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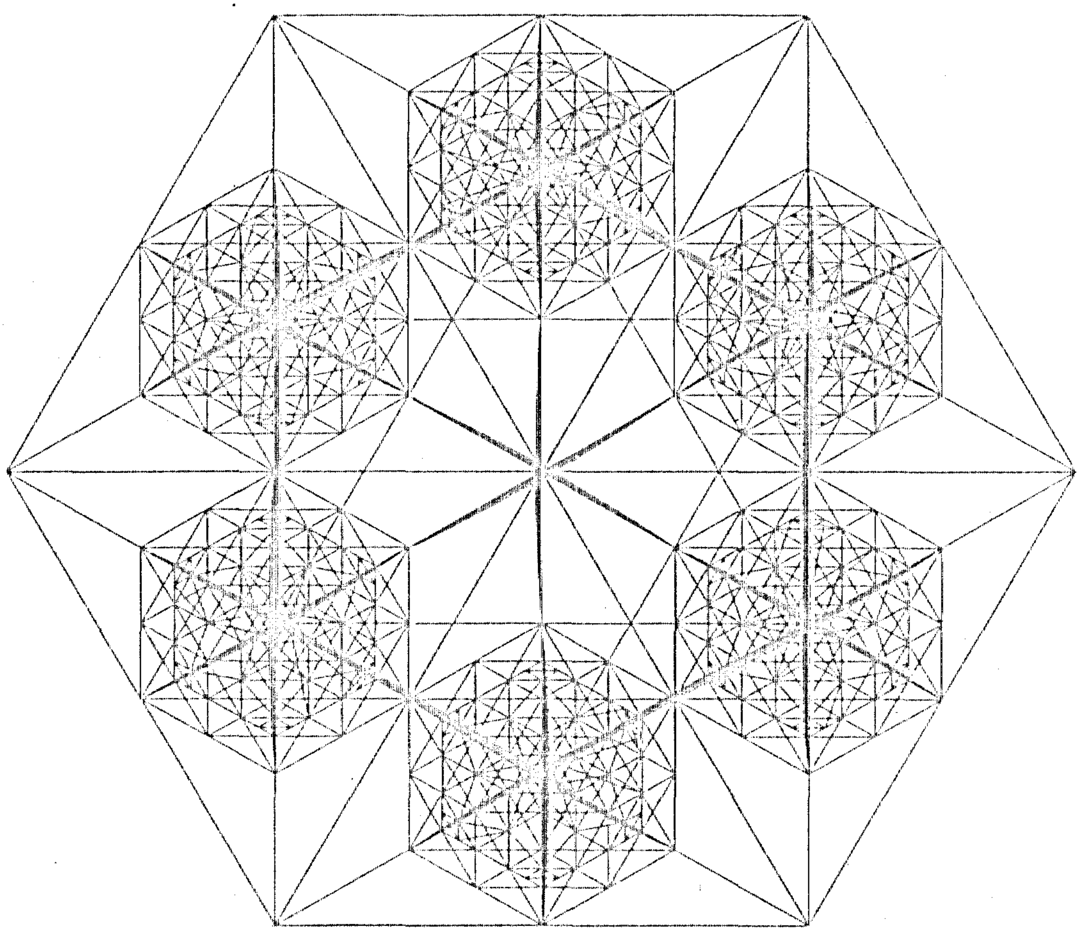

Large synergetical structure on hexagonal figure
Aerial view

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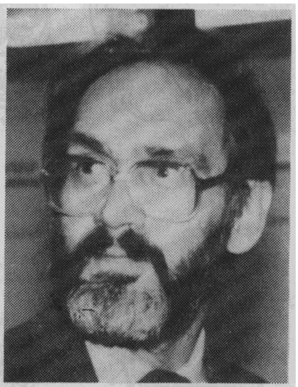
SYMMETRY: SCIENCE & CULTURE

PERCEPTION OF SYMMETRY: SOME PSYCHOLOGICAL OBSERVATIONS

Jan B. Deręgowski



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Abstract: *The paper presents a brief and eclectic review of psychological studies of human perception of symmetry. Special attention is paid to the enantiomorphic confusions common in children and to the influence of symmetry on configurations which although presented in a plane (e.g., as drawings) are seen as three-dimensional. The discrepancies between percepts derived from figures which are, in mathematical terms, cognate is also discussed.*

1. INTRODUCTION

This paper presents a brief and eclectic review of psychological studies of perception of symmetry; a topic which has attracted psychologists for a considerable time, and has led to a large number of investigations. These investigations have, as is so often the case, shown that the issue is much more complex than it appeared to be.

This complexity arises, in part, from the fact that, psychologically speaking, symmetry is not a relatively superficial characteristic of patterns and objects like, say, colour but that it is an essential characteristic which affects profoundly both their immediate perception and their memorability (Corballis, 1963; Corballis and Beale, 1976, 1983).

Practical implications of symmetry have been recognised long before psychologists attempted to analyse its perceptual characteristics. A glance at any handbook of heraldry demonstrates this cogently (Deręgowski, 1973, 1984). The essential heraldic designs are, it shows, both symmetrical and asymmetrical, but the former are overwhelmingly more common as, presumably, they are more memorable; furthermore there are no heraldic designs such that if they were placed side by side a symmetrical pattern would result. That is to say enantiomorphs of existing coats of arms are not used to design new coats of arms, presumably because enantiomorphs are easily mistaken for each other.

