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Arm Chair Perspective Preferences

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Abstract

Do generic observers in their free-style viewing of postcard-size pictures have a preference for specific modes of perspective rendering? This most likely depends upon the phrasing of the question. Here we consider the feeling of ‘presence’: does the observer experience a sense of being ‘immersed in the scene’? We had 40 Italian naïve participants and 19 British art students rate three types of rendering of ten ‘typical holiday pictures’. All pictures represented 130° over the width of the picture. They were rendered in linear perspective, Hauck maps, and Postel maps. The results are clearcut. About a quarter of the participants prefer linear perspective, whereas the Hauck map is preferred by more than half of the participants. Naïve observers and art students agree. Architectural scenes are somewhat more likely to be preferred in perspective. Preferences are not randomly distributed, but participants have remarkable idiosyncratic affinities, a small group for perspective projection, a larger group for the Hauck map. Such facts might find application in the viewing of photographs on hand-held electronic display devices.

Keywords

Perspective, peephole vision, panel vision

1. Introduction

Consider how people typically view pictures. A major dichotomy in daily life is perhaps that between looking at paintings in an art gallery, and

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viewing pictures of paintings in an art book while sitting in one's favorite reading chair (Malreaux, 1949, 1951). In the former case the pictures are presented at their true size and you walk about in their immediate neighborhood, only constrained by pesky proximity detectors. In the latter case, you view postcard size — or at best letter paper size — copies of originals and hold them in some convenient spatial attitude, perhaps allowing for their coexistence with a glass of wine or a cigar.

There are two major differences from the viewpoint of physiological/psychological optics (Gibson, 1954; Graham, 1966; Pirenne, 1970), namely the relation of the vantage point to the picture, and the angular scale ratio between the purported scene — well defined at the moment of exposure of a photograph — and the picture in the visual field. Both are crucial. From a phenomenological viewpoint there is also the viewing mode (Koenderink *et al.*, 2011; Oomes *et al.*, 2009). 'Seen as a scene', 'seen as a picture', and 'seen as a small copy of a picture' lead to different expectations and visual awareness. For instance in a scene view there is no pictorial surface. In pictorial mode there is a picture surface, and whether or not the observer is — perhaps in subsidiary awareness — aware of that may lead to automatic corrections for foreshortening, and so forth. The topic is an enormously complicated one, and hard to bring fully under experimental control.

In the old days, several decades straddling 1900 say, many people used *viewers* that would at least put the center of rotation of the eye ball at the perspective center, and would correct for most monocular cues. The Zeiss Verant (Zeiss and von Rohr, 1904) is the top optical design. Binocular designs, effectively rendering an observer cyclopic, include the zograscope (Koenderink *et al.*, 2013), dating from the 18th century, and the synopter (Zeiss, 1907), another Zeiss design. Nowadays viewboxes have gone out of use, perhaps mainly because so many photographs are no longer taken with a 'standard lens' (e.g., 50 mm focal length on 24×36 mm format), and the number of formats has exploded. But even when all pictures were taken with a standard lens, so it would be easily possible to 'put the eye at the right place', this rarely happens. People leave both eyes open, and assume any position that suits them. We know of no art museum that indicates where visitors should stand to see the paintings. The marble circle on the floor of the Church of Sant'Ignazio in Rome that shows the correct position from which to view Pozzo's fresco on the ceiling is a very rare exception. In museums, one almost never sees visitors take the trouble to close an eye, stand right in front of a painting, or try to find a good viewing range, unless perhaps they are artists who have been trained how to find the 'centre of perspective'. The textbook mode of picture viewing, which presents pictures as peephole shows (Alberti, 1435; Gibson, 1954; Pirenne, 1970), is rarely adopted or enforced outside laboratory settings.

In a recent paper (Koenderink *et al.*, in press) we distinguish between 'peephole' and 'panel' presentations. In the former case viewing is monocular, and the vantage point is strictly enforced. In the latter case viewing is free. The actions of the observer are eyeball rotations in the peephole case, and translational movements, augmented with eye movements, in the panel case. One desires the viewing to be 'transparent' with respect to such actions. That is to say, the pictorial content should be invariant with respect to the observer's actions during viewing (Koenderink *et al.*, in press). This can be served through different modes of pictorial rendering. Peephole presentation combined with linear perspective yields 'virtual reality', that is to say, viewing is like looking out through a window. In panel presentations translational movements replace eyeball rotations. In such a case the optimal solution is not linear perspective. A formal theory is developed in the paper mentioned above (Koenderink *et al.*, in press). The two types of rendering are categorically distinct. Historically, artists have generally employed panel rather than peephole renderings, as is evident through recent analysis of the work of Canaletto, which reveal he amalgamated several viewpoints into one painting (Franke *et al.*, 2008). Non-Western cultures never even considered peephole renderings, as artists like David Hockney have consistently pointed out (Gayford, 2007).

