Mental Image Reinterpretation in the Intersection of Conceptual and Visual Constraints

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Abstract

Psychological experiments indicate that mental images are more difficult to reinterpret than physical drawings. This difficulty is often attributed to various limitations of the mental image and/or mental image fading. However, experiments indicate that additional, non-visual factors might be involved. In view of this, we propose a model of mental image reinterpretation which focuses on the interaction between conceptual and visual information in the cognitive system. Simulations of this model support our hypothesis that reinterpretations are inhibited when the presently held interpretation is kept within focus of attention. Also, it appears that the mental image itself can inhibit the reinterpretation process in cases when potential new interpretations do not match well with the mental image.

1 Introduction

Mental imagery in general, and mental image reinterpretation in particular, has attracted much attention in the field of cognitive science, as it involves a highly debated phenomenon, namely that of seeing a visual image in the mind's eye. Alternative accounts for this mental experience range from the descriptive view that mental images are non-visual and non-functional [1,2], and the claim that mental images are by definition overspecified and therefore unambiguous [3], to the depictive view stating that mental images constitute *rich* repositories of visual information which can support alternative interpretations [4,5,6]. These views take opposite sides in what is called the imagery debate, and offer different accounts for how mental images are represented in the cognitive system, and whether they constitute a pregnant sounding board for non-visual processes or are non-functional by-products of these. Psychological experiments are far from conclusive: Mental images are pregnant enough to provide a basis for reinterpretation. Yet, alternative interpretations are discovered less frequently in a mental image than in the same drawing [7]. The issue is further complicated by the findings of Finke and colleagues, who report of cases when mental image reinterpretation is *not* difficult [8].

The long term objective of the present project is to suggest ways in which mental image reinterpretation could be facilitated, and thereby contribute to the design of computer systems which support the creative use of visual images. To this end, we need to map out the constraining mechanisms of mental image reinterpretation.

Much of the debate around mental imagery is focused on the alleged shortcomings of the mental image as such. We believe instead that successful reinterpretations arise through an interaction between previously stored conceptual knowledge *and* temporarily evoked visual information. To uncover the implications of this idea, we have developed a cognitive model of mental image reinterpretation. By varying central aspects of this model in a computer simulation, we hope to distinguish between model properties which propel cognitive processing towards the discovery of new interpretations, and those which obstruct the reinterpretation process.

2 A Model of Mental Image Reinterpretation

Among the psychological experiments conducted in this area, perhaps the most astonishing findings are those of Finke and colleagues, who report that the ease with which a mental image is reinterpreted depends on what type of interpretation is produced [8]. They found that in mental imagery, 'geometric' patterns were easier to discover than 'symbolic' concepts (Fig. 1). What is more, geometric patterns were detected as frequently in a mental image as in the same drawing. Symbolic interpretations occurred less frequently in mental imagery than during perception.

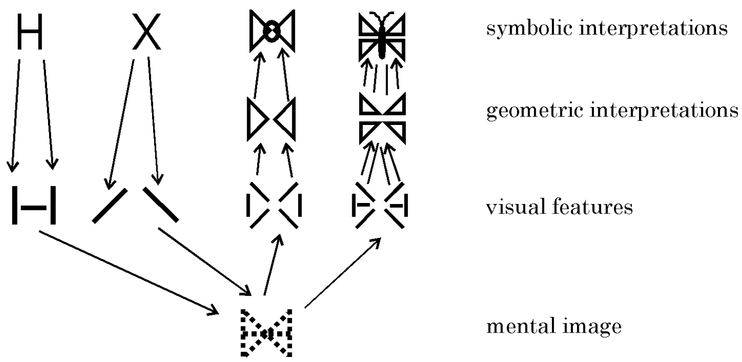

Figure 1. Alternative interpretations of a mental image generated from an upper case 'X' *mentally* superimposed on an upper case 'H'. The two interpretations in the upper right corner of the figure denote "bow tie" and "butterfly", and exemplify symbolic interpretations (using the terminology of Finke and colleagues, [8]). Alternative geometric interpretations would be, for example, "two large triangles" or "four small triangles pointing towards each other".

