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Gross failure to utilise alignment cues in children's drawing of three-dimensional relationships

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Abstract. There are two major ways of classifying the development of children's attempts to represent three-dimensional relationships on the page. One is in terms of discrete drawing systems and the other is in terms of local decisions that have to be taken within more than one system. An observation is made which appears paradoxical from each of these approaches. Nonetheless, study of the observation reveals a systematic relationship with a systems approach. But this cannot be explained without extending the assumptions of a systems approach.

1 Introduction

1.1 *Systematic decisions in depth-drawing*

The drawings in figure 1 show how children represent a table top: as they develop, the shape alters dramatically (Willats 1977a, 1977b). In order to understand how a fixed scene can take different shapes on the picture plane it is necessary to treat the problem of defining shape in terms of the projective systems which could generate it. Dubery and Willats say that "Any projection system depends on the idea of straight projection lines running from points on an object to corresponding points on a flat surface. The type of projection system depends on the relationship of these lines to each other: whether they diverge, converge or run parallel, and the angle at which they strike the surface" (Dubery and Willats 1972, p 10). See figure 1 for examples discussed below.

Imagine a table with a variable light source behind it projecting an image onto a screen. If the source is an infinite distance away, perpendicular to the picture plane, then an orthographic projection results: the orthogonals are compressed to points as the light source (the projection point) gives rays which are perfectly aligned with the contours of the object which are perpendicular to the picture plane (the orthogonals). The perspective system results from bringing the projection point to a finite distance behind the picture plane, so, in these terms, the orthographic is a limiting case of linear perspective. The oblique system too has a projection point at infinity, but now it lies oblique to the picture plane. It is not possible to bring the projection point to a finite distance without inducing greater trapezoidal distortion in the picture than can conveniently be handled by a rectangular coordinate system which maps the canonical form of the object onto the picture, because all the angles and the relative sizes of the sides change. So the oblique system does not generate a family of

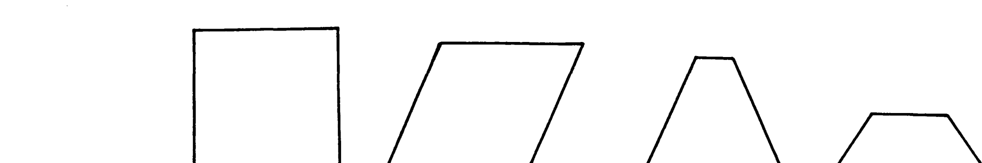

Figure 1. Five methods of representing a tabletop, ordered according to structural complexity of the projective-drawing system. From left to right they are orthographic, vertical-perpendicular, oblique, naive-perspective, linear-perspective.

projections in the way that the perspective system does (at least for the centre of the field of projection). The vertical–perpendicular system cannot be generated at all by manipulating the distance and horizontal displacement of the projection point.

These simple principles of projection enable one to classify depth drawings in terms of the formal complexity of the structural description for each of Willats' systems. They all are reducible to the extent to which scenic azimuth constraints (radial direction in the plane of depth) are represented by oblique lines in the picture plane, with special reference to the scenic orthogonals. There is no available competing account. Nonetheless, the approach has its weaknesses. It cannot specify the relative difficulty of different decisions taken during the sequence of drawing (Freeman 1980), and it cannot account for the fact that children can understand the azimuth uses of oblique lines in pictures (Jahoda and McGurk 1974) long before they can draw them for themselves. Finally, all advanced systems of drawing, those above the level of vertical–perpendicular, involve a *conflict* between different types of geometrical scaling, usually described as polar coordinate and rectangular geometry, as pointed out by Finch (1977), Willats (1977a, p 200), and Arnheim (1956, p 266). The systems approach cannot give prior weighting to how conflicts are resolved. These are all aspects of the general criticism that no process model is uniquely entailed.

1.2 *Local decisions*

The alternative approach is diametrically opposed to the previous one. It attempts to construct a process model from the start, and its basic assumption is that developmental change occurs primarily in the ability to produce linear inclination irrespective of the symbolic content of the picture. The work of Olson (1970) demonstrates unambiguously the difficulty young children have with diagonals.

