging). And indeed, if we were to draw the poles according to the laws of optics, i.e. converging, the drawing would look wrong. That is to say, linear perspective is not followed in the picture, yet it looks okay to us. Goodman concludes that

> the behavior of light sanctions neither our usual nor any other way of rendering space; and perspective provides no absolute or independent standard of fidelity. (1976, 19)

It is no more than a well-used, familiar convention within the Western tradition of representing reality, while even within that tradition it is occasionally violated in order to arrive at a representation which is experienced as having more faithfulness and resemblance.

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[40] All pictures are ambiguous in the sense of being underdetermined. So solving the underdetermination may well be a serious problem, but it is not a special problem for the realist about linear perspective.

In a recent article 'Perspective on perspective: Gombrich and his critics' (1996) David Topper aims to protect Gombrich against this critique. He formulates the objection as:

> That artists usually do not depict telegraph poles converging shows that the rules of perspective are broken so that a picture looks correct. Hence perspective construction is a mere convention - so the argument goes. (85)

Topper has no problem showing that this is wrong. He points out that telegraph poles are parallel to picture plane.

> And a very important fact of geometry is that parallel lines project on to the intersection as parallel lines. Thus telegraph poles, being parallel to the surface, project as parallels. ... So the artist is correct in drawing railroad tracks *converging* to the horizon and telegraph poles *parallel* on the surface. (85)

However, this seems the wrong defense. Goodman has a point. The sides of tall building do converge when you stand underneath it, and we can see this, - even though it takes some effort and time to see this. But usually we do not see this, - and in the case of telephone poles it would be even rarer that we see it. So Goodman is not right either. Telegraph poles are not that long, so to us (in normal circumstances) their appearance is that of parallel lines. Since a (faithful) picture should catch our appearance, linear perspective, which yields parallel telegraph poles, is doing just fine.

I conclude that Goodman's pole-argument does not undercut the realist's thesis that linear perspective is non-conventional. On a picture we should not see convergence when we do not see convergence in reality.

3.2 Reduced perspective - Gregory's solution

Because the depth cues on a picture will not be as complete, and hence presumably not as powerful, as the ones in real (visual) space, Gregory (1997, 185) assumes that size constancy scaling within the pictorial space will be smaller than in real visual space. He therefore suggests that the painter should use some kind of reduced perspective (reduced in

comparison to linear perspective). The idea behind it is that linear perspective would reduce the objects too much (the constancy scaling within the pictorial space does not require the complete reduction of linear perspective). That is to say, precisely by avoiding linear perspective we would obtain a faithful picture.

However, such a reduced perspective would conflict with the horizon ratio relation. This horizon ratio relation takes its intuitive starting point in the following insight. All objects that are as tall as the observer (the observer's eyes) will be seen by that observer (standing up) as reaching to the horizon. All objects which reach over the horizon are taller than the observer, and the objects which remain under the observer's horizon are smaller than that observer. This translates in pictorial terms as follows: if the station point of the painting is at the height of the painter's eye, then all things which are the size of the painter, will reach to the horizon.

And now for the conflict between the horizon ratio relation with the reduced perspective. Suppose that our two monsters have the same size as the painter. If the painter would now follow Gregory's suggestion and would not reduce the far monster according to linear perspective, that monster would stick with his head above the horizon, and so look larger than the painter (and the other monster). If, to prevent this from happening, we now paint the horizon at a higher point on the canvas, the near monster will look too small, as he does not reach the horizon. If - to cancel this complication - we now increased the near monster in size, we are back at linear perspective. That is, either the perspective is reduced and gets into problems with the horizon ratio relation, or we remove these problems and we are back at linear perspective. So reduced perspective is not an option that threatens the realistic approach.

3.3 A painting should use some kind of curvilinear perspective to appear faithful

It has been claimed that the lines that we take to be straight lines in our visual field, are curved rather than straight. For instance, Robert Hansen (1973/74) writes:

> we see curves wherever we look at straight lines. Or is it more accurate to say that we are looking at curves whenever we believe we

> see straight lines? (148)
>
> the lines that appear to curve ... are the raw uninterpreted sensory data; we have been persuaded by centuries of drawings, paintings, and photographs (by lenses selected to eliminate curvature) that our brain must reject what does not appear straight. (150)

So Hansen prefers a curvilinear perspective to linear perspective.[41] His reason is simple:

> it surpasses [other systems] in the empirical test – it looks like the curving world (157)[42]

Topper (1996), in defense of Gombrich, follows an ingenious line. Taking Hensen at his word – for the sake of the argument – he asks:

> if straight lines are really perceived as curved should not the artist still draw them straight, since the act of perception will curve them? (91)

the suggested conclusion being: curvilinear perspective is wrong as it would "double-curve" the allegedly straight lines. The painter should draw straight lines to satisfy Hensen.

Let us spell out the argument. Topper's argument uses two assumptions, to wit: (1) in real (visual) space straight lines in the proximal mode will show up curved in the "default mode".[43] Call this the curving operation in real (visual) space; (2) in pictorial space straight lines will be experienced as curved (this is the curving operation in pictorial space). With these assumptions Topper's argument goes through. However, Hensen is not committed to either of them.