In this study we attempt to establish preferences of generic observers in the case of 'typical' viewing, that is to say, mainly informally viewing smallish copies in books, on postcards, on one's cellphone, and so forth. This is probably the major mode of exposure to pictorial material for most people, at least for still pictures.

Of course, it is not that easy to define a notion of 'preference'. If you ask a person to judge whether a pictorial rendering is *free of unpleasant pictorial curvatures of obviously straight edges, as in renderings of architectural configurations*, the answer is forced by the question. Only linear perspective renders any straight line as pictorially straight. However, this in no way implies the rendering will *look good*. In fact, it is a well known fact that observers often spontaneously complain that wide angle photographs look somehow 'distorted', or 'unnatural', whereas telephoto renderings tend to look unnaturally 'flat' (Pirenne, 1970; Pont *et al.*, 2011). Such complaints are rare in the case of paintings, or minified copies of paintings, in which the depicted space is often rendered differently from photographs. The latter are in perfect linear perspective, except in certain singular cases (lens distortion is generally insignificant; Bass *et al.*, 1995).

Artists have often striven to capture the sense of presence within a space or scene in their work. The painter Pierre Bonnard declared in 1937: "Let it be felt the painter was there" (Terasse, 1988). In this study we decided to test the extent to which a picture can elicit this experience of 'presence' by asking observers to report how much they feel 'part of' or 'being present in' a pictorial scene. Numerous informal observations involving ourselves, artistic friends, and children, suggest that renderings not in perfect linear perspective are often preferred over those that are. One criterion for this preference appears to be the capacity of the picture to convey this sense of 'presence', or 'immersion'. Asking for 'apparent depth range', or 'absence of deformation' would certainly lead to different results. Presence implies an emphatic relation between the picture and the viewer, and is likely to be correlated with the aesthetic power of pictures. Here we present a simple, straightforward study in which a group of naïve observers and a group of visual arts students were required to make such judgments about samples of pictures rendered in both linear perspective and non-linear perspective forms.

In a limited study one has (at least) to decide on the task and on the stimuli. As a task we asked for the feeling of 'presence' (or 'immersion') in the pictorial space. This is a *quale* that is independent of aesthetic dimensions and avoids the notion of depth. As stimuli we used (very) wide-angle photographs rendered in three different ways. One of these is linear perspective, the 'default'. For the others we selected the Postel and Hauck renderings. The reason is simply that these have been suggested by artists and art theoreticians. We do not believe that the obvious formal choices, such as stereographic instead of Postel and Mercator instead of Hauck, would have made much of a difference. However, in order to *know*, one would have to check that too. This is frankly a limited study and we do not pretend that generalization is at all a harmless exercise. However, we also believe that there are even more important factors not even considered here, such as absolute size and viewing distance, mode of presentation, use of color, choice of subject matter, and countless others. The topic is a very wide ranging one that has hardly been seriously considered thus far.

This research has numerous potential applications. For instance, it is a simple matter, given modern electronics, to show wide-angle photographs in various renderings. It is obviously of some interest to establish observer preferences.

2. Methods

In this study we are almost *forced* to use photographs. Artworks are problematic because one does not easily produce parameterized versions, unlike in processed photographs where one has pixel for pixel identity of color and well defined geometrical relations. Computer graphics renderings might seem a good option, but unfortunately these tend to look artificial — more like 'good CG' than a picture of an actual scene. Fortunately, photographs are easy enough to acquire. The major problem is the choice of subject matter, which almost certainly will be important, for a variety of reasons. The choice will necessarily be arbitrary in various ways, regardless of sample size.

We prepared ten wide-angle photographs of diverse scenes. Landscape aspect ratio was used throughout. The horizon was always placed at the center of the image, and the central vertical was positioned vertical in the image. Searching for suitable subject matter soon reveals the fact that most scenes yield pictures that show only relevant articulation in the vicinity of the horizon. Indeed "fill the foreground!" is standard advice for the use of wide-angle lenses (Rockwell, 2014), if you deviate from this the picture is guaranteed to be boring. The lower half of the photograph tends to show empty pavement or soil and the upper half tends to be all sky, or ceiling. One has to search for subject matter that 'fills the frame' in a pictorially satisfactory way. This is certainly relevant to the experiment. Suitable subjects include narrow streets, smallish interiors, dense forests, and so forth. Thus there is an evident bias. We do not consider that a serious drawback, since *any* set of ten images is bound to be biased. We decided on an informal variety of the 'holiday snapshot' type. The images are shown later in the text (Fig. 6 below), and as online Supplementary Images.