If one considers just the vertical–perpendicular, oblique, and naive-perspective systems, and assumes that any individual child has access to all three, how many local decisions are needed in the transitions? The answer is that only one degree of freedom in the rectangular coordinates needs to be altered at each step (Freeman 1980, pp 255–256). The introduction of one acute angle at the left-hand side of the baseline would transform a vertical perpendicular into an oblique system, and the same move for the right-hand side would transform that into a naive-perspective system. The transition to linear perspective proper would require an alteration in constant-proportion scaling to give polar coordinate computation the precedence over rectangular that it takes with adult art. Accordingly, if we just concentrate upon the number of decisions needed for constructing acute angles, then the major systems used by children fall into a simple sequence. Perhaps, then, a model of system transition should also take into account performance factors which might militate against the construction of acute angles. It transpires that there is ample evidence for these. Freeman (1980, chapter 6) reviews much of the evidence. One problem is that much of the available evidence comes from studies of rather young children, below the age of seven or eight years (e.g. Naeli and Harris 1976; Bryant 1974). However, there are just enough data available to argue for two propositions: first, that the utilisation of alignment cues is a stable feature of subjects' production of linear inclination at all ages, and, second, that a bias towards making acute angles more oblique than they should be is also a general feature in all ages [see especially Ibbotson and Bryant (1976) for the error carried to an extreme in young children: a perpendicularisation bias]. The purpose of this paper is to present the first attempt at examining an unexpected error in drawing from the point of view of a general-drawing-systems and a local-drawing-decision approach.

1.3 *A paradoxical observation*

The starting point was an observation we made which is at first sight difficult to reconcile with either of the approaches outlined above. In figure 2 can be seen a drawing given to a ten-year-old child, consisting of a factory in perspective, a lamppost in the foreground, a road, and a horizon line: the child had to draw a lamppost on the horizon, followed by one in the middle ground. It is the horizon lamppost which is remarkable. What could lead the child to tilt it so dramatically?

According to a local-decision approach, it should be easy to draw it vertical. If any perpendicular bias were operative, then it could be drawn vertically on the horizon line. If nonsymbolic alignment cues were used, there are two nearby parallelism cues: the side of the factory and the side of the page. If a more distal alignment cue is needed, there is an in-line relation with the foreground lamppost available. So here is a case in which all factors should work together: a perpendicular bias, internal and external parallelism cues, and an in-line cue. Yet they do not.

Let us now take a systems approach. All systems are based on preservation of vertical and horizontal lines with obliquity being reserved for the orthogonals. A lamppost is not an orthogonal, so in itself the inclination cannot be attributable to a system. Therefore, if a systems approach is to be considered, one would have to extend its assumptions: the foreground lamppost does its size-distance scaling by intersecting the groundline of the factory: it 'points towards it'. This is a general aspect of all drawing systems above the level of vertical-perpendicular, that alignment for separate elements in the scene has to be achieved in the picture plane by preserving verticality whilst yet judging the distance relations according to the angle of intersection between verticals and obliques. Accordingly one can make a simple prediction: the phenomenon in figure 2 should be seen only in children who are above the level of vertical-perpendicular systems use because only they would use this alignment cue in *picture production*. Children in the vertical-perpendicular stage would only use orthogonal alignment cues, so should not be tempted into making the error. Experiment 2 of this paper tests the prediction.

However, it is now necessary to end by considering whether an extension of the local-decision approach could yield a testable prediction. All comparable examples of elicitation of tilt (e.g. the rod-and-frame test) work by identifying an extra alignment cue. All that can be done here is to look for extra alignment cues or sources of a perpendicular bias. For the former, there is the sloping roofline. For the latter there is the oblique baseline provided by the roadway adjacent to the foreground

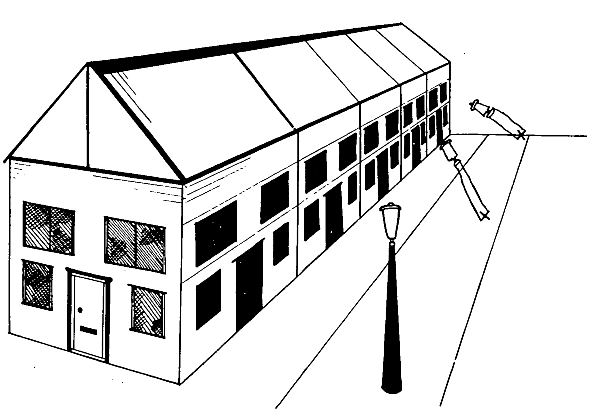

Figure 2. Picture given to a ten-year-old to draw in lampposts. Note the inclination of the one on the horizon.

lamppost; and this is the only truly local bias, since the roofline cue could conceivably be related to a system since it is a particular sort of depth-defining cue. Accordingly the first experiment now eliminates the roadway and its horizon line to see whether the horizon lamppost will be drawn vertically.