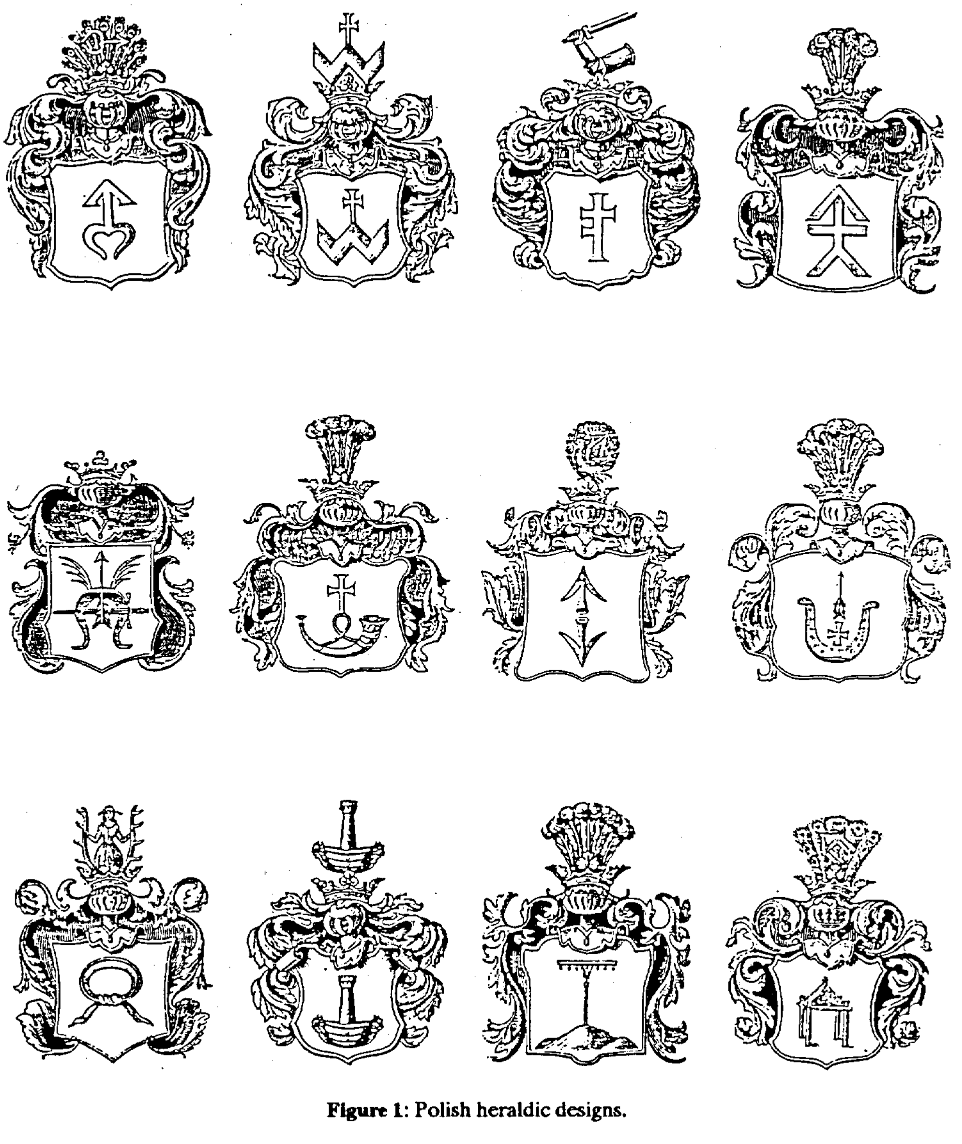

Figure 1: Polish heraldic designs.

Heraldic designs demonstrate therefore an awareness of two intrinsic and salient characteristics of symmetry; memorability of symmetrical designs and confusability of their constituent enantiomorphs.

They are when properly displayed, generally symmetrical about the median plane of an observer. This kind of symmetry is commonly called 'vertical symmetry' and I shall use this conventionally accepted term.

Let us now move forward into the era of experimental psychology and consider an experiment (Deręgowski, 1972, 1974) in which children were required to reproduce simple patterns using small wooden tiles; two of these patterns are shown in Figure 2.

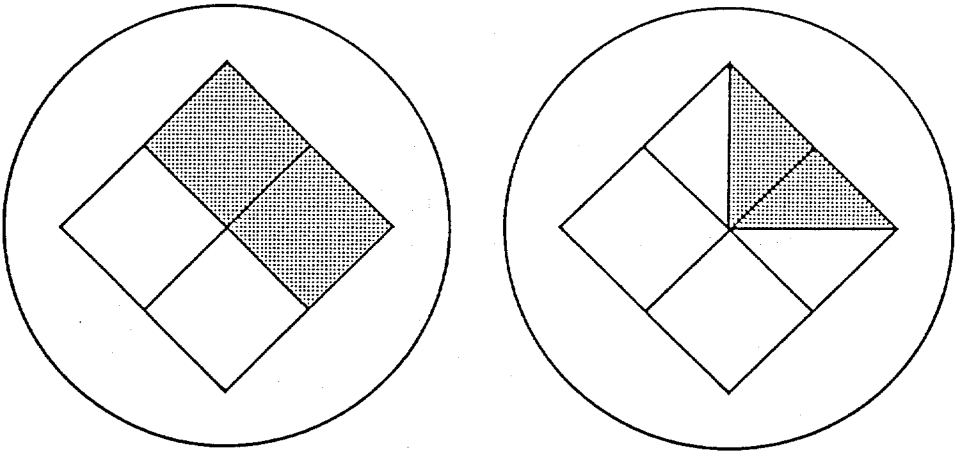

Figure 2: Simple patterns which subjects had to reproduce. Reproductions were often rotated so as to render than vertically symmetrical.

The results show that reproductions of such patterns which are symmetrical *per se* but which This rotation was further explored (Deręgowski, 1977) by obtaining a set of responses in a concatenated stimulus-response series, whereby a subject's response to a stimulus served as the next stimulus. The task was that of setting a pattern mounted on a turn-table at an angle identical to that of a displayed pattern. This adjustment was recorded and used for the setting of the next stimulus, and so on. The results (Fig. 3) show a clear asymptotic drift towards a vertically symmetrical setting of the figure.

A more startling demonstration (Deręgowski, 1971a) of the importance of the orientation of a symmetrical pattern to its perception is provided by comparing Figure 4*a* with Figure 4*b*. The figures are geometrically congruent; they differ only in orientation. Yet most people see the vertically symmetrical figure as flat but the congruent figure rotated through 45 degrees as having three dimensions. This and other similar demonstrations have led some psychologists (Welford, 1971; Deręgowski, 1976) to argue that vertical symmetry facilitates perceptual processing of the figure and that when it is abandoned the figure becomes difficult to process.

