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Introduction

Spatial Biases: What Are They and Why Are They Important?

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What is a spatial bias? This can be most easily understood if we consider each of the words in the term. First, "spatial" refers to configurations of or distances between objects in the environment. Its use in the term "spatial bias" fits our everyday conception of what we mean by "space," but also goes considerably beyond our everyday conception to include stimuli that might not initially be considered spatial. For example, we might think of different auditory pitches as being located in an auditory space (e.g., height on a musical staff) or different numerical quantities as providing a framework for mapping space (e.g., reflecting different extents or different coordinates in a graph). Second, "bias" refers to a consistent pattern of perceptual judgment or motor action. In some cases, there might be a consistent direction of error in judgment or action away from the veridical response (e.g., as when observers consistently overshoot the actual final location of a moving target in their judgment of the final location); in other cases, there might be a consistent pattern of judgment or action in the absence of a clear veridical response (e.g., associating higher auditory pitches with higher locations in the picture plane). Thus, a "spatial bias" is a consistent pattern of perceptual or cognitive judgments or motor actions involving configuration or distance in response to a stimulus when those judgments or actions do not correspond to the veridical stimulus or when there is no clear veridical stimulus to compare with those judgments or actions.

Although various spatial biases have long been of interest in psychology and related disciplines, information on such biases has been scattered across many different sources. One aim of this book is to provide a catalog of spatial biases and descriptions of the different domains and situations within which such biases have been found. A second aim is to highlight the potential relevance of spatial biases in a wide range of domains and situations. Although historical examination of spatial biases often focused on various types of static illusions (e.g., Müller-Lyer illusion, horizontal–vertical illusion) or spatial biases in cognitive mapping (e.g., effects of hierarchical organization of knowledge), recent decades have seen the discovery of new spatial biases associated with scenes (e.g., boundary extension), invariant physical principles (e.g., momentum, gravity), moving objects (e.g., flash-lag effect, looming), numeric cognition (e.g., SNARC), musical cognition (e.g., SMARC), and social cognition (e.g., group membership, status). The extent to which spatial processing can influence other types of cognition or behavior (e.g., the Simon effect, numerical processing in SNARC) is also important. The book is divided into four main sections. Part I deals with various anisotropies (i.e., asymmetries) and illusions. Part II deals with biases that arise from the dynamics of objects. Part III expands the view from dynamics of objects to dynamics of scenes, and Part IV examines dynamics arising from actions within scenes.

Part I: Anisotropies and Illusions

Part I begins with a consideration of perceptual biases in geometry, which is evidenced in many classical visual illusions. Morgan (Chapter 1) suggests the retina provides a coarse topographic map, and that measurements on the map are carried out by "coincidence detectors" and "collector units" that have wide spatial tuning and are unable to provide precise positional information for single positions independent of the surrounding context. Aznar-Casanova and Bernardino (Chapter 2) widen the focus to consider differences between physical space and visual space, and they consider perceptual anisotropies in the frontoparallel (coronal), medial (sagittal), and horizontal (transverse) planes including the horizontal–vertical illusion, oblique effect, foreshortening, and effects of the observer's eye level and ground surface. Aznar-Casanova and Bernardino note that anisotropies are influenced by properties of the stimuli (e.g., spatial frequencies, size, orientation), the type of task (e.g., search, recognition, magnitude estimation), and within-observer variables (e.g., hemispheric specialization, laterality, age).

Anisotropies are related to numerical magnitude by Cipora, Patro, and Nuerk (Chapter 3), who consider findings on spatial–numerical associations. They distinguish between spatial–numerical associations involving extension (i.e., larger numbers associated with large extents) or directionality (i.e., larger numbers associated with a particular direction or region in space, e.g., the SNARC effect). They highlight that the relationship between numbers and space is bidirectional, review several variables that influence such spatial–numerical associations, and conclude that such associations are highly flexible, situated, triggered by different types of informational content, and operate at different levels of information processing and in different temporal frames. The relationship of space to an individual's perceptual judgments or motor actions is further considered by Umiltà, Bonato, and Rusconi (Chapter 4), who overview the Simon effect (responding is facilitated when the response is located in the same part of space as the stimulus), SMARC effect (higher pitches are associated with higher locations in space), and STEARC effect (different parts of space are associated with the past or the future). Umiltà and colleagues consider these effects as examples of a broader S–R (i.e., stimulus–response) compatibility involving spatial coding of nonspatial information.

