Visual space perception: phenomenology and function

Percepção visual do espaço: fenomenologia e função

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ABSTRACT

This article presents a brief overview of visual space perception. It begins by noting the significance of visual space perception to broader issues in philosophy and science and observes that the appreciation of visual space perception as a scientific topic is impeded by naïve realism. The second section notes the longstanding interest in the phenomenology of visual space and focuses on one issue, the dissocation between perceived location and perceived shape in visual space. The last section discusses three conceptions of how vision controls action, with special attention to the role of visual space.

Keywords: Visual perception; Space perception; Phenomenology

NAÏVE REALISM: AN OBSTACLE TO APPRECIATING THE NATURE OF VISUAL SPACE PERCEPTION

Naïve realism is the commonsense view that the world we encounter in everyday life is one and the same as the physical world. An opposing view is provided by the philosophy of mind and the scientific study of perception—contact with the physical world is mediate, and what we experience in everyday life is a representation created by our senses and central nervous system[1-3]. Indeed, this representation (usually referred to as the perceptual or phenomenal world), being a product of sensory and neural processes that have been perfected by millions of years of evolution, is so highly consistent and veridical that we are able to routinely make life-depending decisions (as in driving) without ever suspecting that the perceptual information upon which we are relying is once removed from the physical world. In fact, it is precisely because the perceptual process is so highly functional that we fail to recognize its very existence. It is for this reason that the layperson thinks of perception as little more than attending to aspects of the environment and that many erudite people, including many scientists, fail to appreciate the scope and magnitude of perception as an intellectual problem.

There is hardly a topic in perception that is more difficult to appreciate as an intellectual problem than visual space perception, especially in connection with natural large-scale environments. In order for us to properly grasp the nature of perception, we need to eliminate naïve realism from our thinking as much as possible. Geometric visual illusions and other visual phenomena, like diplopic vision, binocular stereopsis elicited by stereograms, and perceived 3-D shape from motion, do help expunge naïve realism from our thinking by providing examples of how perception can deviate from physical reality. However, such circumscribed visual phenomena tend to exert only local influences on our thinking rather than inducing a global restructuring of our conceptions of perceptual experience. Thus, even though these visual phenomena make us recognize the fallacy of naïve

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realism, we lapse back into naïve realism when we are driving on our way to work, engaging in sports activity, interacting with other people, and otherwise acting in the world; it is indeed an enormous intellectual challenge to appreciate that the very three-dimensional world in which we normally act is an elaborate perceptual representation. For this reason, many cognitive psychologists, clinicians who treat visual disorders and disease, even some visual perception researchers, mistakenly believe that the study of visual space perception (or "depth perception" as it is colloquially known) is concerned with how people make judgments about size and distance. This is to be expected, for the naïve realist, who takes the experienced world as the physical world, can only construe the problem of distance perception as one of how people form cognitive judgments of distance (e.g., "I estimate the target to be about 30 m away"). But, the problem of visual space perception is much deeper than this — the very world that we see around us, with all of its solidity, complexity, and detail, is the perceptual representation[1-6]. A major goal of research on visual space perception is to understand how stimulation by light leads, through a process that is completely automatic and inaccessible to our conscious awareness, to the visual component of the perceptual world, commonly known as visual space.

PHENOMENOLOGY OF VISUAL SPACE

The phenomenology of visual space refers to its local attributes (like perceived direction, perceived egocentric distance, perceived exocentric distance, perceived size, and perceived motion) as well as its global shape and scale. Understanding the phenomenology of visual space and its correspondence with physical space is important for a number of reasons besides the intrinsic value of such an intriguing problem. First, such understanding is going to contribute to our understanding of the bigger philosophical issues of epistemology and metaphysics[3]. Second, understanding phenomenology is likely to contribute to our understanding of visually controlled action, for surely visual space plays some causal role in the control of action (despite recent controversies, as will be discussed below). Third, understanding phenomenology is essential to developing more effective technology-based visual representations, like scientific illustrations and dynamic visualizations, cockpit displays, and virtual reality. Indeed, achieving realistic perception of size and distance in virtual reality has turned out to be surprisingly difficult[7].