With respect to the first assumption Hensen's point is just the

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[41] To be more precise, he argues for a hyperbolic perspective: 'all straight lines, except those that pass through a line projected straight ahead from a point between our eyes, appear curved, *not as arcs, but as hyperbolas*' (154).

[42] Hansen (1973/74): 'I believe this hyperbolic system is both more logical and more faithful to raw sensory data than either conventional straight-line systems or curvilinear systems employing arcs' (158).

[43] The term "constancy mode" would be misleading.

opposite. Straight lines show up in the default mode. Only after some close examination and practice can we (the painter) start to see the curves (as the 'raw uninterpreted sensory data').

> I must say that straight lines appeared manifestly straight to me until I examined my vision closely. (150)

> with a little practice, these curves can be seen as a single static pattern without moving as much as a eye-muscle. (150)

That is, according to Hensen, the curves appear in the proximal mode, and the painter can see them after some effort, as in Rock's view the painter can see the different proximal sizes of object in the proximal mode.

Hensen also rejects the second assumption. He makes it clear that in his experience physically straight lines curve only when they have some substantial length, and the lines on the canvas will – we may presume – be too small for a decent curvature.[44]

So we have to react more directly. Hanson stated that in the default mode he experienced straight lines which, after some effort on his side, appeared as curved in a kind of "proximal mode". But – so is the realist's argument - since the painter has to deal with spectators who operate in the default mode, the painter has to make sure that the lines on the painting appear straight to the spectator.

Now it might have been the case that to obtain a faithful appearance with straight lines in pictorial space, the painter should paint curved lines, - just as the painter has to reduce far objects to compensate for size constancy within the pictorial space. It might have been so, but it is not so. Reality does not work that way. There is no curving operation in pictorial space. And to be clear about this, Hensen does not claim this, - as Topper implied.

It follows, that since there is no curving operation in pictorial space, the painter should paint the lines which appear straight in the default mode, as straight on his canvas. Thus the lines will appear faithful to the spectator in the default mode.

In conclusion, since the default mode is perception of straight lines,

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[44] Cf. Hansen (1973/74), 150.

and since there is not something like the curving operation working in the pictorial space, the painter should draw straight lines if that is what he wants to make his observer experience. All this could have been different in another possible world, so the painter had to discover in which possible world he lived.

One challenge remains: do we see straight lines in the default mode due to our Western upbringing as Hensen claims? To answer this, we would need (reliable) cultural anthropological data. There are some data suggesting that some illusions which rely on straight lines (Ponzo illusion, Lyer-Müller illusion) are not so effective for people living in an environment with very few straight lines. But then these illusions also become less effective when a Western subject grows older. So it is unclear what conclusion can be drawn from this. I would not be surprised if someone from a "curved" environment would be uneasy in a townscape with all those straight lines (and noise), but that does not imply that the person would see curves rather than straight lines.

There is one revealing experiment by I. Kohler (1962) which may have some relevance here. In this experiment his subject wore glasses which curved straight lines in one direction. After some time the subject got used to the glasses and saw straight lines again. At the moment he removed his glasses, the straight lines curved the other way, to regain their straightness after some times. It seems then that our software does compensate for curves if we know (or if it is "known" by the brain) that the observed lines are really straight. To me it seems implausible that this is a conventional matter. Apparently our brain can uncurve curved lines about which it is known that they are straight.

Note that this is just the opposite of the (hypothetical) curving operation. However, it does not imply a curvilinear perspective for a painting, as the uncurving operation is not effective within pictorial space. Friedrich's painting *Large Enclosure* (c.1832) [45] brings this out. It uses a somewhat curvilenear perspective. The enclosure is seen as curved, and probably meant to be seen as curved (the spherical earth). It does not straighten out, and it is not meant to straighten out.

In brief, curvilinear perspective can be used as an effect to baffle spectators, but it cannot be used to create a faithful appearance. Thus it

[45] Staatliche Kunstsammlungen, Gemäldegalerie, Dresden.

is not a competitor of linear perspective.

3.4 Raphael's solution of the wide angle

We have already discussed the problem of the wide angle, and have mentioned Saenredam's practical solution which prevented us from seeing the distortions by cutting off the pillar at the side of the painting. This solution which stayed within the limits of linear perspective.[46] In his *School of Athens* Raphael chose another solution: he used linear perspective for his architecture, and thus gets a convincing space, but he adopted for each person a station point right in front of him.[47] The consequence is that the circle held by a figure in the far right of the picture is painted circular, rather than as an ellipse. Raphael created a realistic picture by disregarding the laws of perspective. The total image is convincing, but it is - like in all these cases - a question of making and matching.

Topper's (1996) answer is that

> marginal distortions are extremely difficult to see in the world. ... in real space, even with the intervention of a projective plane (such as a window), marginal distortions are impervious to our perception. ... the elongation of marginal objects, so to speak, *resists perception*. (92/93)

Topper does not know why this is so. But whatever the cause, as we do not see marginal distortions Raphael should not paint them on the canvas, where we would see them.

