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# A reversed structure-from-motion effect for simultaneously viewed stereo-surfaces

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**Abstract**

A spatially flat stimulus is perceived as varying in depth if its velocity structure is consistent with that of a three-dimensional (3D) object. This is structure from motion (SFM). We asked if the converse effect also exists. A motion-from-structure effect would skew an object's perceived velocity structure to make it more consistent with the 3D structure provided by its depth cues. This proposed phenomenon should be opposite in sign from velocity constancy and could potentially interfere with it. Previous tests of velocity constancy compared stimuli presented at different times, not simultaneously. This explains why a reversal of SFM has not been previously reported, as it is expected to appear only for simultaneous presentations. We tested this prediction using random-dot stereograms to define two adjacent moving surfaces separated in stereoscopic depth. We found that subjects did not perceive velocity constancy with either simultaneous or sequential stimulus presentations. For sequential presentations, subjects matched retinal speeds, in agreement with previous work. However, for simultaneous presentations, the nearer surface was seen as moving faster when both surfaces were moving with the same retinal speed, an effect opposite in polarity from velocity constancy and a signature of the motion-from-structure phenomenon.


*Keywords:* Velocity constancy; Structure from motion; Binocular disparity; Binocular vision; Speed discrimination; Motion from structure

## 1. Introduction

Structure from motion (SFM) is a non-veridical percept in which the retinal motion field of a 3D object is perceived as having a depth structure closely related to that of the object, despite its being stereoscopically flat. Thus, we can think of SFM as a process in which one visual dimension (velocity) modifies the perception of another dimension (depth), making it more consistent with the object properties implied by the first, inducing, dimension.

We ask here whether the SFM phenomenon can be reversed, that is, if the depth structure of a stimulus can affect its apparent speed, skewing the perceived motion to be more consistent with the 3D structure provided by the depth cues. We will call this hypothetical phenomenon "motion from structure" (MFS), with the understanding that it refers to a perceived modification of existing stimulus motion, not an illusory induction of motion into a stationary stimulus.

Fig. 1A illustrates SFM. Two fields are plotted here, one a field of depth values (given by disparity, shading, or texture gradient, for example) and the other a field of velocity values. The depth field is uniform, consistent with a flat, frontoparallel surface. The velocity field is non-uniform; speeds peak at the center of the display and fall progressively along the flanks. Non-rigid perceptual interpretations of the surface spatial structure are possible, but human observers generally prefer the SFM interpretation of a rigid rotating three-dimensional cylinder. In Fig. 1B, the curvatures of the depth and velocity fields have been switched; the velocity field is uniform, while the depth field is consistent with a cylindrical surface. The MFS interpretation is exemplified by perceiving the *velocity* field as peaking in the center. Of course, SFM does not imply that the perceived spatial structure is consistent with the physical