All photographs subtend the same, rather large, visual angle in the horizontal. The renderings were derived from fisheye photographs in linear angle rendering that subtended a full 180° over the diagonal of a 4:3 aspect ratio frame. (We used a Panasonic GH-2 Micro Four Thirds camera with a Lumix G fisheye 3.5/8 lens, which is almost angle-true; we had to apply only a minor correction.) From these we computed linear perspective, Hauck map, and Postel map renderings (Koenderink *et al.*, in press). This yielded 30 different pictures. These were cropped to the same landscape format rectangular frame of 1.83 aspect ratio, keeping the horizontal scope the same at 128°14'. Of course, this implies that the vertical scopes have to differ.

In the Hauck map (Hauck, 1879), which is 'cylindrical', the verticals are rendered straight and vertical, whereas in the Postel map (Postel, 1581, cited in Snyder, 1997, p. 29; Flocon and Barre, 1968) any objective straight line is generally curved. In all cases the horizon is rendered as the straight, horizontal line at mid height. Both the Hauck and Postel renderings are nearly conformal (exactly so at the horizon), whereas the linear perspective rendering has major deformations near the edges (even on the horizon). These three renderings are mutually very different, and may stand as models for various other possible mappings. For instance, the Hauck map is very similar to the Mercator map (Mercator, 1595), whereas the Postel map is hard to distinguish from stereographic map (Ptolemy, 2nd c. AD; Von Helmholtz, 1866).

The Postel map is similar to Helmholtz's famous figure (Merlitz, 2010; Oomes *et al.*, 2009; Rogers, 2008; Rogers and Brecher, 2007; Von Helmholtz, 1866) that was designed to be 'transparent' with respect to eye movements according to Listing's Law (Listing, 1845). Likewise, the Hauck map is similar to the Mercator map, which was designed to be 'transparent' with respect to horizontal translations (Koenderink, 2014).

We use Postel maps instead of stereographic maps, and Hauck maps instead of Mercator maps, because these renderings have been suggested in the art historical literature as being particularly attractive (Flocon and Barre, 1968; Hauck, 1879; Panofsky, 1925; Pepperell and Haertel, 2014). However, the differences are relatively minor (Koenderink *et al.*, in press), and would probably not show up in a study like this.

In Figs 1 and 2 we present a comparison of these maps. Here we have used a regular grid of 10° × 10° for the Hauck map as fiducial, and show the deviations from the fiducial for the Postel map and for linear perspective. Of course, we could as well have used one of the others as fiducial, but, anticipating the result, the present choice is the most convenient one. The differences are visually obvious: Hauck and Postel maps are similar in many respects, except for the obvious curvature of the verticals, and somewhat less obvious curvature of the horizontals. The perspective projection is very different because of the strong curvature

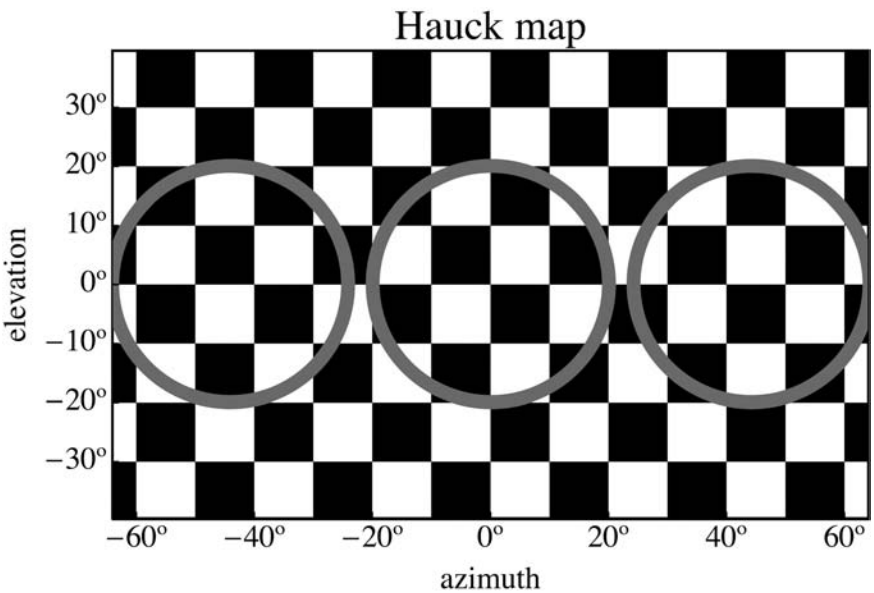

Figure 1. A regular 10° × 10° degrees checker pattern in the Hauck map (formally, the Hauck map is not a 'projection'). It simply tessellates the azimuth-elevation parameter space. The three circles serve to judge the overall differences between the maps (see Fig. 2). The Hauck map is based on the left–right and up–down distinction, which seems to dominate visual experience. Verticals are rendered as vertical lines, and horizontals (parallel to the horizon) are rendered as horizontal lines.