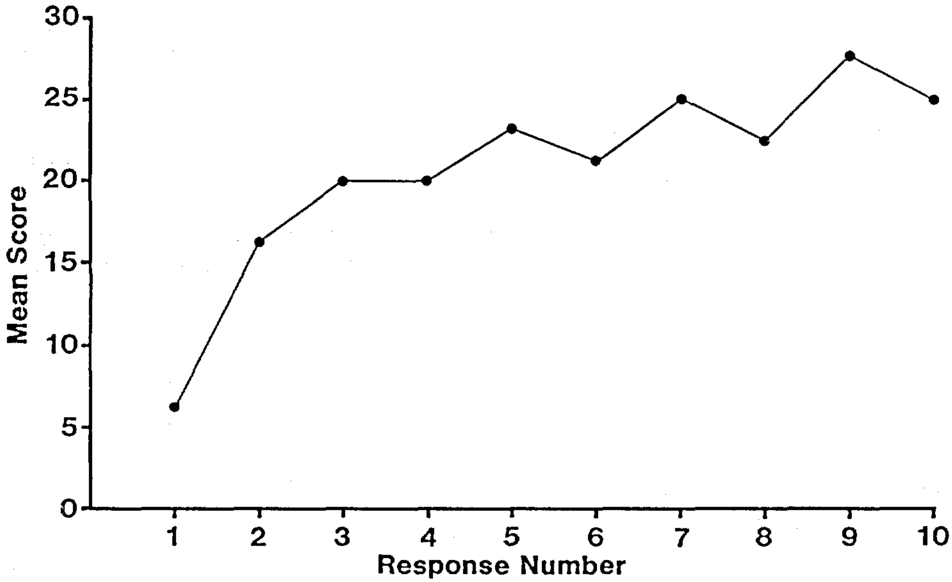

Figure 3: Plot of repeated reproductions of an asymmetrical pattern.

In order to process it as expeditiously as possible, the visual apparatus resorts to legerdemain and since no vertical symmetry in the plane of the figure is observable it resorts to an alternative interpretation and creates a three-dimensional figure which is symmetrical. (The 3D percept of Fig. 4*b* is symmetrical about a plane which bisects normally the member connecting the two square frameworks.)

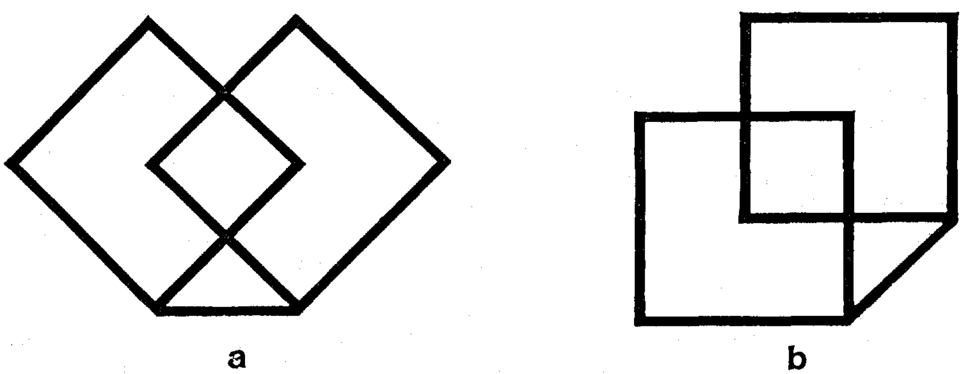

Figure 4: The same pattern in two orientations. **Fig. a** is seen as 2D, **Fig. b** as 3D.

These findings warn us that the perception of symmetry is likely to be even more complex when different types of symmetry are examined. It is indeed so. Perception of *horizontally* symmetrical figures (this term is defined by analogy with 'vertically symmetrical') differs markedly from vertically symmetrical. Horizontally symmetrical figures are more difficult to recall than vertically symmetrical figures. It is also, as Finke et al. (1988) demonstrated, more difficult to imaginarily complete a half of a 'horizontal' figure than a 'vertical' figure. Other immediately relevant recent studies are those of Enns and Howe. Enns (1987) has attempted to analyse how pattern goodness (and therefore symmetry) affects information processing. Howe's (1980) work explored relationship between goodness of pattern and symmetry. Even more striking differences between various kinds of symmetry are found when responses to skew-symmetrical and bilaterally symmetrical figures are compared.

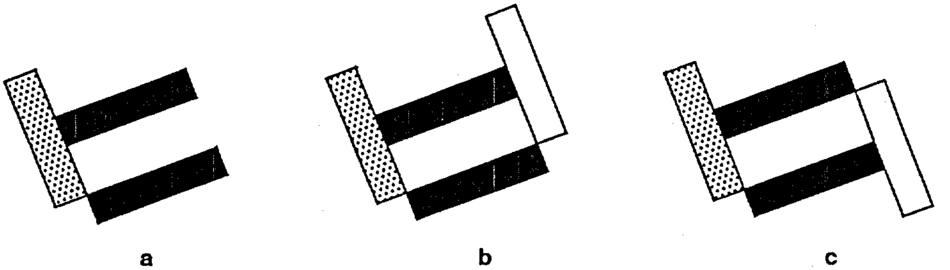

Figure 5: PATCO stimulus and the bilaterally symmetrical and skew-symmetrical responses.

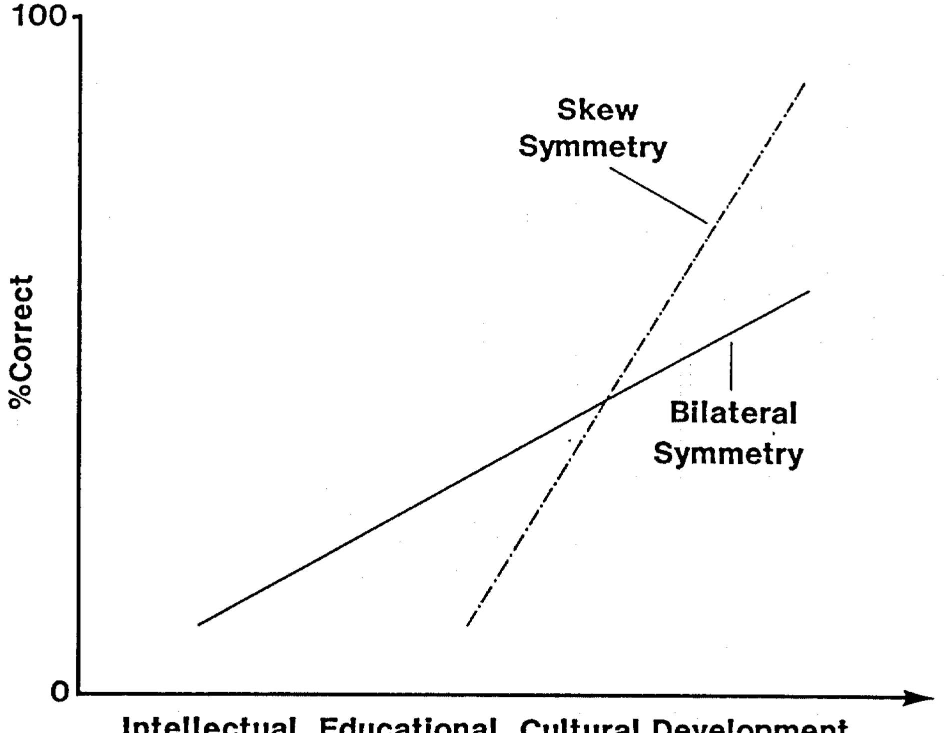

Figure 6: Schematic plot of PATCO test results obtained by Reuning and Wittman (1963).