In general, reinterpreting a mental image, such as that in Fig. 1, involves the projection of long term memory structures into a visual medium, followed by a subsequent inspection of the image, and a re-association of the information contained in the image with new long term memory structures [5]. Based on a broad range of empirical evidence, we propose a model of mental image reinterpretation which centres on the interactive aspect of visual processing [9]. With a late selection view on selective attention as its central component, our model makes the following assumptions:

- Reinterpretations of a mental image arise in the abstract space defined by both conceptual and visual information.
- Focusing selective attention on the current interpretation has the effect of "cementing" the presently held interpretation. Symbolic interpretations are mutually more competitive than geometric interpretations, and are more exposed to suppression by currently focused competing interpretation.

According to the late selection view we propose [9], new interpretations will thus be suppressed by the current interpretation as long as a mental image is in use. This would be the case, for example, if the image is verbally described or mentally manipulated. Since a mental image is maintained via its present interpretation, reinterpretations will be suppressed as long as the mental image is maintained. It is therefore not clear whether mental image maintenance will improve reinterpretation probabilities or instead have a negative effect. A related issue is that of mental image fading: We expect this mechanism to have a negative effect on reinterpretation probabilities.

By simulating our model, we would thus like to answer the following questions:

1. How is reinterpretation probability affected when a currently held interpretation is attended to, in other words when the currently held interpretation is within the focus of selective attention?
2. How is reinterpretation probability affected by mental image fading?

Our model centres around the view that successful reinterpretations hinge on a balancing act between not getting stuck on the present interpretation, on the one hand, and not letting the mental image fade, on the other hand. This insight can be expressed within a model framework which captures the interplay between conceptual and visual information flow in the visual system. Our model is inspired by the comprehensive neurocognitive architecture for mental imagery which has been proposed by Kosslyn [5,10], and embodies the following set of basic assumptions:

- Processing in the visual system proceeds along reciprocally connected stages. The basic computational step which underlies visual processing involves the updating of neuron activation levels in accordance with the momentary activation level of connecting neurons. Unless actively sustained, neural activation throughout the visual system will decay.
- Image inspection and interpretation—be the image mentally or perceptually created—corresponds to a step-by-step propagation of activation levels from lower towards higher levels of processing. Mental image generation and maintenance, on the other hand, corresponds to long term memory structures being activated at a high level and this activation propelled towards lower levels of processing.

- Finally, we assume that geometric interpretations are based on a successful match with geometric patterns stored in visual long term memory, what we call the ‘pattern recognition subsystem’ (Fig. 2). In contrast, symbolic interpretations require that a mapping can be established between visual features in the mental image, on the one hand, and abstract conceptual structures stored in the associative long term memory, on the other hand.

3 The Simulations

In order to map out the causal relationships of individual model components to reinterpretation probabilities, we chose to work with variations of the original model. In these alternative models, central aspects of the proposed model were set to their “opposite” value. The simulations were run in a full two-level factorial design, which allowed every design decision to be cross-combined [11]. Although this simulation design is computationally expensive, it made it possible to trace the effect of individual model components in the resulting reinterpretation probabilities.

