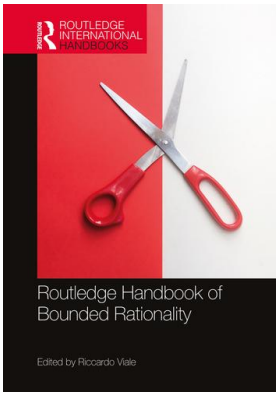

Routledge Handbook of Bounded Rationality

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Seeking rationality

Publication details
https://test.routledgehandbooks.com/doi/10.4324/9781315658353-6
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Published online on: 29 Oct 2020

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SEEKING RATIONALITY

$500 bills and perceptual obviousness

Teppo Felin and Mia Felin

Introduction

The value of a hypothetical $500 bill is obvious. And because it is obvious, "there are no $500 bills on the sidewalk"—if there were, they would already be picked up (Akerlof and Yellen, 1985: 708–709; also see Frank and Bernanke, 2007).

The $500-bill "axiom" provides a useful—albeit informal—shorthand for explaining market efficiency and rational expectations. Metaphorically, everything in the economy could be seen like the proverbial $500 bill. The value of all assets is obvious: everything is correctly labeled, priced and put to its best use (Muth, 1961; cf. Arrow, 1986).[1] This is because "all agents inside the model, the econometrician, and God share the same model" (as discussed by Thomas Sargent, see Evans and Honkapohja, 2005: 566; cf. Buchanan, 1959; Frydman and Phelps, 2013). Agents are omniscient and markets are at equilibrium—put differently, objects signal their own value. This is because there is no heterogeneity in perception or expectations and therefore there are no above-normal, economic profits to be had. If there were, they would largely be a function of luck and thus be quickly competed away (Alchian, 1950; Denrell, Fang, and Winter, 2003).

Behavioral economics has stepped in to fill this vacuum and pointed out many instances where seemingly obvious value is systematically missed or left on the table, whether at the more micro level of judgment, perception, and decision making or at the more macro level of markets (Kahneman, 2003; Thaler, 2015).[2] To put this in terms of the above $500-bill axiom: economic agents may miss valuable and obvious things, like the $500 bill, because they are blind or bounded in some fashion. Bounded rationality thus provides "an alternative to classical omniscient rationality" (Simon, 1979: 357; cf. Kahneman, 2003), helping us understand why we see and attend to some things, but manage to miss and be blind to many other things. Behavioral economics further builds on these ideas (for a recent review, see Lieder and Griffiths, 2019), linking this work to empirical findings of blindness, priming, and bias from psychology and cognitive science (e.g., Bargh and Chartrand, 1999; Simons and Chabris, 1999). This research emphasizes the "prevalence of bias in human judgment" and more generally how humans "can be blind to the obvious" (Kahneman, 2011). Individuals and markets (in the aggregate) seem to routinely violate the axioms of rationality, as obvious things or sources of value are missed. Because of the pervasiveness of these biases and varied forms of boundedness, opportunities

for more optimal decision making and nudging abound (Stanovich et al., 2016; Sunstein and Thaler, 2008; Thaler, 2016).

In this chapter we discuss the outlines of an alternative to both neoclassical and (certain) behavioral conceptions of rationality. Just as Thaler argues "that models of rational behavior became standard because they were the easiest to solve" (2015: 1579), so we argue that behavioral models of rationality have now become standard because omniscience is easy to prove wrong.[3] In short, it is easy to show that people miss obvious things. And just as many economic models build on "bad psychology" (Clark, 1918: 4; Thaler, 2015: 1579), we argue that (some) behavioral models build on a problematic view of perception. We show how certain versions of the bounded rationality concept are built on specific perceptual assumptions: empirical findings of perceptual blindness and deviations from omniscience and full rationality. We discuss problems with the focus on perceptual blindness and value-related obviousness in behavioral economics, specifically in the context of both rational expectations and bounded rationality. We first provide a brief overview of the bounded rationality concept itself, and then discuss its foundations in the psychology of perception (see Kahneman, 2003; Simon, 1955; for a recent discussion see Chater et al., 2018). We revisit key insights from biology and the psychology of perception. We discuss two key issues: (1) perception and the organism-environment relationship; and (2) seeking or "looking for" rationality. We conclude with a discussion of the economic implications of our argument, as these relate to perception, belief heterogeneity and the origins of value in markets.