Such comparisons were made by presenting subjects with PATCO figures. (The PATCO (Pattern Completion) test from which these figures come was developed in South Africa by Hector (1958, 1959); it has been successfully used by Fridjhon (1961), Tekane (1961, 1963) and by Reuning and Wittman (1963)). Each stimulus figure of the test shows an arrangement of three oblongs (Fig. 5*a*). The subject's task is to place a fourth identical oblong (with which he is provided in a form of a thin metal fiche) so as to create either a bilaterally symmetrical (e.g., Fig. 5*b*) or a skew symmetrical (e.g., Fig. 5*c*) pattern. The data obtained show considerable difference between the two tasks. Bilaterally symmetrical patterns are easily constructed even by subjects of relatively little sophistication whereas a distinctly higher level of sophistication is needed for skew-symmetrical responses (Reuning and Wittman, 1963). This results is schematically presented in Figure 6.

Clearly various forms of symmetry are not perceptually equivalent.

The effect of *vertical* symmetry upon perception is also vividly demonstrated by restructuring of slightly asymmetrical patterns. A classical figure used for that purpose is that of a human face (Abraham, 1934 and Lindzey, Prince, and Wright, 1952). Human faces are, approximately, symmetrical and such asymmetries as they have normally pass unnoticed; this does not, however, mean that a mirror image of a face is readily mistaken for the face itself. Asymmetry of a face becomes startlingly apparent in derivative faces constructed using only one of the pseudo-enantiomorphs. When this is done (as in Fig. 7) pictures of two distinctly different faces are created, one of which looks much more similar to the original face than the other.

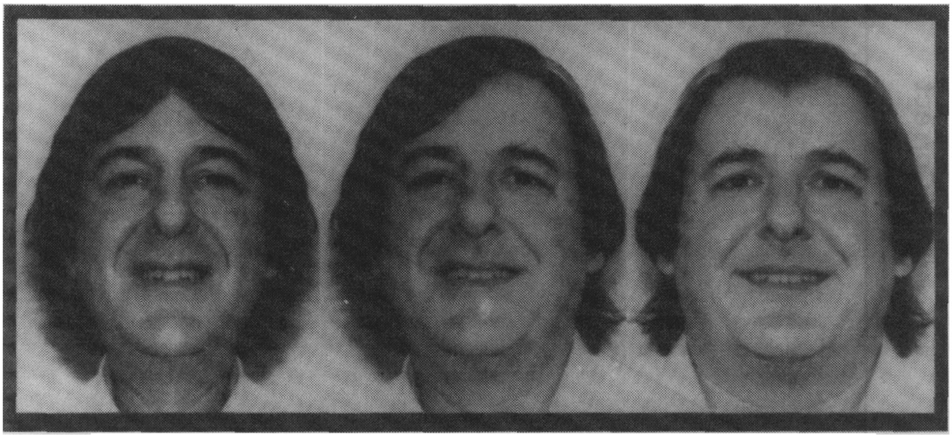

Figure 7: A face and two derivative faces constructed using pseudo-enantiomorphs.

This phenomenon initially led to some excited if probably misguided speculations about the two sides of a face representing different aspects of an individual's character. For example, it was put forward that the right side represents those traits of a person which he exhibits daily and the left side those traits that are normally hidden. Wolff (1942) who espoused this idea reported the following protocols regarding the faces shown in Figure 8. The first photograph is that of Wolff's patient; the next is constructed using the right pseudo-enantiomorph and the last is constructed using the left pseudo-enantiomorph.

Figure 8: Facsimiles of three faces, one real and two constructed, discussed by Wolff (1942).

Wolff comments upon the pictures in the following manner: The first picture "is that of a motion picture scenario writer. Her pose in the original picture already impresses one as being somewhat affected. The 'part' which this woman plays constantly in her daily life, the role of a film diva, in imitation perhaps of a Greta Garbo, is expressed even more clearly in the picture" composed by using the right pseudo-enantiomorph. The picture composed by using the left pseudo-enantiomorph, however, "reflects this woman's hidden nature, disclosing that she is actually a maternal type".

I am not sure that most would agree with any of these statements, and particularly with the last but it is indisputable that the pictures are strikingly different.

Subsequent studies (McCurdy, 1949) have clarified the somewhat mystifying statements just adduced, by showing that generally the face composed by using the right pseudo-enantiomorph is seen more like the original face simply because the right pseudo-enantiomorph is generally projected onto the observer's left visual field and hence processed by his right hemisphere. It is therefore processed by the hemisphere which is normally, in right-handed people, better suited for mediating such visual information and is mainly involved in processing such information.

The emergent percept is therefore, as always, not solely the result of particular stimulus (particular facial features) but also of the anatomical make-up of the observer.

2. ENANTIOMORPHIC CONFUSIONS

Close relationship between enantiomorphs which results in such striking composite faces is also at the root of a much more commonly observed phenomenon. Some people, especially children, confuse enantiomorphic pairs of letters such as **p** and **q** or **b** and **d**, as well as other analogously related patterns.

This problem is often studied by presenting an observer with two plaques bearing the enantiomorphic patterns telling him that one of the patterns is 'right' and requiring him to point to that pattern. (For a review of early studies of discrimination learning see Fellows, 1969). Obviously on the first presentation the observer can only guess. He is told immediately whether his guess was correct or not and presented at random with the next arrangement of the same two plaques. This next arrangement may be either identical or different from the first. He guesses again and is again told whether he was right or not, and the cycle is repeated till the observer makes a predetermined number of consecutive correct responses, and can therefore be said to have learned to discriminate between the two patterns (the number of presentations required to reach this criterion provides a measure of the difficulties that he has experienced), or till the trial is abandoned as no evidence of learning appears. Figure 9 illustrates initial steps in hypothetical trial runs for four patterns. It also shows the number of trials-to-criterion obtained under each condition with American children aged about eight and a half years by Rudel and Teuber (1963). Serpell (1971) replicated and extended this study on Zambian children.