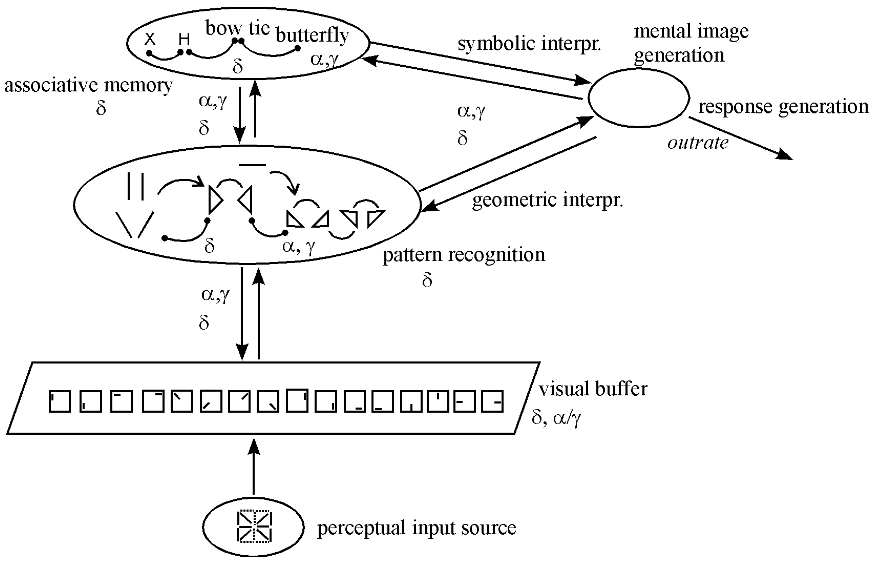

Figure 2. Subsystems and communication structure of the simulated system. The dynamic behavior of each subsystem is controlled via an activation decay parameter, and lateral connection properties. Connections of the same type, going in the same direction between the same subsystems are modulated by excitatory and inhibitory weights, α, γ, and a decay parameter, δ. Depending on whether a symbolic or depictive view on mental imagery is adopted, lateral connections within the two memory subsystems, associative memory and pattern recognition, are used to model either mutual competition or logical implication between interpretations.

To provide an unbiased basis for comparison between alternative models, a priori hypotheses about the underlying system structure were kept to a minimum. Alternative models were embedded in this system framework, and evaluated with respect to the reinterpretation probabilities reported by Finke and colleagues [8].

3.1 System Structure

The system framework is an interactive activation model [12,13,14], which is in essence a local connectionist network, written in Matlab (ver. 5.2). The system comprises of five subsystems organized into reciprocally connected stages of processing (Fig. 2). Two of the five subsystems, 'perceptual input source' and 'mental image generation' are used to initiate the system when the simulation is run in perceptual and mental mode, respectively. Each subsystem contains a number of internal nodes representing visual features, geometric patterns and symbolic concepts which can be evoked during processing. In the two higher level subsystems, pattern recognition and associative long term memory, the internal nodes are organized into a one-layer, lateral network of inhibitory or excitatory connections which reflects mutual competition or inferential implication between long term memory units.

Simulation proceeds in discrete steps, whereby the system's activation levels are updated from their previous state (for a detailed description of the underlying calculations refer to [14]). Activation levels of memory units were measured at predetermined points in time. Reinterpretation probabilities were calculated from the relative activation level of competing interpretations.

4 Results and Conclusions

Finke and colleagues [8] have shown that variables not directly related to the mental image, as such, must be involved in the general mental reinterpretation difficulties which has been previously observed by others. In particular, the fact that symbolic interpretations are more difficult to discover than geometric interpretations seems to suggest the presence of non-visual inhibitory factors.

We have theorized that one additional reason for why symbolic interpretations are more difficult to discover could be that they are more exposed to suppression when late attentional selection fixates the presently held interpretation. This notion seems to be supported by our simulation results. In particular, simulated reinterpretation probability for symbolic interpretations decreased when these interpretations were modelled to be mutually more competitive than geometric interpretations. On the other hand, suppressing the presently focused interpretation has a positive effect on reinterpretation probabilities, and this effect is more pronounced for symbolic interpretations.

In addition to these findings, our simulations show that reinterpretation can, in some cases, be inhibited by the presence of a mental image. Depending on how well a particular image matches the set of alternative interpretations, it will evoke some of these interpretations, and inhibit others. Similarly, the role of mental image fading seems not as clear-cut as we have hypothesized: It appears that mental image fading can have a positive effect on reinterpretation probabilities when the image does not match well with potential new interpretations. In conclusion, mental image reinterpretation seems to rely on *both* a good match with the mental image *and* the relinquishment of old conceptual structures.

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