The relationship between auditory pitch and spatial location is further considered by Deroy, Fernandez-Prieto, Navarra, and Spence (Chapter 5), who review findings that higher-frequency sounds facilitate responding to stimuli in the upper part of visual space and lower-frequency sounds facilitate responding to stimuli in the lower part of visual space. Deroy and colleagues suggest that spatial attributes of auditory pitch result from a crossmodal correspondence between vision and audition that is linked to the connection between auditory perception of sounds and visual perception of sound sources. In the last chapter of Part I, Kranjec (Chapter 6) examines connections between space and language, that is, how verbal and nonverbal representations of spatial relationships interact. A case study of a patient with simultagnosia reveals that exposure to nonlinguistic spatial information can improve perception of spatial relations between stimuli that are otherwise not perceived. Kranjec also suggests that high-level categorical information about space can influence perceptual representation in ways that language does not.

Part II: Dynamics of Objects

Part II begins with a consideration of mislocalization of the onset position of a moving stimulus. Müsseler and Kerzel (Chapter 7) examine two such biases: the Fröhlich effect and

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the onset repulsion effect (judged onset location is displaced slightly forward or backward, respectively, from the actual onset location). They review several possible mechanisms (e.g., sensation time, metacontrast, lateral inhibition, attentional mechanisms) and suggest how the conflict between the Fröhlich effect and onset repulsion effect might be resolved. Mislocalization of the offset position of a moving target is reviewed by Hubbard (Chapter 8), who focuses on representational momentum (judged final location is displaced slightly forward of the actual final location). Hubbard reviews effects of several variables that influence representational momentum and suggests several properties that characterize representational momentum. The flash-lag effect (a perceived misalignment of a moving object with a briefly presented stationary target) is discussed by Hubbard (Chapter 9), who reviews effects of several variables that influence the magnitude of the flash-lag effect, its properties, and its major theories.

The influence of an actual or implied gravitational attraction on perceptual and motor responses is considered by Zago (Chapter 10), who reviews several behavioral tests for perception of the direction of gravitational attraction and acceleration. Zago suggests that the representation of gravity involves a multiplicity of representations, and that although estimates of the gravity vector are generally accurate under typical ecological conditions, they can be biased under unusual conditions. Influences of auditory information on visual motion perception are discussed by Teramoto, Hidaka, and Sugita (Chapter 11), who present findings challenging the traditional view that vision is dominant over other modalities in spatial processing and supporting a view that auditory information can have a strong effect on visual motion perception even when those sounds do not contain explicit spatial information. The dynamics of looming objects are considered by Neuhoff (Chapter 12), who notes that visual and auditory looming objects have priority in processing and bring about responses not evoked by motion in any other direction. Neuhoff points out that looming objects are often perceived as closer than those objects really are, and that this bias might have been shaped by evolution to enhance the probability of survival and reproduction.

Part III: Dynamics in Scenes

Part III begins with a consideration of boundary extension (a previously viewed scene is remembered as including information that was not actually viewed, but that would likely have been present just beyond the edges of the actually viewed scene) by Intraub and Gagnier (Chapter 13), who consider a variety of cognitive factors (e.g., viewpoint, attention, medium of presentation, neuropsychological effects, developmental effects) supporting a multisource model of boundary extension. Spatial contraries (the organizing of space along opposing dimensions, e.g., up–down, left–right, etc.) and the experience of mirror reflections are examined by Bianchi and Savardi (Chapter 14), who suggest that spatial contraries are an essential aspect of the framework within which people gesture and interact and are integral to the relationship between an object/body and its perceived reflection. Aesthetics and preferences in scene composition are discussed by Hubbard (Chapter 15), who reviews findings on aesthetic judgments and preferences regarding relative location, facing direction (orientation), contour shape, and ratio on objects in a scene. Additionally, theories for some of these preferences, as well as general properties of spatial bias in scenes, are considered.

A review of spatial biases in the classic cognitive mapping literature is provided by Tversky (Chapter 16), who presents a new Spatial Reference theory to account for a wide range of such biases. This theory involves spatial biases related to grouping and hierarchical organization of spatial information, use of canonical axes, use of reference points (landmarks), perspectives, paths, schemas, and route planning. The importance of hierarchical and categorical information in spatial bias is underscored by Newcombe (Chapter 17), who overviews data on the effects of spatial categories (e.g., different quadrants defined by cardinal axes) and presents the Category Adjustment Model (CAM) in which fine-grained spatial information is nested within larger spatial categories. CAM is a Bayesian model based on unbiased information that is weighted by category, and it generates predictions consistent with several previously observed spatial biases.