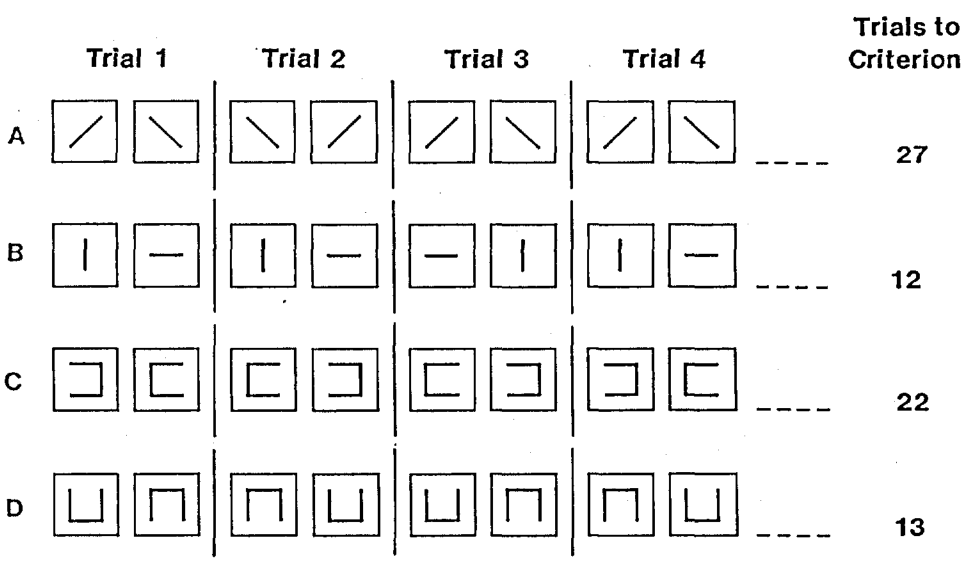

Figure 9: Illustration of the first four trials from discrimination learning runs involving different stimuli. The average numbers of 'trials to criterion' needed by American 8 ½ year old children are shown.

Another study (Deręgowski and Ellis, 1974) involving a similar procedure and Scottish children used two patterns shown in Figure 10.

Learning to discriminate between the symmetrical patterns (which when presented formed a skew-symmetrical array) was found to be much easier than learning to discriminate between asymmetrical patterns (which when presented formed a vertically symmetrical array). This clearly shows that the mere fact that the two figures are enantiomorphic is not the only factor determining the difficulty of the task.

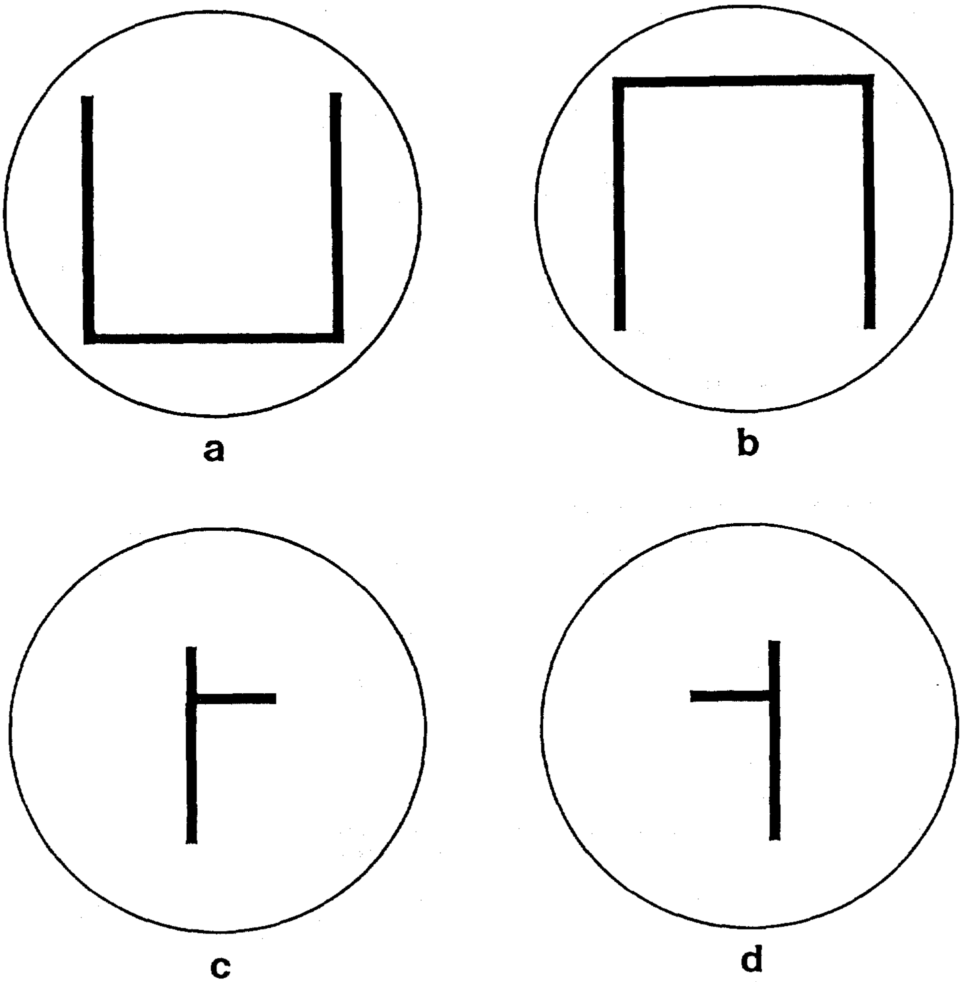

Figure 10: Patterns used in discrimination learning trials by Deregowski and Ellis (1974).

Nevertheless interesting and noteworthy arguments have been made (Attneave, 1954) that the ease with which symmetrical patterns are learned and remembered shows that such patterns are redundant; the redundancy deriving from the fact that one enantiomorph suffices to convey all the information about the structure of the figure, although it clearly does not convey any information about the location of the other enantiomorph.