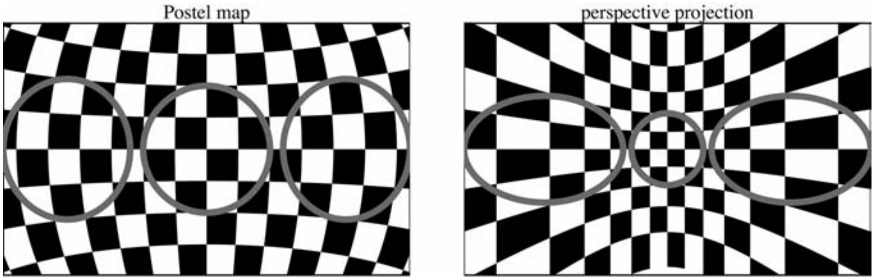

Figure 2. At left the Postel map, at right the linear perspective projection. Notice that only linear perspective is a true 'projection', which is why we denote the others 'maps'. The circles are probably the most useful graphical items to judge the mutual differences. Notice their shapes and relative areas.

of the horizontals, the relative smallness of the center, and the distortions in the peripheral parts. The latter are indeed distortions, because the Hauck and Postel maps are approximately conformal (Koenderink *et al*., in press).

For each photograph the three renderings of a scene were printed together on a single A4 sheet. This is a presentation very similar to illustrations in art books, the picture format similar to postcards, or cellphone images. We prepared booklets made up of 10 sheets, each sheet for a single photograph (see online Supplementary Demo Booklet). The order of placement of the three renderings on the sheet, as well as the order of the sheets in the booklets were fully randomized, so we printed as many (mutually different) booklets as there were observers.

Observers were asked to indicate which of the three renderings yielded the strongest impression of 'presence', the literal phrasing of the task being:

> You will be presented with some pages, each showing three images A, B, C. Although the images initially look similar, they are really different. Look at them intently before you make up your mind in responding.
>
> Try to imagine yourself present in the scene. You are asked to indicate which of the images A, B, C gives you the strongest feeling of 'being present' in the scene.
>
> Indicate your preference by encircling the appropriate letter (A, B, or C) in the box at the lower right corner of the page.
>
> Then move on to the next page until finished.

Observers were 40 students in the humanities from the University of Sassari and 19 students in the visual arts from the Cardiff School of Art & Design. The gender ratio was 78% female at Sassari and 89% female at Cardiff. For the benefit of the students the task was presented in Italian at Sassari, in English at Cardiff. (Translation was checked by a professional linguist.)

Participants viewed the booklets informally, in a lecture room setting, in any way they preferred. They were sitting at a desk and looking down on the pictures. Typically they looked with both eyes open, and in no particular spatial attitude. Since the booklets were freely handled during viewing, the vantage point was essentially undefined and variable, even in the viewing of a single picture. This is fully intentional, as we try to approximate *typical usage*.

Notice that 'typical usage' can hardly be enforced by imposing constraints, as that would be a self defeating 'improvement'. Of course, there are some implicit constraints due to the fact that students were sitting at a desk, so they could not put the samples on the floor, or look at them from a few steps away. However, no observer complained about the conditions, the task appeared natural enough to them.

3. Results

After conclusion of the experiment the collected responses were unscrambled and combined in a single data matrix. Each row is defined by a particular picture (numbered 1 to 10), each column by a particular observer (numbered 1 to 40 at Sassari, 1 to 19 at Cardiff), and each entry by a ternary choice (1 = 'hauck', or 2 = 'postel', or 3 = 'perspective').

Thus the data volume comprises 400 (Sassari) or 190 (Cardiff) ternary choices. In both cases the first singular value accounts for almost 1/2 of the variance, whereas the initial four dimensions capture more than 3/4 of the variance. The data can be analyzed in many different ways. Sorting the matrix immediately reveals excursions from mere randomness (Fig. 3). We discuss only what seems to bring out the relevant structures most easily and clearly. We present a frankly explorative data analysis since we have no particular prior hypotheses to test.

Perhaps the coarsest measure is obtained by counting mutually identical elements in the flattened matrix. The distribution turns out to be very uneven. The Hauck map is preferred most often. The distribution is Hauck 57%, Postel 23%, perspective 20% for the Sassari observers, and Hauck 53%, Postel 19%, perspective 28% for the Cardiff observers. In Fig. 4 we present pie charts. Apparently, the Hauck map stands out, whereas perspective projection and the Postel map are probably not very different (see below). The Cardiff group appears to have a somewhat larger preference for perspective projection than the Sassari group, but see below.

