Size constancy and the problem of perceptual spaces

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Abstract

The phenomenon of size constancy is defined as the apparent perceptual invariance of the linear dimensions of a seen object as this approaches the eye or recedes from it. It has been interpreted as resulting from the application by the brain of a size correction, made possible by the subject's apprehension of distance cues present in the image. We present several observations which, by dissociating accommodation from distance of the seen object and by suppressing the optic effects of accommodation on the visual image itself, show that this interpretation is incorrect, and that in fact the size correction of the visual image is a function of the central effort of accommodation, not of the distance of the seen object.

1. The problem

The perception of what we call the three-dimensional world is usually analyzed in terms of certain components like size, distance, depth and others, that are deemed independent from us and proper to it. What these descriptive notions mean in terms of the functioning of the nervous system, however, is not at all clear.

Consider for example 'size constancy', understood here as a causal disconnection between the perception of an object's size and its retinal image size. This phenomenon can be clearly seen by looking at one's hand at different distances, observation which reveals that although the linear dimensions of the retinal image of an object change with distance, its perceived size remains relatively constant. Conversely, in the Emmert effect, the size of a post-image, viewed against a screen located closer or further away than its source, appears respectively diminished or enlarged in a proportion that would compensate for the change in size of the retinal image of an object moved between those distances, making its dimensions appear constant. Thus, in 'size constancy' one has

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on the one hand a phenomenon that seems analyzable in terms of distance and size of the perceived object, and on the other hand a nervous process that occurs internally in the perceiving organism and which does not seem directly describable in these terms. What is the relation between these two aspects of size constancy? Traditionally its analysis has relied heavily on the first aspect, uncritically using the assumption that notions like distance and size reflect a direct grasping of features of the environment. (Thouless, 1931; Antis, Shopland, and Gregory, 1961; Gregory, 1963, 1966.) In what follows we shall question this assumption and analyze 'size constancy' as a neural process that takes place independently of the features of the environment, and we shall attempt to show how this approach permits new observations, and reveals a gross mistake in the traditional view of perception.

2. Gregory's theory

The most recent, elaborate and complete theory of the perceptual effects of 'size constancy' is that of Gregory (Antis, Shopland, and Gregory, 1961; Gregory, 1963, 1966). In discussing illusions such as the Ponzo illusion, he says:

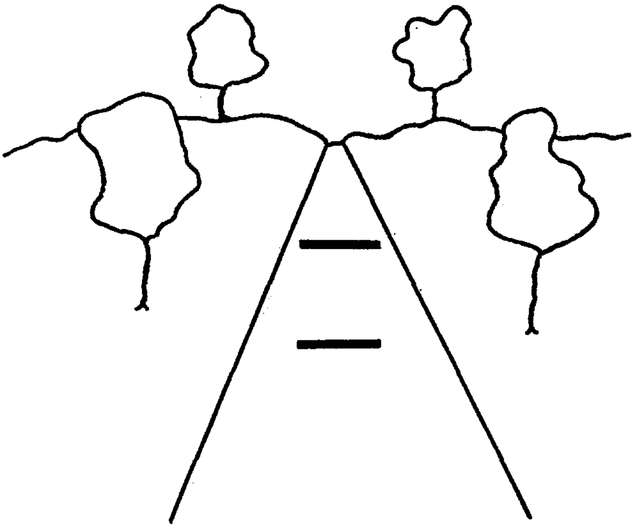
> 'if the constancy scaling tending to compensate for distance were triggered by perspective depth features, then we should expect the observed distortions in the illusion figure... suggesting that the distortions are produced by constancy scaling when this is misapplied. Since the illusion figures are in fact flat, we can easily see that if the perspective features do set the constancy, it must be inappropriate (4:154).'

The basic assumption in Gregory's theory is that distance is a feature of the environment to be grasped by the perceptual system. This notion provides the linkage between illusions and 'size constancy' through the existence of depth features and perspective cues which, if seen, would constitute a perception of distance and determine the application of the size correction by Emmert's law. However, we can point to the following evidence showing the independent origin of distortions arising in illusions and of size changes arising in the Emmert effect:

1: Consider the Ponzo illusion (Fig. 1). According to Gregory, perspective relations suggest a depth whose perception leads to a misapplied 'size constancy' compensation.
However if we transform the perspective context as in Fig. 2, and Fig. 3, the illusion is maintained, although the depth effect disappears.

2: According to Gregory, in the paper-drawn Necker cube the faces appear equal in size because geometric depth cues are suppressed by distance perception associated to the texture of the paper. This is not so: it suffices to en-

Figure 1



large the size of the drawing (20 cm or more) to obtain a noticeable change in the cube's faces upon inversion, although texture remains equally visible. It is as if the distortion effect increases in a nonlinear fashion with the cube's dimensions.