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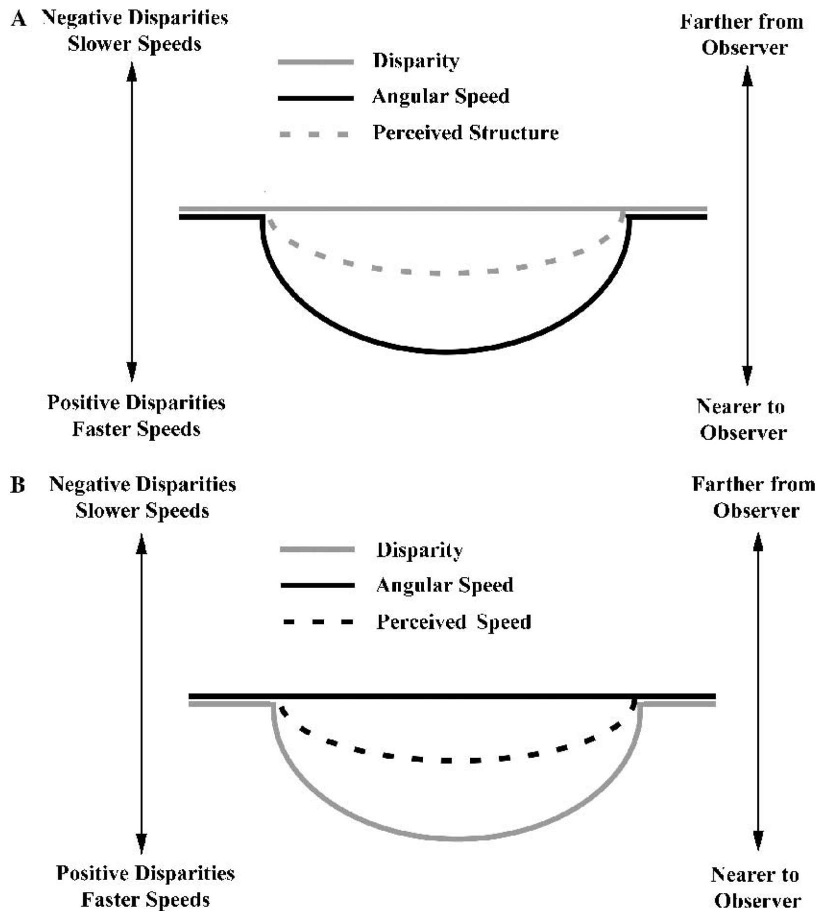


Fig. 1. (A) Structure from motion (SFM): the depth field (gray line) is consistent with a flat, frontoparallel surface. The velocity field (black line) is non-uniform; speeds peak at the center of the display and fall progressively along the flanks. Typically, the 3D SFM interpretation (dotted gray line) is that of a rigid rotating cylinder. (B) Motion from structure (MFS): the depth field (gray line) is consistent with a cylindrical surface. The velocity field (black line) is uniform. The MFS phenomenon is predicted to produce the perceived velocity field (dotted black line) as peaking at the center. Notice the symmetry, from (A) and (B) between SFM and MFS.

velocity field; nor does MFS imply that the perceived velocity structure is consistent with the physical disparity field. What is implied instead is a perceptual shift in the direction of consistency. Thus, the perceived surfaces, as drawn in Fig. 1, are compromises between the physical velocities and disparities in the display.

Both SFM and MFS need to be distinguished from velocity constancy (VC). The retinal velocity of a moving object varies with the frontoparallel component of the object's physical velocity and with the distance of the object from the observer. Yet two objects traveling at the same linear speed in frontoparallel planes at different distances from the observer appear to have the same speed, despite the difference in their retinal velocities (for a review, see Howard & Rogers, 1995). Velocity constancy holds in the presence of adequate cues to depth, such as changes in size, density or texture (Rock, Hill, & Fineman, 1968; Zohary & Sittig, 1993) or the presence of background reference frames (Epstein, 1978). However, velocity constancy is not always observed. McKee and Welch (1989) used binocular disparity as a cue to distance and found no evidence that it supports velocity constancy. In addition, Zohary and Sittig (1993) found that neither convergence nor accommodation supports velocity constancy when random-dot kinematograms were used as stimuli.

The finding that velocity constancy is not always observed can be turned to experimental advantage. As will be demonstrated later, MFS is expected to have the opposite sign as VC. Consequently, the two could potentially interfere with each other. By choosing disparity as the depth cue to probe for the existence of MFS, we are drawing on the previous evidence that disparity alone does not provide an adequate depth cue for VC. Thus, disparity will not generate a VC effect that could interfere with MFS.

In previous tests of velocity constancy, the stimuli to be compared were presented at different times, not simultaneously. Comparisons were either made across temporal intervals within a trial or between stimuli situated at different sides of the head, so that only one stimuli was seen at a given time. We are not aware of any study of velocity constancy involving simultaneous comparisons. This fact could explain why no MFS effect has been reported previously, even in the absence of VC. Structure from motion