The relative standard deviations from the best fitting multinomial distributions (the default assumption) are 4.3% (Sassari) and 6.9% (Cardiff) for the Hauck, 9.1% (Sassari) and 15.0% (Cardiff) for the Postel, and 10.1% (Sassari) and 11.5% (Cardiff) for perspective. Given these spreads the two results, from Sassari resp. Cardiff, are mutually not significantly different.

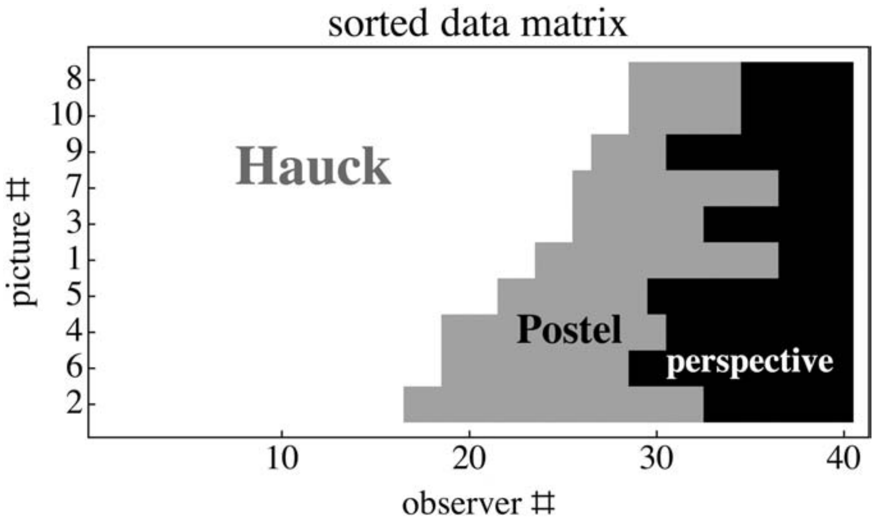

Figure 3. The sorted data matrix for the Sassari observers. There are 400 entries, they have been indicated as white: Hauck, gray: Postel, and black: perspective. The sorting is with respect to the frequency of preference for Hauck counted per picture over all observers. The sorted data matrix for the Cardiff observers looks very similar. (The pictures 1–10 can be found as Supplementary Images on the publisher's website.)

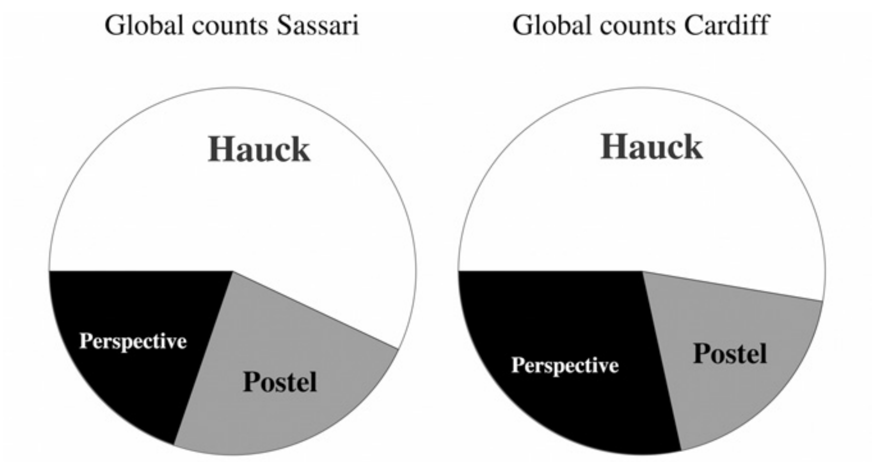

Figure 4. The distributions of the global counts. These may be taken as the most compact summary of the empirical data. However, see below for additional structure.

We conclude that the Sassari and Cardiff observers cannot be differentiated. Because there exist various differences between the groups (art/non-art, British/Italian, English/Italian instructions), we decided to proceed with the Sassari data for a more detailed analysis, since this comprises the largest homogeneous group. It is an important finding that these two rather different groups yield essentially equivalent results. Although mainly reporting on the larger group, we will comment on occasional differences found in the Cardiff group. However, such differences are never significant at the 5% level under the default multinomial assumption.

Although the default description would indeed be a multinomial distribution, a Pearson chi-squares test rejects the multinomial distribution ($p =$ 0.0005) as a model that explains the data. This is interesting, since it implies that there is more to mine from the data than just raw count ratios. It is a priori likely that statistics will differ for the individual pictures, as well as for the individual observers. This is also the reason we occasionally mention (small) differences between the groups. We pursue this below.