Part IV: Perception and Action

Part IV begins with a consideration of the consequences of brain damage, and Charras, Lupianez, and Bartolomeo (Chapter 18) review findings involving brain damage and visual neglect. The authors present evidence for a general left–right imbalance in visuospatial and representational processes, review evidence that pre-attentive processing is relatively spared in neglect patients, and argue for an attentional account of neglect. An evolutionary account for several spatial biases is provided by McBeath (Chapter 19), who argues that many biases reflect predictive expectations. McBeath suggests that observers and actors exhibit an array of spatial biases that vary in robustness from universal invariant properties (e.g., increases in visual angle of a looming object) to socially learned tendencies (e.g., American pedestrians who are approaching each other usually veer to their respective right sides). One spatial bias that is related to visual search is inhibition of return (IOR), and Klein and Redden (Chapter 20) argue for the existence of two different types of IOR: one type involves a reduction in signal strength in an early salience map, and the other type involves a response bias criterion shift in a later map.

The effect of action on perception is discussed by Witt (Chapter 21), who reviews data suggesting that a perceiver's ability to perform an intended action affects his or her perception of the salient stimuli. Witt provides a historical overview of the action-specific approach to perception, addresses whether such effects reflect perception or judgment, and discusses unresolved issues regarding action-specific perception. Biases involved in navigating from an initial origin point to a desired destination are discussed by Wiener and Meilinger (Chapter 22), who review studies on route choice in which navigators have different levels of knowledge regarding that environment. Social aspects of space related to group membership, stereotyping, and status are addressed by Suitner and Schubert (Chapter 23), who review the links between social cognition and spatial cognition from both an applied and a theoretical perspective. Finally, on a more philosophical note, Jordan, Cialdella, Schloesser, and Bai (Chapter 24) discuss two forms of bias within cognitive science (efficient-cause bias, realism bias) and how those biases influence theories of perception, cognition, and action in general and spatial representation in particular.

Why Spatial Biases?

As the preceding brief introduction to each of the chapters shows, spatial biases are relevant in a wide range of domains and situations. Although for many years such biases had been of limited interest, appealing primarily to researchers interested in perception and psychophysics, the chapters in this book show that spatial biases impact many different areas of our everyday experience. In many cases, spatial biases are not errors per se, but reflect adaptations based on expectations (e.g., Chapters 8, 9, 10, 13, 19). In some cases, spatial biases might have been selected for by evolution (e.g., Chapters 8, 10, 12, 19, 23) or reflect recent experience or context (e.g., Chapters 7, 14, 15, 16, 21, 24). In other cases, spatial biases reflect the hierarchical or linguistic organization of spatial knowledge (e.g., Chapters 6, 15, 16, 17, 22, 23) and contributions of language (e.g., Chapter 6) and attention (e.g., Chapters 7, 9, 18, 21). In still other cases, spatial biases reflect crossmodal or multisensory (e.g., Chapters 5, 11) or motor (Chapter 4) influences and an interplay of multiple mechanisms (e.g., Chapters 2, 3, 4, 20). Spatial biases reflect consequences of our neural structure and development (e.g., Chapters 1, 2, 18, 20, 22) and our responses (e.g., Chapters 2, 4, 15, 24), as well as cultural practices (e.g., Chapters 19, 23, 24).

Several different themes emerge across the chapters in this book. One theme is that different spatial biases arise from different causes or combinations of causes, and these causes can range from low-level physiological mechanisms to high-level organization of semantic knowledge and culturally specific learning. A second theme is that some spatial biases appear to provide at least some adaptations for daily functioning; even so, whether other biases provide as yet undiscovered adaptations or were too harmless to be selected against is not clear. A third theme is that consideration of spatial biases can provide useful tools that can yield important insight into the functioning of perception and cognition. A fourth theme is that spatial biases do not just reflect illusions based on a few laboratory artefacts, but permeate much of our everyday perception and cognition. Indeed, such biases are ubiquitous, even if unnoticed, in our everyday experience. Overall, an understanding of the roles and mechanisms of spatial biases is important in a variety of domains and situations in our everyday experience, and the chapters in this book represent important steps toward such an understanding.