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Visual-illusion distance paradoxes: A resolution

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Abstract Several illusory phenomena are susceptible to explanations that invoke size scaling, but *only if* the distance estimates used to compute size are allowed to contradict the estimates of distance that are consciously experienced at the same time. However, such "paradoxes" make sense within Milner and Goodale's (2006) two-stream theory of vision.

Keywords Size illusions · Distance perception · Moon illusion

In an extensive review of research by themselves and others—including studies from a wide range of paradigms—Milner and Goodale (2006) provided compelling evidence for their claim that humans and other primates possess a two-part visual system: one part being a ventral pathway whose activities lead to *conscious* visual experience (the "vision-for-perception" system), and the second being an older, dorsal pathway whose activities guide motor behavior in the *absence* of awareness (the "vision-for-action" system). To take just one of their examples, Loomis, da Silva, Fujita, and Fukusima (1992) found that subjects made systematic errors in their *reports* of the relative distances of two points on the ground, but that they could *walk* with great accuracy to any such point when asked to do so. If we assume that those verbal reports closely tracked perceptual experience, then clearly the sense of distance that guided their motor responses was independent of the distortions that occurred in their conscious experiences of distance.

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While this and other observations recruited by Milner and Goodale (2006) involved a contrast between some aspect of experience and motor performance, a second theoretical proposal involved contrasting events *within* perception itself. That is, it has been suggested that several perplexing phenomena occur because humans possess two, sometimes conflicting, senses of distance—one of which we are aware of, and one of which is not, itself, directly available (although it influences our experience of size; Parks, 2001). For example, in one experiment, subjects who projected an afterimage onto a vertical surface all reported that that projected image increased in size when they backed away from that surface. Of course, this result can be explained by size scaling on the basis of *increased* distance. Paradoxically, however, most of those same subjects *also* reported that the image seemed to be moving toward them—which is to say, perceived distance apparently tended to *decrease* (Day & Parks, 1989)—leading, in part, to the later suggestion that two contradictory estimates of distance were simultaneously registered, one experienced only indirectly, through its effect on size scaling.

Obviously, this hypothesized duality is highly reminiscent of Milner and Goodale's (2006) proposed coexistence of conscious and unconscious visual streams. Specifically, it may be that the sense of distance of which we are aware is produced within Milner and Goodale's vision-for-perception stream, while the sense of distance involved in size scaling occurs in their vision-for-action stream.

And indeed, in an entirely independent development, Servos (2006) has since found that "D.F.," a victim of damage to her vision-for-perception stream, responded quite erratically to a test of consciously registered distance, while retaining the ability to respond systematically and appropriately (albeit with some attenuation) to changes in distance in an afterimage

size-scaling task. To this may be added an instance of the opposite pattern, resulting from damage to the other—vision-for-action—stream. That is, "Case 5" described in Ettlinger, Warrington, and Zangwill (1957), who suffered damage to that stream, apparently had normal conscious experiences of distance, but complained of difficulty in judging "the space to allow . . . as in parking a car." That is, his lesions had deprived him of accurate and reliable size scaling. All of this clearly supports Servos's conclusion that the distance registration that is necessary to successful size scaling occurs in a separate physiological stream. Furthermore, the two distances that arise in attempting to explain certain illusory events are thus matched by the different distances registered in Milner and Goodale's (2006) two visual streams.

The important new point here is that, since the two senses of distance occur in separate pathways, their being sometimes mutually contradictory—such as, to take another example, in the size-scaling explanation of the moon illusion—engenders no perplexing paradox after all.[1]

[1] As is well known, the size-scaling theory holds that the larger appearance of the moon when it is near the horizon is due to its incorrectly being taken to be at a *greater distance* (combined with its constant visual angle). An equally famous criticism of that theory is that, when asked, observers report that the horizon moon appears to be *nearer* rather than farther away. Lloyd Kaufman and Irv Rock, the leading proponents and developers of this theory (Kaufman & Rock, 1962; Rock & Kaufman, 1962), suggested that this difficulty could be avoided if we assume that those nearer-distance reports were not, in fact, *perceptual* reports as we usually conceive them, but rather were *postperceptual* cognitive "judgments" (see, especially, Kaufman & Rock, 1989). By contrast, the present suggestion is that those reports are, indeed, based on a genuine sense of distance, but one that is separate from—and independent of—the sense of distance that leads to the impression of smaller size. Also by contrast—and by the same token—the present proposal to encompass the size-scaling explanation of the moon illusion within Milner and Goodale's (2006) two-stream theory differs fundamentally and importantly from Norman's (2002) suggestion that what occurs in the ventral stream are Kaufman and Rock's (1989) "judgments." Here, instead, rather than avoiding the potential paradox by assuming that only one stream (the dorsal stream) possesses a true sense of distance, it is assumed that they *both* do.

Equally gratifying is the additional light that this theory casts on the symbiotic relationship between the traditional realm of research in visual perception and the more recently developed field of visual neuroscience. On the one hand, it is widely accepted that findings and theory in the former may tell neurophysiologists "what to look for." Here, on the other hand, we have a rarer instance of the latter informing efforts within the former, specifically by providing a physiological basis for theoretical assumptions that otherwise would be, at best, discomforting.

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