In a fascinating paper dealing with visual space as a mental representation, Lehar[5] argues that research on visual space perception needs to focus on characterizing the spatial correspondence between physical space and visual space, which will then act as a powerful constraint on a computational theory of visual perception. Unfortunately, he cites very little of the extensive experimental and theoretical literature on visual space perception that has been concerned with bettering our understanding of the mapping between physical and visual space[4,8-15]. Especially valuable is Gogel's article on "phenomenal geometry"[4] which describes and explains a number of important phenomena of visual perception, including the internal consistency exhibited by various attributes of visual space.

To focus on just one aspect of the phenemonology of visual space, the author mentions some research that began with his collaboration with José Aparecido Da Silva during the author's extended visit to the University of São Paulo, Ribeirão Preto in 1986. Some of our research, based on motoric responses to visual targets, showed that visual perception of egocentric distance was linear in physical distance and accurate out to at least 15 m[16-17]. Other research we conducted, however, indicated large distortions in visual space relative to physical space; in particular, cross-shaped figures on the ground plane, even those within several 4 m, were systematically misperceived, with the depth component being greatly foreshortened[14,17]. Based on these results, we hypothesized that perceived exocentric distance (the distance between 2 objects in space) might be dissociable from perceived egocentric distance. More recent research[18] has confirmed a slightly modified version of our hypothesis — that perception of shape is dissociable from the perception of location, of which perceived distance is one determinant. In particular, we showed that whereas changing from monocular to binocular viewing had no influence on the perceived locations of targets on a visually specified surface, binocular viewing of shapes on the same surface led to more accurate perception of shape than did monocular viewing. The import is that shape perception is not fully constrained by the perceived locations of the vertices defining the shape. This result indicates that geometrical models of visual space involve more complexity than originally thought.

ROLE OF VISUAL SPACE IN THE CONTROL OF ACTION

Currently, there are three very different conceptions of how vision controls action (Figure 1). The "visual space" conception builds on the view of perception presented above. Visual processing of light stimulation, complemented by internal assumptions about physical space, results in visual space — the visual component of perceptual space. Furthermore, this perceptual representation is a causal determinant of action. According to this conception, understanding visual space will contribute to our understanding of action.

The second conception is associated with the ecological approach to perception, originating with Gibson[19-20]. Here, it is assumed that very specific aspects of the optic flow field, termed "optical invariants", are tightly coupled to particular aspects of the desired action[21]. For example, in connection with the visual control of locomotion, aiming toward a point is controlled by the global radial outflow[22], aligning with a straight path is controlled by splay and splay rate[23], and