2 Experiment 1

2.1 *Method*

The subjects were eighteen children between nine and ten years of age. Each child was given two sheets and asked to draw a lamppost on the horizon. One sheet was as in figure 2. The other had the roadway and horizon line deleted. The drawings were scored for deviation from verticality.

2.2 *Results*

The variable error (degree of tilt irrespective of direction to the left or right) was remarkably similar for both drawings (9·4° and 7·0° for with-roadway and without-roadway, respectively) and did not even approach a reliable difference. The constant (directional) error was to the left. The mean for the roadway drawing was greater than for the one without (6·9° and 1·0°, respectively) but not reliably so ($t_{17} = 1 \cdot 46$; n.s.). This was because both drawings tended to induce bimodal performance: rather accurate performance plus discontinuous gross inclination, with six observations of tilt greater than 9° with the roadway, and three without the roadway.

Two conclusions follow. First, the initial observation cannot be due to the roadway and the horizon line. Second, performance tends to be discontinuous, with three-quarters of the tilts falling within 9° of the vertical, and the rest being extreme ($\overline{X} = 21° \pm 9°$). So this looks more like a discontinuous than a continuous bias, and as such more easily handled by a systems than by a local-decision approach. However, note that there have been observations of discontinuous error distribution in inclination in systems-free tasks (Freeman 1980, pp 176, 193) so the question must remain open. The next step is to repeat the study, and conditionalise the results upon the individual's preferred drawing systems according to a Willats classification. Since the roadway produced marginally more tilted drawings than the other, it was decided to keep the roadway in for the next study.

3 Experiment 2

3.1 *Method*

There were twenty subjects from a class of ten-year-olds ($\overline{X} = 10$ years 7 months). Each child was asked to draw a doll's table set frontally on the desk; then to copy a drawing of the table prepared in his own system, as well as one in the next system up; and finally to draw a radio set put on the table with its longer axis paralleling the picture plane. Then each was asked to draw the two lampposts to complete the factory-plus-roadway drawing.

3.2 *Results*

The drawings of tables and the radio were used to classify the children according to preferred system. They fell into two clear groups, with only three individuals being a little difficult to judge. Reference back to figure 1 will give an indication of each type of system next discussed.

3.2.1 *Vertical–perpendicular group.* This consisted of ten children who used that system in copying the toy table. They all copied one of our drawings in the same system accurately, and all failed to copy one of our drawings in oblique projection, rendering it again as vertical–perpendicular. They all again used solely perpendicular angles in drawing the radio set. The one individual added to the group, to make

$N = 11$, differed solely in trying to copy the toy table in naive perspective, but thereafter reverted to vertical–perpendicular for three drawings.

3.2.2 *Oblique group.* This consisted of seven children who used acute angles in copying the toy table and in a copying task, and in drawing the radio set. Two were added to the group, to make $N = 9$, who differed slightly. Both of them produced one of their four drawings in vertical–perpendicular, but managed even naive perspective for the rest.

The performance of each group was examined for horizon–lamppost inclination from the vertical. The results were very clear-cut. The oblique group performed with extreme accuracy, $\overline{X} = 4°$, with only one subject greater than 5° (at 17°). The vertical–perpendicular group tilted their lampposts, $\overline{X} = 23°$, with six of them greater than 5° (ranging from 13° to a massive 59°). The group difference was reliable beyond the 1% level. So it is mainly the vertical–perpendicular children who go in for an acute angle with the lamppost (the basis of the original observation) and the oblique children who go in for a perpendicular lamppost!

This obviously merits closer scrutiny, and therefore the additional information in the lamppost task was extracted for intergroup comparison. First, the inclination of the middle-ground lamppost was measured and compared with that of the horizon lamppost. The two groups' results were virtually identical here, with five in each group tilting the middle-ground lamppost more than the horizon lamppost, one in each group having identical inclination and the rest tilting the horizon one the more. Again, measuring the heights of the two lampposts gave virtually identical readings for both groups, in that the majority in each group made the middle-ground lamppost larger than the horizon one and the minority made it smaller (nine and two, respectively, for the vertical–perpendicular group, and seven and two, respectively, for the oblique group). But there was a reliable difference between the groups in the relationship between relative height and relative inclination. For six out of eight in the oblique group there was a positive association between the two: the larger lamppost was the more tilted. In contrast, eight out of ten in the vertical–perpendicular group showed a negative association: the larger lamppost was the less tilted. The six-to-two–two-to-eight contrast is reliable at $p < 0 \cdot 05$ by the Fisher Exact Probability Test.