The evidence obtained (Locher and Nodine, 1973) by observing eye movements of people looking at symmetrical and asymmetrical patterns supports this view. As shown in Figure 11 when examining a symmetrical figure the consecutive fixation points of the eye tend to only one half of the periphery constituted of the two enantiomorphs – not so when examining an asymmetrical figure, where the entire periphery is scrutinised.

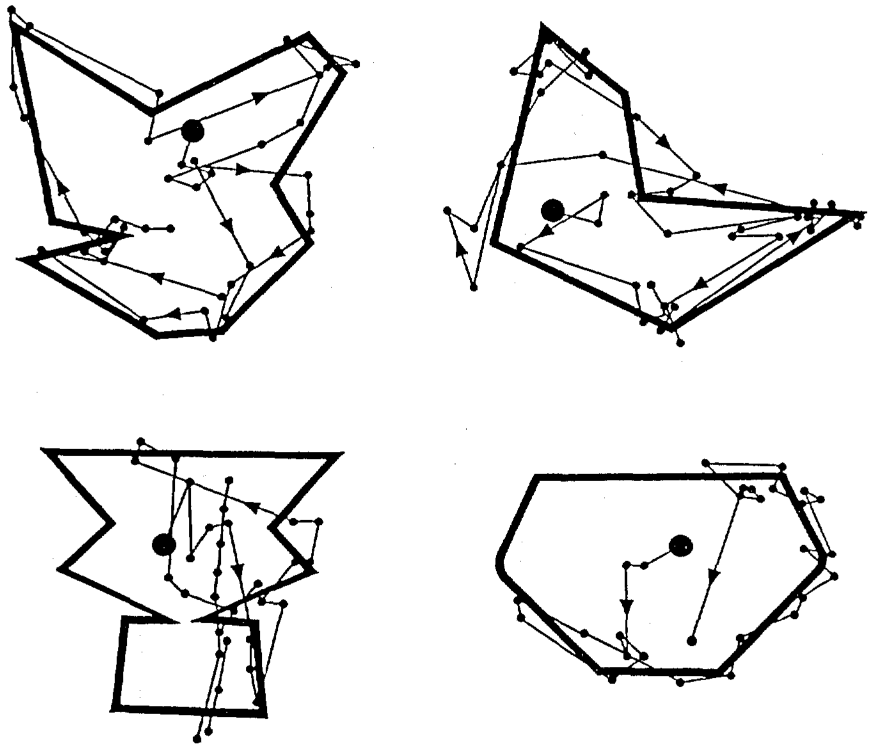

Figure 11: Patterns of eye movements made in response to symmetrical (top row) and asymmetrical (bottom row) patterns (after Enns, 1987).

However, as an experiment involving reproduction of simple matrices (Deręgowski, 1971b) suggests, it would not be correct to conclude that vertically symmetrical arrangements are better recalled because they contain half the information contained in corresponding asymmetrical patterns. If this were so then repeated patterns such as '**pp**' would be as easy to remember as the corresponding symmetrical patterns such as '**pq**'. This is not so. The symmetrical patterns are remembered significantly better.

A simple explanation of the phenomenon may be as follows. The relationship between the enantiomorphs in the symmetrical pattern is such that one of them has to be transformed (flipped over or rotated) to yield a geometrically congruent unit, and such a transformation is not required in the case of 'repeated' type patterns. The overall arrangement of a symmetrical pattern is such that the identification of the constituent units is easier than it is in the case of a corresponding repeated pattern, and this facilitation more than compensates for the necessary perceptual transformation.

Such a bipartite explanation of the superiority of symmetrical patterns is supported by a simple pilot experiment involving irregular heptagons. An observer was presented with a stimulus figure on a screen for a brief period. The figure disappeared and after a short interval three enantiomorphs of the stimulus figure appeared in a random array, a 'vertical enantiomorph', a 'horizontal enantiomorph' and a 'skew enantiomorph' (see Fig. 12). The observer was required to indicate which of the three figures was most like the initial stimulus. The choices made by adults (and therefore perceptually highly sophisticated observers) showed no significant difference between the first two enantiomorphs, both of which were more frequently selected than the 'skew enantiomorphs'.

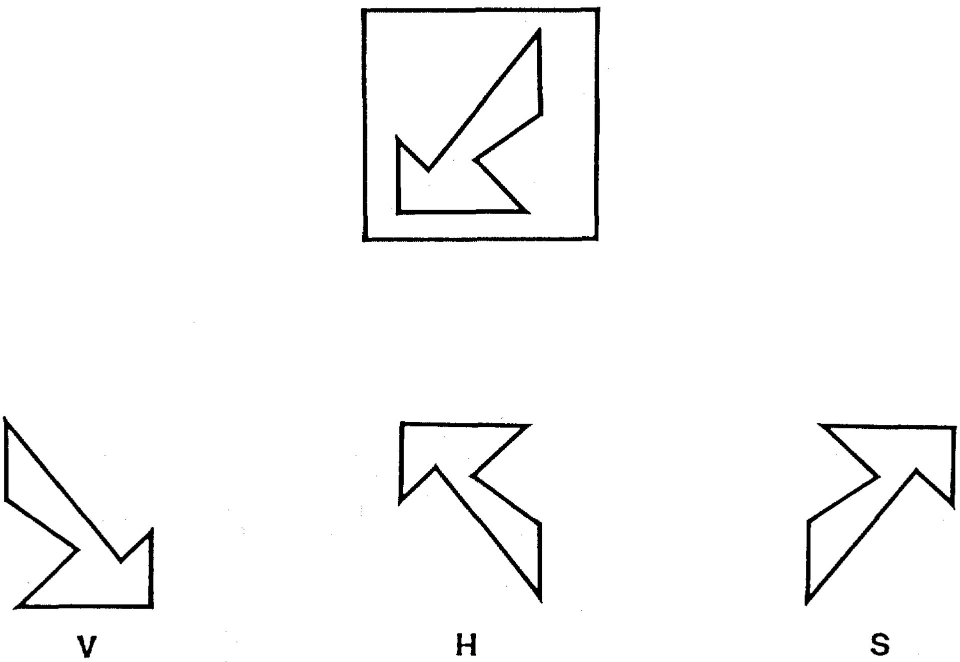

Figure 12: A stimuli and its three fundamental enantiomorphs: vertical, horizontal, and skew.