Clearly the notion of perceiving distance is not enough to explain this distortion. We can only say that there are relations in the seen image which bring into play the so-called size distortion.

3: If we obtain a post-image and look through a diverging glass at an object lying at the same distance as the source of the post-image, although the whole

Figure 2

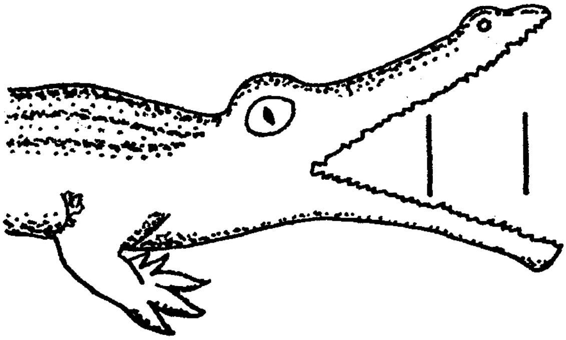
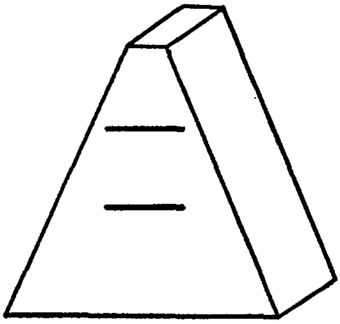


Figure 3



object is reduced in size and thus appears further away, the size of the post-image is slightly reduced.

Depth features have changed, but 'size constancy' would be working in a direction opposite to that expected according to Gregory's theory. There is, then, independence between the effects of what Gregory calls depth or perspective cues and 'size constancy'. Therefore we claim that:

a. Size illusions such as the Ponzo illusion do not arise as Gregory assumes from the perception of depth and perspective and the application of Emmert's law, but depend on relations present in the visual image which are not contained in the description of depth or perspective.
b. Apparent changes in size obtained with geometric figures such as the Ponzo illusion are independent from changes in size introduced by 'size constancy', insofar as they can be independently produced. In fact, there is no justification in lumping them both in the same category, although it is certainly attractive to believe that these phenomena are related due to their apparent similarity in effects. Furthermore not only is there no evidence that this should necessarily be so, but, on the contrary, we have shown them to be separable.

We shall postpone the study of the class of relations that can introduce distortions in the perceived images, and the possible mechanisms through which this effect might be produced. Our discussion will be centered on the problem of 'size constancy'.

3. 'Size constancy' as a process

What is 'size constancy' as a nervous process? To answer this question let us turn to the following evidence.

4: There is a circumstance under which the phenomenon of 'size constancy' disappears completely: this is when vision is obtained through a pinhole. In this situation there is no change in the size of a post-image, neither is there a compensation of the object size with varying distance.

Since the effect of a pinhole is to produce infinite depth of focus, this evidence strongly suggests that 'size constancy' is related to accommodation. Can we dissociate focusing and visual context to support this suggestion?

5: If after a post-image is obtained the eyes are closed, and, while the eyes are closed, an effort is made to look at the tip of the nose, the Emmert effect appears and the post-image shrinks.

Thus with no visual context, Emmert's law can be brought into play. We next look for a dissociation between accommodation and convergence.

6: Using diverging prisms which modify convergence but not accommodation, the size of the post-image remains unchanged.

We are thus led to the conclusion that accommodation is directly related to 'size constancy': the more the accommodation, the more the reduction in size. We can now understand the experiment presented in Evidence 3. The accommodation effort goes in the opposite direction of the reduction in size (apparent distance), due to the diverging lens, thus the size of the post-image is decreased.

7: If one has several identical objects at different distances on a visual line, they appear to differ in size, depending on exactly the amount of accommodation; while, if a single one is moved back and forth, it appears to be constant in size.

Thus the degree of size-change compensation is uniformly applied to the field according to accommodation, and it affects the appearance of all objects in it. The question then arises of whether the peripheral effect of accommodation is the significant parameter for size constancy.

8: The effect of the ciliary muscles can be suppressed by atropinization. In this circumstance the Emmert effect remains equally effective.

The correlation that one is led to establish, then, is between the 'size constancy' effect and the neural components in accommodation, i.e., the activity of the class of central neurons that control the contraction of the ciliary muscle.

In summary, then, 'size constancy' is dependent on accommodation. Furthermore, *8* points to the neural components of accommodation as the only possible correlation with the Emmert effect. This is significant because it reveals that the neural components of a motor event specify a perception. What, then, is 'size constancy' as a process? We have shown it to be a correlation between a sensory and a motor phenomenon, such that the state of neural activity that specifies the motor event serves to determine the perceptual effectiveness of the sensory process.