The covariance matrix is not isotropic, there are two non-zero eigenvalues, mutually differing by a factor of 2.7. The corresponding eigenvectors are in the directions of (Hauck)–(Postel *or* perspective), and (Postel)–(perspective).

In view of the ill fit the standard deviations from the best fitting multinomial distribution yield only a baseline. It is the perfectly random, *maximum entropy model*. In a perfectly *deterministic model* each observer would use only a single preference for any picture, in such a model the standard deviations would be zero. As we will show, the empirical situation lies between these extremes. The multinomial distribution is the perfect baseline to display the remarkable features.

A slightly more articulate view of the data is obtained by preserving either the observer, or picture distinctions in the counts. Thus, if one generalizes over pictures, one has three numbers per picture, such that the numbers add to 40 (the number of observers in the Sassari group). Such data are conveniently represented in triangular scatter plots. In such plots the preference for the Hauck map is immediately evident, as was to be expected (Fig. 5). However, especially in plot 5 top left, one sees a coherent cloud of points stretching from the Hauck vertex to the Postel vertex, and a few scattered points near the perspective vertex. The distribution suggests to us that observers hesitate between the Hauck and Postel maps, but are fairly certain in their aversion against perspective projection.

The scatterplots of Fig. 5 lend themselves naturally to a clustering analysis by thresholding (a standard cluster analysis yields the same result (see below), albeit at a loss of intuitive content). One simply finds items that exceed a threshold of 1/2 in the barycentric coordinates.

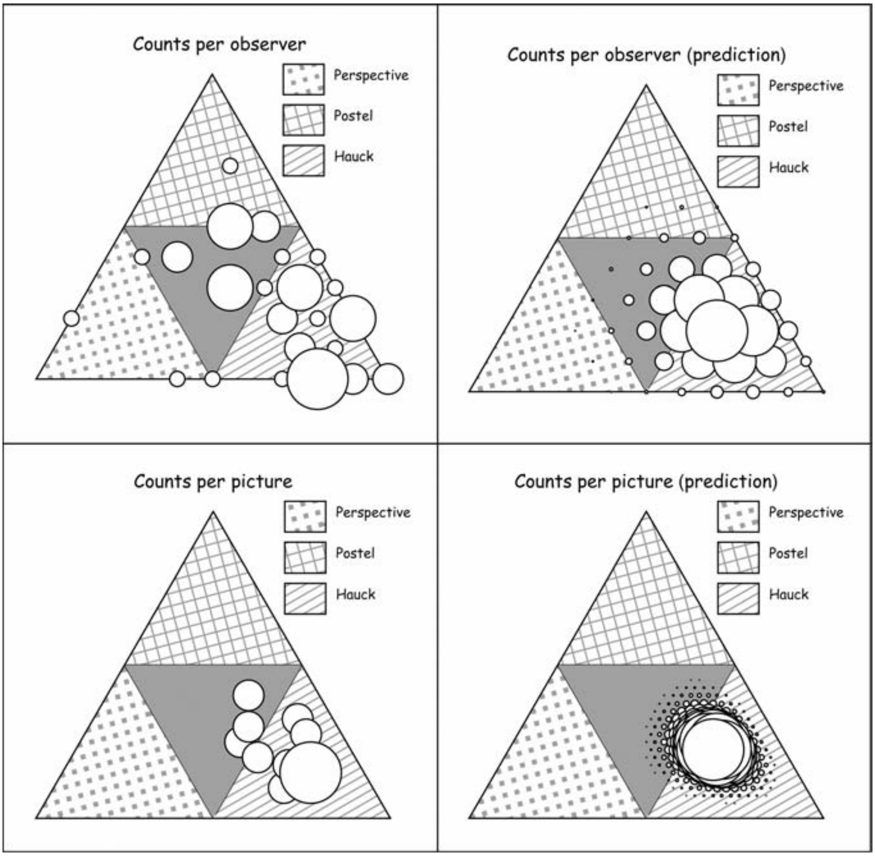

Figure 5. Triangular scatter plots of counts marginalized over pictures or over observers. The diameters of the dots are proportional to the frequencies. (Dot diameters scaled for fixed maximum diameter per plot.) Notice the difference between the prediction from the multinomial model and the empirical distribution.

We find that of the 40 observers, 23 prefer the Hauck map, one the Postel map, two the perspective projection, whereas the other 14 have no clear preference. Doing the same for the ten pictures we find that seven of them draw mainly Hauck map preferences, whereas the other three invite no particular preference.

The preference counts per picture for the Sassari and the Cardiff groups of observers are correlated, with Pearson correlation coefficients for the Hauck preferences being 0.37, for the Postel preferences 0.42, and for the perspective preferences 0.53. In the Cardiff group of 19 observers, eight prefer the Hauck map, one the Postel map, one the perspective projection, whereas the other nine have no clear preference.