4 Discussion

The tendency to tilt the lamppost is associated with subjects who use the vertical–perpendicular system. It is possible that a temptation to use one of the limbs of the predrawn x-which-marks-the-spot contributes to the phenomenon; but then the perpendicular bias should lead to lampposts simply tilted at 45°, and this does not occur as a modal tendency. Therefore it follows that such subjects cannot be described as being locked onto right angles, hence the confinement to the vertical–perpendicular cannot be attributed entirely to an inability to construct acute angles. This introduces a difficulty for the local-decision approach. There is, however, a precedent for this type of finding, if a more general view of the data is taken. The solution to a linear-inclination problem is to search for alignment cues for the target. Lines with an orthogonal relationship form a good basis for this, especially if the constituent lines fall along the favoured axial coordinates. Under certain conditions, though, it is known that the use of alignment cues can be interfered with grossly (Ibbotson and Bryant 1976; Bayraktar 1979) in the very same children who are otherwise acutely dependent upon alignment cues. This means that in any given task there are three analyses to be made. The first is to establish the phenomenon; the second is to enquire whether explanation is suited by a systems approach, and the third is to try to distinguish between the idea of performance breakdown or the idea that the children are still responding to an alignment cue, albeit a queer one. We now take up this last point, then return to the other two in order.

So not only do the two groups differ in their propensity to tilt the horizon lamppost, but have a different association between linear inclination and the size scaling that is the basis of depth drawing. For the oblique group, the results mean that size scaling is not interfered with by a temptation to tilt, but for the vertical–perpendicular group it is: the tendency to tilt the further lamppost lends to less accurate size scaling. There are other ways of discussing the data, of course, but this one has the virtue of being easily tested empirically.

We begin by focusing on the different relationship between linear inclination and size scaling in the two groups. The argument runs as follows. Suppose that both groups of children appropriately regard the oblique of the factory ground-line as the main axis of the figure. This is a systematic decision *above* the level of vertical perpendicular. They then scale their additional lamppost round this new axis. The less able group do so by taking up the decision that they will need for their next highest system, oblique projection, by being tempted towards a perpendicular bias for the lamppost in relation to that axis (treating the acute angle as reversible, in a Piagetian sense). This then induces less size scaling. The oblique group also select that main axis, and try to use it for size scaling, being unaffected by any residual perpendicular bias because they understand that the obliquity is fully used up in calculating obliquity as representing orthogonality plus depth. These suggestions are easily tested by giving different types of picture completion (e.g. by providing the two lampposts and asking for the roadline to be drawn). The argument accords with the use of main-axis definition by Sutherland (1979). However, it also points to the major weakness in all current approaches to the symbolic representation of depth: the systems approach of Willats (1977a, 1977b), the local-decision approach of Freeman (1980), and the computer-intelligence approach reviewed by Sutherland (1979) all base their analyses primarily upon the problem involved in scaling the parts of a single object in the scene. It seems that an extension to the relations *between* objects in the scene will need a new set of assumptions. The preliminary work has been done by Freeman et al (1977) in classifying drawing devices, and by Cox (1978) in identifying a verticalisation bias in rank-and-file drawing. The evidence is reviewed in Freeman (1980, chapter 7), but at present the available data do not provide enough prior criteria for handling the observation upon which this paper was founded. Without it, the problem of developmental transition between drawing systems cannot be theorised.

Finally, we return to a systems approach. The assumption made by this is that children are completing the drawing according to the system they currently have at their command. Therefore, it would have to be proved that a tilted lamppost accords with the symbolic content of a vertical–perpendicular system. This, in fact, corresponds to the analysis laid out at the start of the preceding paragraph: attempted construction of a right angle upon a redefined main axis of the figure instead of the horizontal baseline. There it was pointed out that such redefinition can only be done at a level *above* that of the vertical–perpendicular system. So how might this disparity be resolved? One obvious answer is that picture encoding is more advanced than picture production in the individual, so that the child might well employ an advanced coding for interpreting the picture and then employ a less advanced one for using cues in drawing on it. Such a notion has a respectable pedigree (reviewed by Freeman, 1980, pp 244–245, 256–258). The implication is simple: future research should identify a few more 'paradoxical' observations with underlying orderliness, then pit a systems approach against a local-decision approach by analytic separation of encoding from executive skills. Experimental psychology has many useful recipes for so doing.

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