4. Discussion

The phenomenon of size constancy is not, according to the preceding results, a function of an independent feature of the *seen* object or scene; it is a function of a given correlation of activity between what takes place in the visual centers and what takes place in the central nuclei that control accommodation. Distance as an independent parameter of the *visible* world does not count: we do not see distance. Thus we have shown that, if we are to understand 'size constancy' we must look at the nervous system in a different manner. Maturana (1971) has suggested that the nervous system should be looked at as a closed homeostatic system, in which one state of activity leads to another and so on in a recursive manner, where motor and sensory processes do not depart from this condition and motor states close the system, either internally or externally by modifying the state of activity of the sensory surfaces or centers. In such a system, any change produced by an independent external source that modifies the state of activity of some of its neurons, will do this in a manner determined by the plasticity of the modified neurons, and the disturbance will be compensated in a closed manner indistinguishable from the compensation of an internally generated change. These compensations may be detectable by an observer and he may describe them, whether or not they have or follow a regular pattern which can be repeated under recurring circumstances. It does not make sense to talk about input and output functions in a system like this, which being homeostatically closed always remains determined in its changes by its own anatomical and functional organization. The observer cannot obtain (nor expect to obtain) from his description of the changes of the system a characterization of the independent properties of the source of disturbances. In the case at hand, the reduction in apparent size of an object whose distance from the eye is diminished should not, and in fact cannot be interpreted as arising from grasping distance as a feature of the disturbing source. We must recognize that this effect corresponds to a process that takes place completely enclosed within the nervous system, independently of any feature of the environment, although it may be elicited by interactions of the organisms in its environment. This leads us to the question of how the notion of distance comes about if it is not obtained from the environment.

If the observations which we have just made are correct, the phenomenon that we call perception cannot be considered to represent a process by which features are grasped from the environment to be incorporated into the operation of the nervous system. A perception, (ignoring as irrelevant the question of consciousness), is a process of compensatory changes that the nervous system undergoes in association with an interaction. Correspondingly, a perceptual space is a class of compensatory processes that the organism may undergo. Perception and perceptual spaces, then, do not reflect any feature of the environment, but reflect *the anatomical and functional organization of the nervous system in its interactions.* The question of how the observable behavior of an organism corresponds to environmental constraints cannot be answered by using the traditional notion of perception as a mechanism through which the organism obtains information about the evironment. A perturbed organism undergoes certain changes that compensate for the perturbations; if the perturbation is repeated, the organism undergoes similar or different changes that compensate for it in the same or in a different manner. The changes that an organism undergoes in compensating for its perturbations may be considered by an observer as descriptive of the perturbing agent because he establishes a correlation between the conduct that he beholds and the circumstances that he assumes give rise to it. The organism is an homeostatic system that has its own organization as the fundamental parameter which it maintains constant through the regulation of many others. As an homeostatic system the organism compensates deformations and retains its identity as long as it can do so. Thus, that it should have a behavior appropriate to the restrictions of the environment is to be expected. Furthermore, all that requires additional explanation is the way the organism behaves as it does at any moment. Of course, this depends both on its ontogeny and on the evolutionary history of the species to which it belongs. What is significant in the context of the present discussion is that perception and perceptual spaces constitute operational specifications of an environment, not apprehensions of features in an independent environment. An organism does not extract perceived distance as a characteristic feature of the environment but generates it as a mode of behavior that is compatible with the environment through a process of closed homeostatic compensation of disturbances. Thus, unavoidably, the more plastic the homeostatic organization of an organism, the more diversified modes of behavior it can generate that fit the environment.

When we study perception in an organism we face three problems: (i) to correlate the behavior of the organism with the disturbances that it suffers in its observable interactions, physical or social; (ii) to describe the closed neurophysiological processes through which the disturbances are compensated; and (iii) to treat the compensatory changes of the organism as behavioral specifications of the dimensions of an environment, but not as its characterization. These three problems should not be confused, and the mistake should not be committed of attempting to represent the activity of the nervous system or the behavior of the organism as a mapping of the description that the observer makes of the environment, which is itself a class of compensatory behavior through which he compensates for his own deformations.

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Résumé

Le phénomène de la constance de taille est défini comme l'apparente invariance perceptive des dimensions linéaires d'un objet lorsque celui-ci se rapproche ou s'éloigne de l'oeil. Ceci a été interprété comme étant du à une correction rendue possible par certains indices de distance présents dans l'image perçue. Nous présentons plusieurs observations, montrant que cette interpretation est incorrecte et que la correction de la taille d'une image visuelle est fonction d'un effort d'accommodation au niveau central, et non de la distance perçue. Pour montrer cela, nous avons dissocié le phénomène d'accommodation de celui de la distance, en supprimant les effets optiques de celle-ci sur l'image visuelle même