The well documented difference between ease of recall of vertically and horizontally symmetrical patterns derives therefore not from the difference in difficulty of seeing vertical and horizontal enantiomorphs as identical with the original stimulus, but from the difference in difficulty of detecting vertical and horizontal axes of symmetry and therefore of identifying the enantiomorphs. The stronger such identification, it appears, the more resilient the percept derived.

Patterns can, this suggests, be ranked as shown in Figure 13. The first pattern is asymmetrical, and is followed by a skew symmetrical, a horizontally symmetrical, vertically symmetrical and doubly symmetrical, in this order, the memorability of patterns increasing with their position on the list.

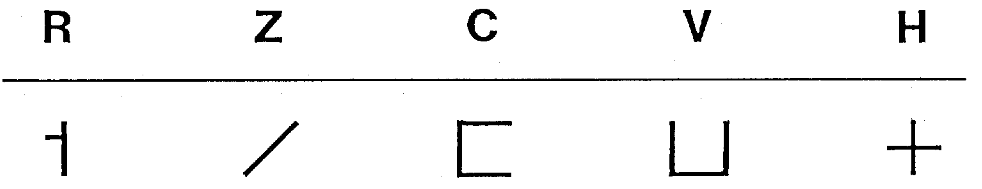

Figure 13: Basic patterns, illustrated by letters and geometric figures.

"Big fleas have little fleas", and when such patterns and their enantiomorphs are used to construct larger patterns, such as shown in Figure 14, the discrimination between the elements will depend on : (i) the memorability of the element, (ii) perceived unity of the array, and will grow easier with the increase of the first factor and more difficult with the increase of the second. Therefore it will be easier, in a discrimination learning task, to learn to respond to '**b**' when it is presented in the '**bq** – **qb**' sequence than when it is presented in the '**bd** – **db**' sequence. The task is even easier if '**b**' is replaced by a vertically symmetrical and therefore more memorable '**u**' and the experimental sequence '**un** – **nu**' used.

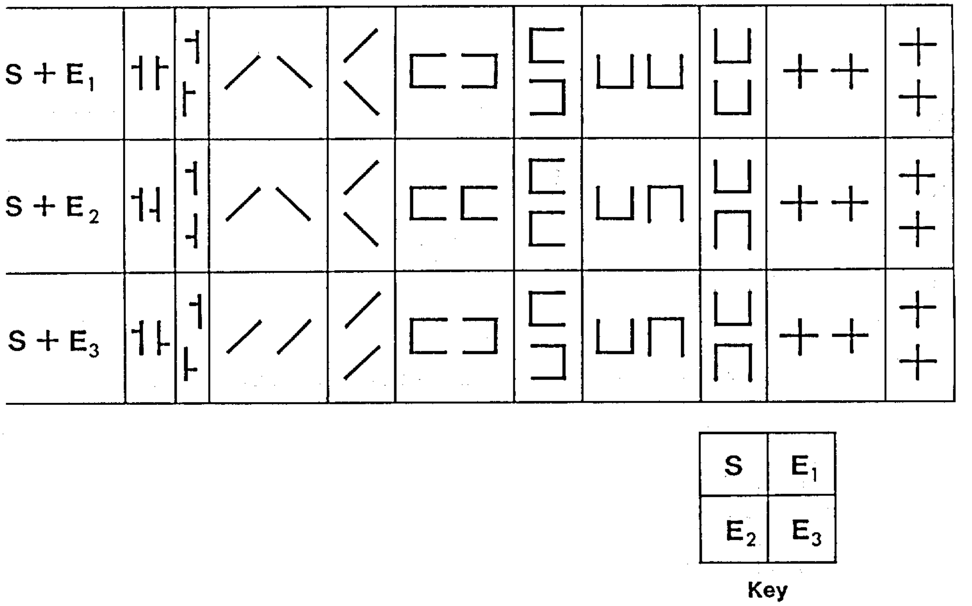

Figure 14: Basic patterns and their combinations.

3. THE THIRD DIMENSION

The impact of symmetry on perception of the third dimension in drawings has been mentioned earlier. It appears that asymmetrical patterns are more readily seen as having depth than symmetrical patterns of the same family. This applies even to very simple configurations of lines such as those shown below (Fig. 15).

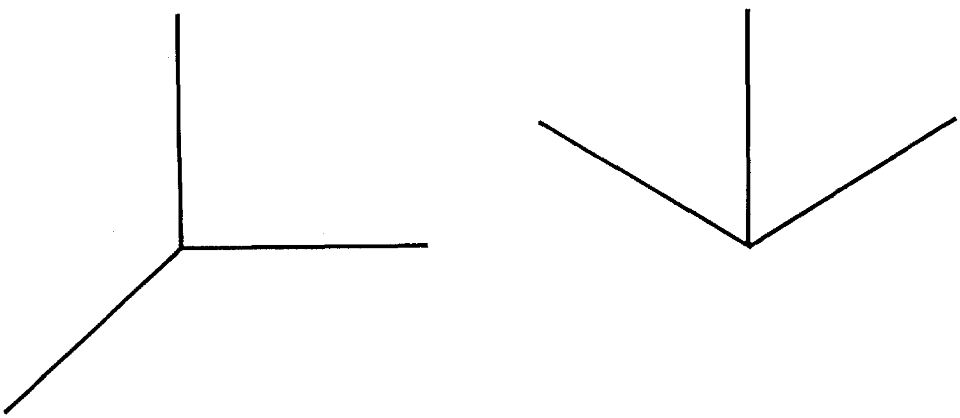

Figure 15: Two figures of which the asymmetrical appears to change significantly more when moved in the observer's fronto-parallel plane.

Both the symmetrical arrowhead and the inverted *y* figure appear to change with the change of angle at which they are viewed in a manner showing that they convey depth. These changes are, however, much more pronounced in the case of the latter, asymmetrical, figure. Indeed the asymmetrical arrangement presented here is derived from the arrangement of walls in Vermeer's 'The music lesson', a picture whose appearance changes dramatically as the observer walks past (Deręgowski and Parker, 1988).

The extent to which a figure conveys depth can be assessed in terms of Welford's 'Economy Principle' (Welford, 1971) according to which the likelihood of the 2D – 3D transformation is not determined by the nature of the flat figure but by the difference between the 'perceptual complexity' of the flat percept and of the three-dimensional percept which the stimulus figure evokes. The greater the 'simplification' brought about by the three-dimensional percept, the more likely it is to be entertained. The following experimental results (Deręgowski, 1976) support this rule.

