

Book Review

Perception

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Casati, R., & Cavanagh, P. (2019). *The Visual World of Shadows*. Cambridge, MA: MIT Press. 408 pp. \$45.00 S|£38.00 (hardcover), ISBN 9780262039581.

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In Giorgio Vasari's (1511–1574) “Origin of Painting,” a shadow cast by a human figure is depicted on a nearby wall, its shape closely resembling the figure, leaving no doubt as to its origin. Yet however compelling is the shadow and its contribution to the perceived three-dimensional layout of the scene, the shadow is a physical impossibility given the geometry of form and lighting portrayed in the rest of the painting. This paradox is just one of the numerous themes explored in Casati and Cavanagh's richly illustrated, expansive, and well-organized treatment of the physical, perceptual, cognitive, and artistic world of shadows.

You only have to turn the pages of this book to realize that here is something special. With chapter titles like “The Shadow Mission,” “Shadow Ownership,” “Labeling Shadows,” “The Shadow Concept,” and “The Art of Shadows,” any doubts you might have had that there was not enough about shadows to justify an entire book on the subject are quickly dispelled. As you read the book you feel you are being taken on a journey through a whole new research field that has suddenly opened up. Detailed arguments backed up with illustrations take preference over excessive amounts of experimental detail, making the book engaging and accessible. The summary take-home messages and suggested research questions at the end of each chapter help to reinforce the impression that this is no coffee-table book but above all else a book of science and a tool for research.

The book is also a long time in coming. Why so long a wait for a book dealing with one of the most ubiquitous features of our visual world? I might be treading on contentious ground here but I suspect that one reason is that the cast shadow, the form of nonuniform illumination formed by the occlusion of light, has traditionally been regarded as the junior cousin of two other principle types of nonuniform illumination: shading and highlights. Shading, the variation in luminance caused by a change in the orientation of a surface with respect to the direction of illumination, long ago captured the attention of the computational vision community in its search for algorithms for extracting the shape of an object from the pattern of its shading, the so-called shape-from-shading problem. More recently, advances in computer graphics have propelled highlights, the cue to the shininess of a surface, to center stage. There have always been compelling demonstrations of the importance of shadows for perception, for example, Mamassian and Kersten's “ball-in the box,” in which the perceived motion trajectory of an object is dramatically altered by

the motion trajectory of the shadow it appears to cast. But shadows have received relatively little treatment in the literature, if anything regarded as an encumbrance to successful vision, to be “discounted,” for example, when estimating the lightnesses of surfaces beneath. Casati and Cavanagh’s book goes a long way to redressing the imbalance by alerting us not only to how much there is to know about shadows but to how interested our brains are with them.

The book rightly begins with the physical characteristics of shadows. Shadows vary considerably in form because of the innumerable combinations of the shape, position, and illumination of the objects that cast them. Yet however varied are their characteristics, they are sufficiently constrained to be potentially useful for telling us about object and illumination. In this section of the book, there were new concepts for me. For example, an object in front of the viewer but lit from behind sends “shadow rays” that converge to a point in the distance, termed the “antisource,” resulting in impressive panoramic views of distant clouds when the light source is a bright-shining sun. But it is the finer details of shadow characteristics that are critical to perception, and these are described in the later chapters where the intimate relationship between the physical and the perceptual becomes center stage.

My favorite of these chapters is the one entitled “Labeling Shadows.” This chapter deals with the conditions that give rise to the impression of a region being a *shadow* as opposed to something else, the something else typically being material, e.g. paint or stain. The chapter highlights (or, and I can’t resist, “downlights”) how our unconscious knowledge of the luminance relationships between a shadow and its surround are critical to its interpretation. When the rules are broken, such as when one draws an outline around the shadow or inverts its luminance polarity, our perception switches to the alternative, material interpretation. Yet even when this happens, as Casati and Cavanagh are at pains to point out, the shadow, albeit now perceived as material, still contributes to our perception of the layout of the scene, exemplifying the flexibility of vision in utilizing all the information that is available.

What of the overall importance of shadows for vision, particularly in relation to other illumination cues? Perhaps wisely Casati and Cavanagh do not delve too deeply into this difficult question, content as they are to persuade us of the value of shadows in helping to create an accurate perception of the scene. The authors are nevertheless acutely aware of one of shadows’ shortcomings: shadows are, to varying degrees, physically separate from the objects that cast them, posing the computational problem to vision of deciding whose shadow belongs to whom, the subject of the chapter “Shadow Ownership.” Casati and Cavanagh provide examples of situations where the challenge is considerable, such as with the shadows of foliage. With shading and highlights, on the other hand, there is little question of ownership as they are literally attached to the objects they appear on, with the result that shading unambiguously implies surface curvature (even if the sign of curvature is ambiguous) and highlights unambiguously imply a glossy surface. The rigid attachment of shading and highlights to object surfaces might arguably confer upon them a position higher than shadows in the pecking order of illumination cues to object perception, yet not so much higher as to diminish the importance of shadows to perception.

Are shadows in the end a double-edged sword, useful for telling us about the shapes and positions of objects, but cluttering up the scene with potential false targets? Casati and Cavanagh suggest that shadows are “demoted” for the purposes of scene segmentation once they have fulfilled their mission. However, such demotion is only partially successful (else we would never be afraid of tripping over our own shadow), so the question remains: how much of our perceptual world would be lost if we became shadow-blind? The book implies that there would be a significant loss, and examples are provided to support the case. One is of a flat sculpture of a bird viewed from above whose shape is only visible from its

shadow (admittedly a rare situation); another is a photograph of three pedestrians standing in the street with their shadows removed with the result that they appear to float above the street (a similar effect is seen in other figures in the book where the shadows have been shifted downward). But these examples only hint at what a world without shadows would be like for vision. A fuller answer to the question might benefit from measuring the perceptual consequences of removing *carte blanche* the shadows and shading from images of natural scenes using the algorithms developed by computer vision scientists, algorithms that exploit the physical constraints on shadows that Casati and Cavanagh describe so well in their book.

Do I have criticisms? I sense a slightly uneasy relationship with the topic of shading. Shading is discussed here and there, necessarily so in a book about shadows as shading and shadows often co-occur, as with a shadow cast by the nose on the shaded part of a face. Yet given that the authors consider shading as a subspecies of shadow—they adopt the widely used designation of shading as an “attached shadow”—and given the traditional importance of shape-from-shading in vision science, one might wonder why shading does not feature more prominently in the book. I suspect the reason is the need to redress the imbalance between shading and shadows in the literature I alluded to earlier, combined perhaps with a reluctance to divert readers’ attentions away from the main topic by diving too deeply into the computational complexities of the shape-from-shading world. What might have helped, however, would have been a section in the first chapter that introduced the main types of nonuniform illumination: shadows, shading, highlights and light spots (regions brightly lit by virtue of being surrounded by shadow) together with their relatives—transparency and mirror reflections. This could have served as the prelude for making the case for a book focusing primarily on shadows, one that nevertheless discusses shading where appropriate. It would also have served to anticipate the useful chapter toward the end of the book detailing the relationship between shadows, light spots, transparency and mirror reflections.

This book was an eye-opener for me. I could never have imagined there was so much to know and so much still to discover about shadows and their role in perception. Casati and Cavanagh have done an invaluable job in bringing to the fore an underappreciated feature of our visual world. This is compulsory reading for anyone interested in the importance of nonuniform illumination in perception, cognition, and art.