# Visualizing the possibilities

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Since I am in general agreement with Johnson-Laird & Byrne (JL&B)'s approach and find their experiments convincing, my commentary will be limited to several suggestions for extension and refinement of their theory.

**Images and Models.** The distinction between *models* and *images* is treated briefly in JL&B (pp. 38, 93, 140), but four differences are described in Johnson-Laird (1983, esp. ch. 8). I'll argue that the distinction better treated a matter of degree than of kind.

First, Johnson-Laird (1983, pp. 157, 165) defines images as models from a particular viewpoint, but this is inessential to the idea of an image. For example, the transformation of an image from an occulocentric frame to an object-centered frame is just one of many transformations it may undergo in being put into more abstract form. It seems arbitrary to treat differently images in different reference frames, since many of the same processes (e.g., rotation and translation of components) will be applicable to both of them.

Second it's claimed that models differ from images in that models can represent negation and disjunction whereas images cannot (JL&B, pp. 38-39, 196; Johnson-Laird 1983, pp. 423-424), but it is better to consider these "propositional tags" to be related to *intentions* toward perceptual and motor images. Here, by 'intention' I mean a functional relation to a component of a mental representation (including both images and models). Thus it has both *form* ('anticipation that', 'denial that', 'surprise that', etc.) and *content* (indicating its content); essentially a predicate plus a vector. The point is that intentions toward sensory images are closely related to intentions toward mental models.

For example, orientation toward the absence of an expected object is an intention, the content of which is the absent object. Thus, for perceptual images that are sufficiently abstract, there is a mechanism for representing the negation of a token within an image. Similarly, the presence of an unexpected object can produce an orienting reaction and generate an intention of the form 'this shouldn't be here'. Intentions to absent and unexpected objects are closely related to negations of components of mental models, which are intentions of the form 'this can't be here'. Other "tags" proposed by JL&B, such as 'exhaustive representation' (p. 45) are intentions corresponding to perceptual intentions, such as those of the form 'this is typical' or 'this must be here'.

Furthermore, just as we may judge an entire scene beautiful, threatening, or absurd, so an entire mental model may be the content of an intention to the effect that the entire model is impossible, incoherent, or unacceptable; this is JL&B's negation of an entire model, but it corresponds to intentions referring to an entire image. Disjunction is not a relation that has to be represented within images, since a disjunction of models is represented by multiple models in working memory (e.g., p. 52), and this works as well for images.

The third distinction between models and images is that the tokens of a mental model may not be accessible to consciousness (JL&B, p. 39), whereas, presumably, the tokens of an image are accessible. These "invisible tokens" may simply correspond to unattended elements in a perceptual image; that is, they are represented in the background, but are not the object of an intention. For components of both images and models, presence in conscious awareness is a matter of degree, with some elements being more salient because they are the objects of intentions. Although JL&B (p. 39) say, "What matters is, not the phenomenal experience, but the structure of the models," consideration of the phenomenal experience may benefit a more general understanding of mental representation.

Finally, JL&B cite as evidence in favor of models over images that there was no significant difference in performance of subjects on relational reasoning problems that differed in imageability (p. 140), but this is not supported by the experiments described, since all the relations they cite are conducive to visual reasoning. The relations 'in the same place as' and 'equal in height to' have obvious visual representations, and 'related to in the simple consanguineal sense' is simply visualized as 'in the same place as'. In fact, experiments to refute imageability are hard to design, since 3D space is so powerful a medium for relational reasoning. On the other hand, positive evidence for imageability comes from the results presented on p. 97: there was no significant difference in the performance on two-dimensional and one-dimensional problems. This suggests that we use our two-dimensional visual reasoning ability for both one- and two-dimensional situations, further evidence that models are abstract images.

In conclusion, the difference between images and models is not one of kind, but a matter of degree of abstractness: models correspond to images at very abstract stages in the sensorimotor circuit, where we find abstract reference frames, intentions of various kinds and a continuum of degrees of presence to conscious. Treating models and images as two species of the same kind may illuminate both and, in addition, expose the nature and role of intentions in cognition.

**Cultural Universals.** JL&B (pp. 207-209) claim that the culturally universal aspect of rationality is "the search for counterexamples." I suggest this be generalized as follows: (1) The function of comprehension is construction of an acceptable model of the stimuli, which is more than a consistent model in that it must be acceptable within a cultural context, and less than a consistent model in that it may contain culturally permissible inconsistencies. (2) The function of validation is to search for unacceptable models, which would cause a hypothesized conclusion to be rejected. Consistency is not a universal of logic, even within Western culture (Prier, 1976).

**Comprehension and Connectionism.** JL&B describe deduction as a three-stage process, comprising comprehension, description and validation (pp. 35-36). Comprehension is a kind of constraint satisfaction: finding the best (most acceptable) representation of the input. Connectionism suggests a mechanism for comprehension, since background knowledge and the stimuli define an "energy surface" with multiple local minima corresponding to acceptable interpretations of the stimuli. The interpretation chosen is the global minimum, but if it later becomes unacceptable, then the state (interpretation) can rapidly move to the next best minimum. Since the possible interpretations are, in effect, constructed in parallel, any necessary reinterpretation is more efficient (cf. multistability in perception). Multistability may also play a role in validation, since it provides a mechanism for generating alternate interpretations of the stimuli against which a hypothesized conclusion may be tested.

**References**

Johnson-Laird, P. N. (1983) Mental models: Towards a cognitive science of language, inference, and consciousness. Harvard University Press.

Prier, R. A. (1976) Archaic Logic: Symbol and Structure in Heraclitus, Parmenides, and Empedocles. Mouton.