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SHORT AND SWEET

On representation of solids: A note

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Abstract. Current theories of representation of 3-D objects assume that they are geometrical facsimiles of represented objects and, therefore, imply that various aspects of the representations are as concordant as are those of the objects themselves. Empirical data presented here question this as they show that subjects' choices of distinct views of objects are not mutually concordant. This being so, it seems unlikely that a facsimile representation of a solid yields a full description of the process of representation.

A theoretical representation of a 3-D solid should embody the relative sizes and positions of its parts—their concordance, thus ensuring its coherence. All theories of representation do accept this principle, some (eg Marr 1982 and Biederman 1987) do so explicitly, some (eg Tarr et al 1998), which give increased credence to particular aspects of a solid, by implication. The principle ensures that whatever the stance of the observer with respect to the solid, the solid is recognisable; it does not, however, ensure that it is equally recognisable from all stances.

A drawing of a solid does inevitably, in some measure, relate to its representation; if the representation of a solid is coherent, drawings depicting the solid from different stances should be mutually compatible.

There exists, however, evidence of systematic incoherence, related to perceptual processes of depictions of distinct features of a solid drawn from a single stance, which suggests that incompatibility of distinct views may prevail and, therefore, that either the representation is incoherent, or that several distinct representations are entertained simultaneously. Such incoherent drawings were obtained from students of engineering, who were required to draw a cylinder (Deręgowski and McGeorge 2008). Their drawings show the top face of an upright cylinder as a closer approximation to a circle than they show the bottom face. Toomela (1999) found that this manner of representation of cylinders is prevalent in children's drawings. The occurrence of this phenomenon in groups differing greatly in sophistication suggests that it is of perceptual origin.

These examples suggest incoherence of representation, which one would also expect to detect were the subjects required to recognise depictions of a solid with which they are familiar. This is the crucial notion; for if such incoherence does indeed occur, then it puts into question those theories of mental representation of solids that postulate that the representations consist solely of entities which are geometrically similar to the represented solids.

The present note endeavours to assess whether such questioning is justified.

To do so, four kinds of truncated prisms were used (see figure 1). Each kind was represented by three items. The four kinds differed by the shape of their bases (two had square bases and two had triangular bases) and in the manner of truncation (the sloping truncating faces had their greatest height either at one or two of the vertical edges). Their least heights had three distinct values and therefore yielded three distinctive variants.

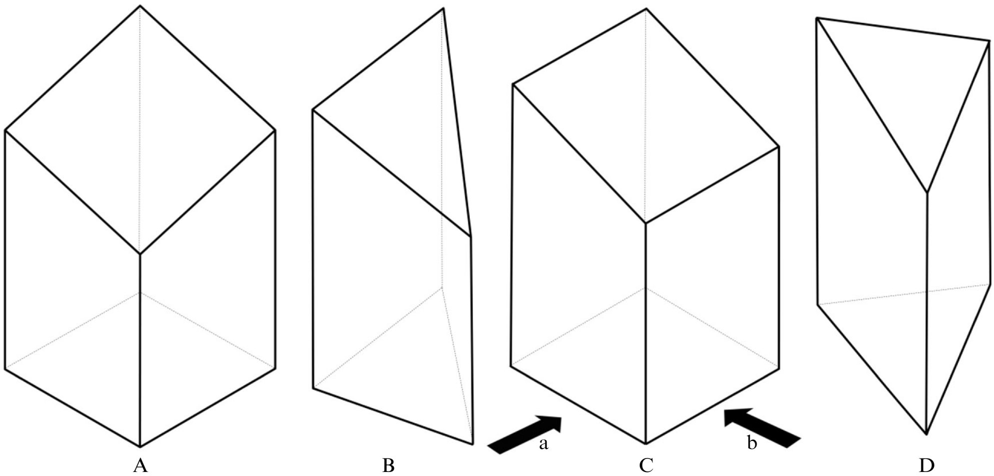

Figure 1. Examples of the models used. Arrows at model C show how the two orthogonal views were derived.

For all models, edges of the base measured 70 mm, and the longest vertical edge(s) 120 mm. The lengths of the shortest vertical edges were: A: 60, 70, 80; B: 80, 90, 100; C: 80, 85, 90; D: 80, 90, 100 mm.

The models were presented on a turntable, placed on the table at which the subject sat, for one full revolution of 40 s duration. Their depictions used as recognition stimuli were contained in response booklets. Two depictions of each kind of model were used. One of them (called here lateral) showed solely an orthogonal view of a trapezoidal side of the depicted solids and the other (called here frontal) an orthogonal view, such that the angle between the frontoparallel plane of the notional draughtsman and the plane of truncation was at its minimum. Figure 2 shows exemplars of the response figures. Arrows in figure 1 show how the two views, lateral (arrow a) and frontal (arrow b) would be derived in case of model C. For each kind of model, two booklets were prepared, one containing lateral, the other frontal depictions. Each page of a booklet presented six depictions showing in a random arrangement, depictions differing in the magnitude of the portrayed inclination of the truncated face.