A more principled method looks for deviations from a standard multinomial distribution for three types in the frequency ratio given by the global count. This model accounts for the mean of the data, but we already showed that it does not really explain the empirical distribution. Thus the outliers are likely to be of conceptual interest. We use the multinomial distribution as a baseline, whereas its outliers yield potentially insightful data.

Concentrating on perspective versus non-perspective preference for the pictures, we apply the binomial distribution. We find that only one of the pictures is an outlier at the 5% level. Thus our booklets are apparently not seriously biased. The picture outlier draws significantly too many perspective preferences. It is an architectural scene, a deep street view (Fig. 6, bottom right, discussed below).

It is also of interest to compare *observers*. Here we find many remarkable outliers. Testing against the binomial distribution at the one-sided 5% level we find:

- For the Hauck map there are 12 observers with a remarkable high preference, and five with a remarkable aversion.
- For the Postel map there are six observers with a remarkable high affinity, and none with a remarkable aversion.
- For the perspective projection there are six observers with a remarkable high affinity, none with a remarkable aversion.

Figure 6. The 10 pictures sorted with respect to the number of times (out of a possible 40 Sassari participants) they were preferred in perspective projection (the numbers are printed below the pictures). The sorting order is from left to right in the picture, with the righthand side drawing the highest perspective preference. Only the last picture (selected 12 times for perspective) is a significant outlier in the multinomial model. Notice that, intuitively, one has a gradation from open, often architectural scenes (most preferred) to more closed scenes, like interiors (least preferred). (We show the original photographs here, which are very close to the Postel rendering.)

- There are four observers that have both a remarkable high affinity for the perspective projection, and a remarkable aversion against the Hauck map.
- There is one observer that has a remarkabe high affinity for the Postel map and has a remarkable aversion against the Hauck map.
- In total 24 of the 40 observers are — in some way — outliers in the multinomial model.

Apparently, some participants have remarkably strong preferences or aversions. One of the participants preferred perspective for eight of the 10 pictures, whereas 12 observers picked the Hauck map for a least eight out of 10 pictures, with two picking it *always*. We conclude that the empirical distribution has many of the traits of the deterministic model. There are subgroups of observers with idiosyncratic preferences that very strongly deviate from the mean. Indeed, a cluster analysis, using Manhattan distance metric, yields two clusters, one with a preference for the Hauck map (26 observers), one with a preference for the perspective projection (14 observers).

The difference is also evident from a comparison of the covariance matrix for the empirical distribution, and the prediction from the multinomial model. The principal directions are not significantly different, but the principal variances are *very* different. In the direction of Hauck–(Postel *or* perspective) the empirical variance is only 0.6 times the predicted one, and in the direction Postel–perspective even 0.4 times.

Such results, considered together, seem to corroborate Hauck's (1879) informal observation that observers can be divided into what he calls 'primitive, or natural man', with a preference for other maps than perspective, and those who are 'collinearly infected' and will prefer perspective projection *any* time. Hauck reckoned most women to be in the 'natural man' category, obviously in politically doubtful taste nowadays. We cannot check that in our data, due to the marked gender imbalance (78% female in the Sassari group).

One might assume that the 'collinear infection' has spread even more widely since Hauck's time, because of the frequent exposure to photographic renderings in perfect linear perspective. [Even in Hauck's time lens distortion was practically insignificant. However, no lens is perfect (Bass *et al.*, 1995).] The main cue here is most likely the visible curvature of lines that are cognitively known to be 'actually' straight. The fact that some of our stimuli perhaps contain an overdose of architectural material perhaps biases our study towards the collinear disease — to stay in Hauck's terminology.

It is of some interest to check whether there is an intuitive 'trend' in pictorial content that relates to the preference for perspective. In Fig. 6 we show the pictures sorted with respect to the number of times they were preferred in perspective projection. The highest frequency is 12 times out of 40 (it is the image that previously was identified as an outlier at the 5% level). There appears to be an evident intuitive difference. Deep, architectural scenes, like city squares, or long streets, are more often preferred in perspective rendering than more closed scenes. It is hard to quantify this trend, because we cannot parameterize the photographs, but on the intuitive level the gradient is quite striking. It would certainly work as an effective heuristic.

The linear perspective and Hauck renderings can be compared (Fig. 7) for one of the images that was least often preferred in linear perspective. In this interior scene it seems (our informal observation) that in linear perspective one looks at the person on the couch as through a long 'tunnel', which evidently runs counter to the notion of 'presence'. It is interesting to study other differences. The perspective shows gross local deformations of detail, the Hauck doesn't, evidently something that might appeal to 'man of nature'. On the other hand, the perspective rendering shows expectedly straight lines as straight, whereas the Hauck rendering shows non-vertical lines as curved to various degrees, a feature that is abhorred by the 'collinearly infected'.