Subjects were presented in turn with each of three drawings shown in Figure 16 and asked to build whatever they saw in them.

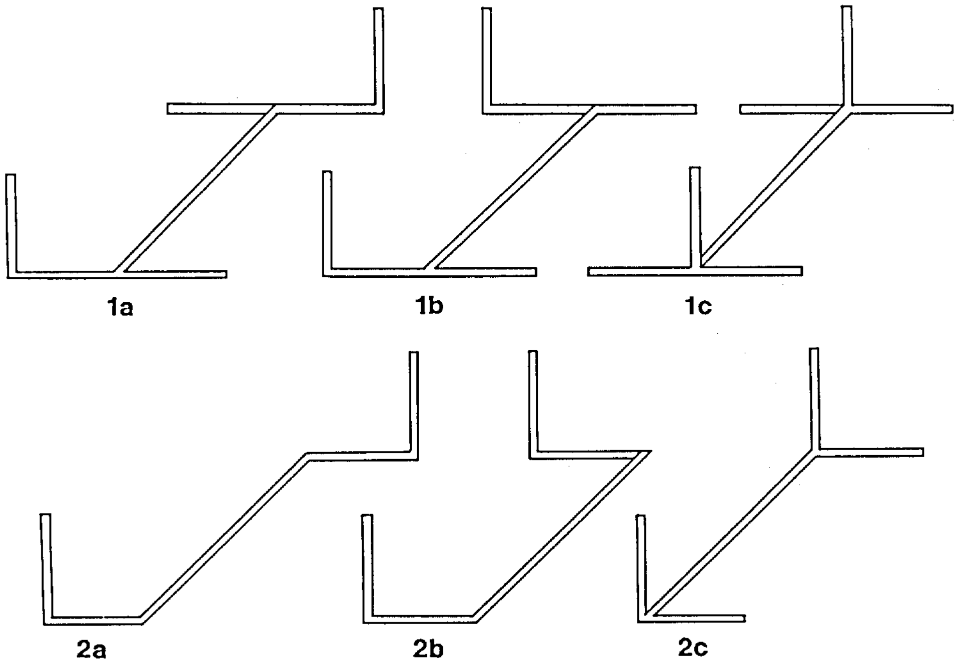

Figure 16: Six stimuli used in the construction task.

The ratios of the frequencies with which flat models were built to the frequencies with which clearly spatial models were built were as follows:

Fig. 1*a*	15 : 3
Fig. 1*b*	6 : 12
Fig. 1*c*	4 : 13
Fig. 2*a*	16 : 2
Fig. 2*b*	14 : 4
Fig. 2*c*	10 : 5

There are therefore clear differences in the frequencies with which the two types of models were built and the figures can be ranked in terms of decreasing 'three-dimensionality' as follows:

1*c*, 1*b*, 2*c*, 2*b*, 1*a*, 2*a*.

Considering the symmetry of flat stimulus figures (Fig. 16) only one of them, 2*c*, is symmetrical. It is symmetrical about an axis parallel to the longest member of the figure. All the others lack symmetry.

The corresponding 3D percepts are, however, much more differentiated:

(1) 1*a* and 2*a*: are skew-symmetrical about an axis normal to the longest member

(2) 1*b* and 2*b*: are symmetrical about a plane normal to the longest member

(3) 1*c* and 2*c*: are symmetrical about two orthogonal planes; one containing the longest member, the other normal to it.

The responses to the two sets of figures clearly fall in the sequence one would expect from consideration of symmetry of responses; '*a*'s are reproduced as 3D models least frequently and '*c*'s most frequently, as Welford's Principle of Economy would lead us to expect.

4. CONCLUDING COMMENT

This paper is concerned with the way in which the perceptual mechanism treats symmetrical and asymmetrical arrays. Possible physiological origins of the phenomena are not considered. It seems appropriate, however, to mention briefly the most widespread explanations of the 'symmetrical' confusions; that these result from the essential symmetry of the visual system. Indeed, conceptually this view is unassailable if it is taken to mean that the properties of the perceptual mechanism are such that presented with a pattern it automatically evokes not only the percept of the pattern, but also that of its enantiomorphs, and *not* that the mechanism itself is physiologically perfectly symmetrical. The strengths with which the pattern and its enantiomorphs are evoked are not expected to be equal. On the contrary the latter are expected to be weaker (see Deręgowski and Ellis, 1974). Such findings as those of Corballis, Miller, and Morgan (1971) are not, therefore to the contrary. However, unqualified acceptance of this notion would imply acceptance that all the enantiomorphs of a pattern are perceptually equivalent and this is clearly contrary to the evidence at hand.

Such equivalence is also implied in the explanation based on learning and often advanced in explaining children's difficulties in discriminating between, say, 'b' and 'd'. A teddy-bear we are told is recognised by a child as a teddy-bear whether it faces left or right. This demonstrates the fact that an object's orientation does not affect its essential nature and is not normally attended to by a child. Indeed it follows that if it were attended to, as the dominant feature of the object, a child would not recognise its teddy-bear placed in an unfamiliar orientation. Only in the highly artificial world of writing does a child encounter the signs wherein orientation is important. To this explanation the already noted objection of non-equivalence of enantomorphs applies in equal measure.

Notwithstanding this objection the explanation has been extrapolated (Gross and Bernstein, 1978) backwards in time and evolutionary origins of difficulties with discrimination between enantiomorphs have been postulated. The notion advanced is that it was, and still is, not useful for animals to distinguish between enantiomorphs. Two sides of an animal are naturally enantiomorphic (or approximately so) but it is not adaptive to see the difference between them; it is more adaptive to see the animal as one. Yet, even constraining this argument to vertical symmetry (and suspending for a moment the point about non-equivalence of various symmetries previously raised) it is difficult to accept it as valid, because, surely, it matters to a predator whether its potential victim is facing to its left or to its right. It also matters to the potential victim, perhaps even more so, whether the predator is facing to its right or to its left.

There seems therefore to be no readily acceptable grand 'ground' theory concerning the causes of the special treatment of symmetrical patterns by the human perceptual mechanism, but some aspects of such treatment are well documented and some very modest theoretical speculations have been advanced.

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