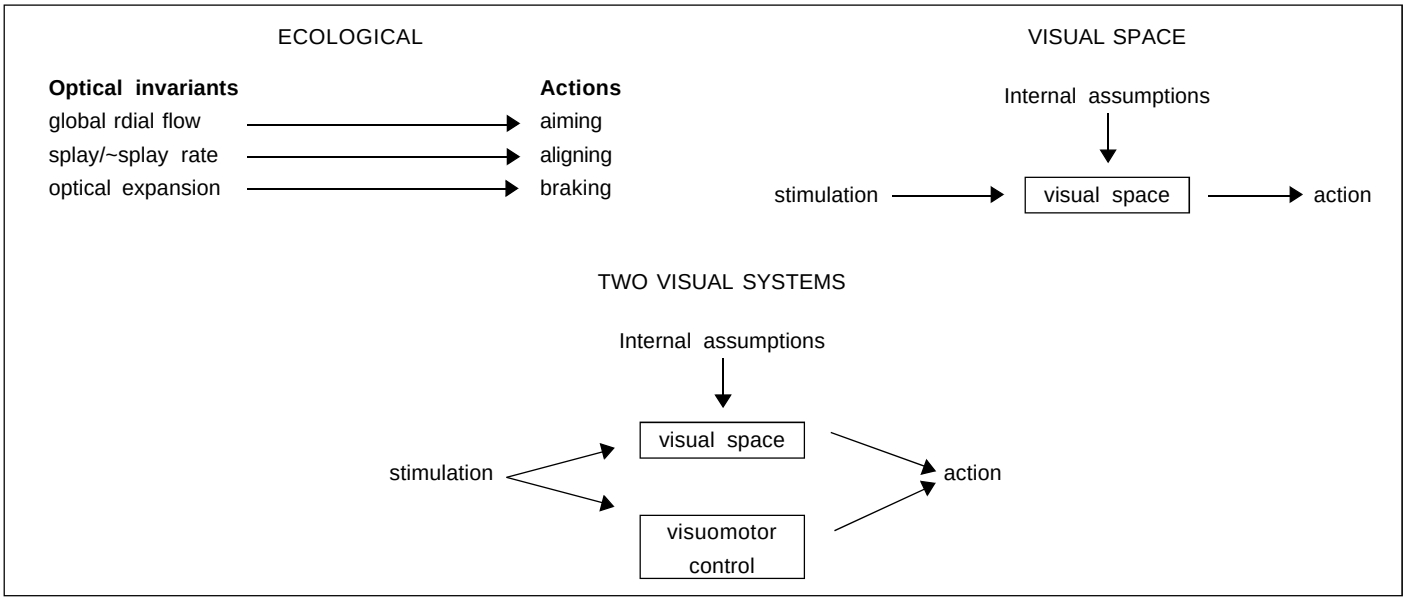

Figure 1 - Three conceptions of how vision controls actions

braking is controlled by an optical variable based on optical expansion[24]. Ecological researchers consider the mechanisms of perception and cognition and the internal representations resulting from them to be unnecessary for explanations of action.

The third conception, termed "two visual systems", recognizes that there are circumstances, possibly widespread, where visuomotor control depends upon processes and representations independent of conscious visual perception (visual space). Milner and Goodale[25] summarize much of the evidence from patients with brain lesions, including their own work with a brain damaged patient who can reach and grasp appropriately for visual objects which she cannot perceptually discriminate. Other evidence supports the dissociation of conscious perception and visuomotor control even in intact individuals[26].

Surely there is merit in all three conceptions. There is an abundance of evidence, some of it cited above, that a variety of visually controlled spatial behaviors can be explained in terms of invariants of optic flow[21]. There is also plenty of evidence, some of it cited above, that visuomotor control is sometimes carried out independently of consciously perceived visual space. However, research by Loomis, Da Silva, and their colleagues[16-17,27] and by other researchers[28], also provides clear evidence of actions that are guided by visual space. In these studies of "visually directed action", observers view a target in space from a fixed location and then indicate its perceived location by means of some locomotor response carried out without vision. For a fixed target under constant viewing conditions, different actions converge on a single location in space, which presumably corresponds to the perceived location[27]. Moreover, the concordance of the perceived location and the physical target location depends on the availability of distance cues, and the perceptual errors are in close agreement with those measured using verbal report[27,29]. These findings are strong evidence that action is sometimes controlled by visual space, rather than by invariants of optic flow or by some independent visuomotor control system. Future research will determine the role visual space plays in spatial behaviors involving concurrent vision, including sport activity, driving, and piloting of aircraft[30].

RESUMO

Este estudo apresenta uma breve visão geral da percepção visual do espaço. Começa relatando a significância da percepção visual do espaço para questões mais amplas na filosofia e na ciência, e observa que a apreciação da percepção visual do espaço como um tópico científico é evitada pelo realismo ingênuo. A segunda seção relata o interesse perene na fenomenologia do espaço visual e foca em uma questão, a dissociação entre localização percebida e forma percebida no espaço visual. A última seção discute três concepções de como a visão controla a ação, com atenção especial para o papel do espaço visual.

Descritores: Percepção visual; Percepção espacial; Fenomenologia

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