4. Conclusions

The overall conclusion is evident. It applies equally to the group of Sassari and the group of Cardiff participants. Of course, it only applies to wide angle (about 130° over the width) photographs, presented postcard-size at normal reading distance — such is the design of the study.

Our study is limited in several ways. There is no doubt that other parameters such as absolute picture size and viewing distance, the precise way in which the various renderings are compared, and so forth, are relevant. Moreover, our task was limited and perhaps ill defined. The latter cannot be circumvented, because a feeling of 'presence' is a *quale* and does not allow of an

Figure 7. At left an image in linear perspective rendering, at right the same image in Hauck map rendering. Both renderings show exactly the same image content over the mid-horizontal cross section. Of course, that implies that the extents over the mid-vertical cross section are very different. Notice the shapes of the floor tiles, and the curvature of the edge of the ceiling.

objective definition. The study reports frankly experimental phenomenology. An excuse is not in order, because it is all one can do. An obvious extension of the task would be to use a questionnaire (say ten questions on seven-point Likert scales) probing 'presence', 'immersion', 'depth', 'spatial envelope', 'spatial coherence' and various aesthetic dimensions, and so forth. That is one example of a follow up study that would be relatively easy to do.

The Hauck map is preferred in more than half of the cases, the perspective projection in about one out of four cases. The Postel and Hauck renderings are treated on similar basis, with a decided preference for the Hauck map, whereas the linear perspective projection is treated as categorically different. The distribution is only approximately multinomial, for there exist remarkably idiosyncratic preferences. Observers really fall into different categories. We have shown this for the Sassari group, but it also applies to the Cardiff observers, although — for this smaller group — the statistical resolution is less. The general agreement between the two groups indicates that our results have fairly general applicability.

We consider this to be a striking result. It reflects our informal observations, predominantly collected in interaction with artists and colleagues with an interest in the phenomenology of visual awareness. One of the authors — an artist — discovered that he intuitively 'painted in Hauck maps' (Pepperell, 2012).

The result is no doubt related to the informal observations by Von Helmholtz (1866) and Kepler (2000, orig. 1604) that they 'saw everything in front of them'. These eminent scientists, and remarkably keen observers, were — as scientists well aware of the scope of the human field of view, but they spontaneously noticed that their visual awareness did not at all reflect that. Helmholtz estimates his visual field to subtend about a right angle, although he *knows* it to subtend about a half-space. We have investigated this 'external local sign' over a large population of naive observers in the past (Koenderink *et al.*, 2009), and were able to affirm Helmholtz's subjective estimate fully. It applies to about three-quarters of the population. It is perhaps surprising that such observations are rarely discussed in the literature, because they give rise to astonishing errors of judgement, exceeding a hundred degrees in the judgment of spatial attitude (Oomes *et al.*, 2009). The reason is perhaps that contemporary vision science abhors phenomenology.

Intuitively, there appear to be two major reasons for the general preference for Hauck maps. One is that the center of the picture is stressed and the periphery attenuated as compared to linear perspective. Indeed, in the linear perspective renderings one often has a feeling of looking down a long 'tunnel' at the main subject matter. Thus perspective will very likely come out on top if one asks for 'amount of depth' instead of 'presence'. This 'distant look' naturally translates into diminished 'presence'. The above mentioned property of the Hauck map is shared by the Postel map. The other reason is that the verticals in the Hauck map are rendered straight, which is the major difference between Hauck and Postel maps. For some subjects this is irrelevant, for others curvatures look offensive and evoke an instant rejection. Such findings directly relate to various observations in art historical research (Baldwin *et al.*, 2014; Panofsky, 1925; Pepperell and Haertel, 2014).

According to Hauck, people who are collinearly infected will automatically reject *any* rendering that shows objectively straight lines as curved. Our results appear to at least partly confirm this informal observation. Some observers *always* prefer either Hauck or Postel maps, and a few almost singularly perspective projection. It is certainly the case that a minority of observers have a strong affinity for linear perspective, and a somewhat larger group an equally striking aversion.

As mentioned in our introduction, these findings have potential implications for various applications. We mention book illustrations, postcards, and handheld electronic devices. 'Presence' and 'impact' are not that far apart, thus advertisement illustrations would often gain by a well-considered choice of rendering. Of course, professional visual artists and illustrators have little need for our advice, since they intuitively create, or select images that 'work best'. It might well be of interest in computer graphics and the rendering of wide angle photographs though. In such cases a simple remapping would help to heighten the potential impact of the image for the larger part of the audience. It can be implemented automatically, since most digital images contain EXIF data revealing their field of view.

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