Twenty-three second-year students of psychology [$M = 19$ years ($SD = 3.2$ years)] were randomly allocated either to respond to models A and C (ten subjects), or to respond to stimuli B and D (thirteen subjects). Three responses were obtained to each

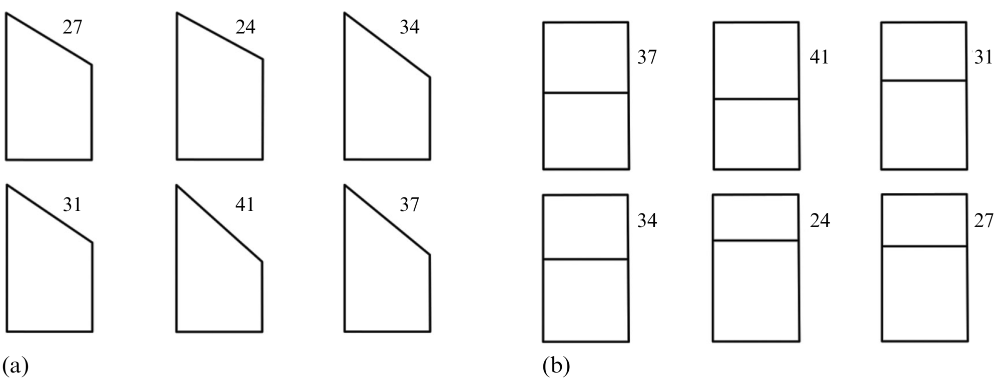

Figure 2. Pages from two types of response booklets showing (a) lateral and (b) frontal figures. Numbers next to figures show the heights (in mm) of the sloping faces as depicted. These measures were used in the analysis.

model when using each of the two versions of the response booklet. The order of presentation of the stimuli was random.

As an introduction, each subject was shown the moving turntable with an unrelated stimulus (a segment of a sphere) on it, and told that various solids would be shown one at a time on the turntable for one full rotation and immediately afterwards its depiction would have to be identified in an array presented in the booklet.

The height of the depicted sloping faces (see figure 2 above) of the chosen depictions was taken to be the response score and the sum of the three response scores to be the score obtained with a particular stimulus. These stimulus scores were used in analyses of variance of responses to each kind of model. The results for the repeated measures concerning the slope of the truncating plane (three) and the depicted aspect of the model (lateral/frontal) are as follows. There were significant effects for slope for all models (all ps < 0.0010) and significant effects of aspect (for three of the models ps < 0.001; for the fourth $p = 0.085$). There was no slope $\times$ aspect interaction. Paired comparisons of responses to the values of the three slopes of each model show the expected differences in eleven of the twelve cases (lowest significance level: 0.02). The deviant paired comparison showing no significant difference between the medium and the greatest slope obtains in data yielded by model A.

The significant aspect effect always results from the choices of frontal figures showing greater slope than the choices of lateral figures, as shown in figure 3.

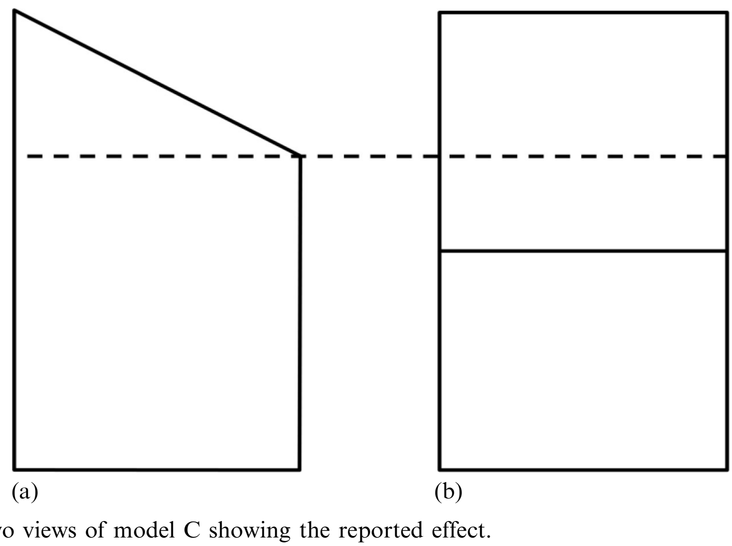

Figure 3. Two views of model C showing the reported effect.

The aspect effect, since it demonstrates the perceptual impact of shape constancy of inclined planar surfaces, is clearly consistent with the observations of Deręgowski and McGeorge (2008), and poses a problem as to the manner of the representation of solids.

In order to ensure their viability, the representations have to be coherent as, indeed, they are postulated to be by all the theories. The present data show, however, that subjects choose incongruent representations of distinct aspects of models, representations which, if combined, would yield incoherent entities. The perceptual origin of such incongruent representations is obscure. They may be derivations from coherent representations—in such case the mechanism responsible should form part of the theory of representation; or they could indicate that multiple representations are created, whereby each element is represented both as part of a coherent entity and individually—this would call for a separate mechanism responsible for selection of individual elements and for their representation. The latter solution carries the threat of a large number of mechanisms and is a reminder of Russell's (1961) observation that he found Occam's Razor a particularly useful device. None of the theories appears to address the issue although, as the presented data suggest, incoherence is inherent in the manner of representation, and any theory of representation which does not allow for this 'coherent/incoherent' duality does not appear complete.

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