However insightful, this cannot be the total story. True, when we would have been at the actual School of Athens, we would have seen no marginal distortions because there were no marginal distortions to be seen. So they should be avoided in the painting. But note that in the actual School of Athens we would have seen very different things depending on where we had been located. If we had been placed straight in front of the circle, we would have seen it as a circle and it would have appeared to us as circular. If we had been some way off, we would still

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[46] And Vermeer's rug does the same.

[47] Cf Rembrandt's *Night watch* which uses the same strategy.

have seen it as a circle, and probably we would still have seen it as circular. (This is shape constancy). But the pressure of the proximal mode would have become increasingly stronger the further we would have been located from the circle. So what should the painter paint to create what we would have seen? Well, that depends on where we would have been. So the painter has a choice for the depiction of the people and the circles. But he has no choice for the architecture which is responsible for the pictorial space. It has to be in linear perspective, and to minimize distortions the main depth should preferably be located in the middle of the picture. Once the painter has safeguarded a convincing pictorial space (by means of linear perspective), he faces the problem of placing people and attributes in that space. As the spectator of the huge painting can move about, and probably will move about, the painter has to take into account the serious distortions that will result if he were to take the station point used in the architecture for all people and objects. The clever and practical, and apparently successful, solution is to make a station point for every group of people.

"So the painting is faithful and yet it conflicts with linear perspective?" Well yes, to some degree. But note that linear perspective is used to obtain the main pictorial depth - and that is not conventional – and that the deviations from linear perspective are forced on the painter by linear perspective itself because of the wide angle. To obtain a faithful picture is then a question of trial and error, and, if the painter is lucky, a question of discovery, and not of convention.

3.5 Viewed from wrong point and yet the picture looks faithful

There is also a bright side to the distortions: even though the theory of linear perspective predicts distortions as soon as the spectator is not lodged at the station point, the spectator is blissfully unaware of them as long as the angle is less than 30^0. 'In some cases, the visual system appears to tolerate small distortions', as Rogers (1995, 148) tells us. We can see this for ourselves: in spite of the fact that we do not stand at, or in line with, the station point, we will often experience a linear perspective painting as faithful. We can also see it in a movie theater. Only if the moviegoers are seated more than 22^0 of the perpendicular,

will they notice distortions.[48] Linear perspective might not have worked, but we are lucky, it does.

What is the explanation? Pirenne (1975) seeks the explanation in the fact that we are aware of the flat surface of the canvas, and that we compensate for this. He supports this with the observation that, if the spectator is not aware of the flat surface,

> then strong deformations appear when the spectator is in the wrong position. (463)

He concludes that

> the stability of our perception of ordinary paintings is due to our subsidiary awareness of their flat pattern, since this is the only essential difference between the two cases. [In that case] an intuitive compensation takes place when we look at ordinary pictures in the usual manner. (463)

Unfortunately, Rogers (1975, 153) cites experimental evidence that this cannot be true. So we have to take a purely empirical line, and do without explanation. Apparently a linear perspective painting still offers a convincing pictorial space, even if we do not stand at the station point. As we have just seen, there are limits to the possibility of skewed vision. There is also the simple fact that we do not usually compare our view of a painting from the left of the station point with the view to the right of the station point. If we were to do so, - and it is instructive to do so - , we can see a clear shift of direction of the objects on the painting. But since both positions are possible in reality, and since we usually see only one, we experience both views as convincing and faithful, and not as distortions.

So the "wrong viewpoint" which is brought forward as an argument against linear perspective, turns into a (further) fact in its favour. All these properties are based on objective facts about our perceptual apparatus, not about conventions. Painters had to discover what works. What they find are objective "tricks", which are based on objective (that is ontologically objective) features of our subjective experience. Together

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[48] Cf. Rogers (1995), 151.

with linear perspective these tricks provide objective means of creating a faithful pictorial space.

4. Conclusion

Nobody should believe that linear perspective is perfect. The question is: can it help to represent visual appearances faithfully? And the answer is: Yes, it does but it has also some clear limitations. To prevent these from becoming too explicit and too disturbing, the painter has to do something to manipulate and remove the distortion. Distortions could have become a problem if painters could not have coped with them, either by hiding them (Saenredam), or by preventing them (Leonardo). But, as an actual fact, they do not.

Linear perspective pictures have also some other, vaguely worrying features about which a painter has no control. For instance, if we follow Koenderink, pictorial depth seems to be different for different people, and pictorial depth is different for the same person when that person looks at the painting from different distances. But it is important here that this (personal) pictorial space has objective features which are stable. The painter is fortunate that linear perspective does not suffer from these properties. Also this is a practical matter for the painter, he has no choice but to try to discover empirically what works. Linear perspective works, that is the major finding. Nowhere does linear perspective emerge as a convention, apart from the obvious convention that it was chosen in some periods, and not in others.

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