Economics, bounded rationality, and perception

Herbert Simon introduced bounded rationality as a counterweight to the full rationality presumed by many in economics. His aim was

> to replace the global rationality of economic man with a kind of rational behavior that is compatible with the *access to information* and the *computational capacities* that are *actually* possessed by organisms, including man, in the kind of environments in which such organisms exist".
>
> *1955: 99*

In short, Simon introduced a psychologically more realistic conception of rationality, behavior, and human decision making. Simon's concept of bounded rationality has become a central building block across a wide swath of disciplines, including economics, management, psychology and cognitive science (Chater et al., 2018).

What is important to our arguments in this chapter is that Simon anchored his model of rationality on certain "psychological theories of perception and cognition" (Simon, 1956: 138; cf. Felin, Koenderink, and Krueger, 2017). Simon frequently used the example of an organism searching for something of value, like food, in their environments. An organism naturally is not fully rational or aware in the sense that it knows where the most optimal sources of food might be in its environment (cf. Todd and Gigerenzer, 2003). The organism instead searches for food locally within its immediate, *visible* vicinity. Search activity is driven by the organism's "perceptual apparatus" and its "length and range of vision" (Simon, 1956: 130). The search is never complete, exhaustive, or perfectly optimal—rather, it is bounded. Organisms satisfice based on more proximate aspiration levels, foregoing full optimality and perfect rationality.

The visual and perceptual emphasis associated with Simon's concept of bounded rationality is further reinforced in the work of Daniel Kahneman (cf. Chater et al., 2018).[4] As noted by

Kahneman in his Nobel speech, behavioral economics "[relies] extensively on visual analogies" and visual perception (2003: 1450–1453; also see Kahneman, 2011). While Kahneman builds on Simon's program of research, his focus is even more strongly on the perceptual rather than computational aspects of bounded rationality. He argues that the behavior of organisms is "not guided by what [agents] are able to compute"—central to Simon's approach—"but by what they *happen to see* at a given moment" (Kahneman, 2003: 1469). The argument is that the human visual system is marred by varied forms of blindness and bias, as illustrated by visual illusions, perceptual priming and concepts like inattentional or change blindness (Simons and Chabris, 1999; also see Bargh and Chartrand, 1999). These illusions and forms of blindness also provide the central evidence of the popular press books published by scholars in the cognitive and behavioral sciences (e.g., Chabris and Simons, 2010; Chater, 2018; Kahneman, 2011). The touchstone of this program of research is the suboptimality of much decision making and pervasiveness of bias and blindness. Metaphorically, humans routinely miss (or ignore or don't see) obvious things, like proverbial $500 bills, right in front of them. This has led to a large program of research to try to nudge decision makers toward better judgments and more optimal choices (e.g., Sunstein and Thaler, 2008; Thaler, 2015; Sunstein, Chapter 38 in this volume).

Before discussing the perceptual aspects of this argument, it's worth recognizing that the behavioral program of research has recently been challenged by scholars who have failed to replicate many of the key findings that purport to provide evidence of widespread human irrationality and bias. A significant portion of the empirical studies and evidence used by Kahneman in his bestselling *Thinking, Fast and Slow* has failed to be replicated, or the work has been theoretically questioned in different ways. This includes empirical and theoretical challenges to a number of key biases and fallacies, including the hot hand fallacy (Miller and Sanjurjo, 2018), social and perceptual priming (Crandall and Sherman, 2016; Ramscar, 2016), dual process theory and the idea of System 1 and System 2 thinking (Melnikoff and Bargh, 2018), inattentional and change blindness (Chater et al., 2018; Felin et al., 2019), and so forth. Furthermore, there is also a long-standing argument about whether biases and blindness are rational heuristics, as illustrated by the rationality of the anchoring bias (Lieder et al., 2018) or the rationality of inattention (Matejka and McKay, 2015). This work on heuristics has been pioneered and further developed by Gerd Gigerenzer and his colleagues over the past decades (Gigerenzer and Todd, 1999). Furthermore, the visual illusions that are frequently referenced by behavioral scholars as metaphorical examples of blindness—extended to the context of rationality (see Kahneman, 2003)—have been shown by perception scholars not to be illusions at all (Braddick, 2018; Rogers, 2014). That said, scholars of course are actively debating these issues, and thus it is hard to point to conclusive answers (see van Buren and Scholl, 2018; Rogers, 2019). However, while these debates will undoubtedly continue, the problem is that the evidence for pervasive human bias and blindness is often couched as established, scientific facts to external audiences. For example, related to perceptual priming (a literature currently under severe empirical scrutiny), Kahneman argues that "disbelief is not an option. The results are not made up, nor are they statistical flukes. You have no choice but to accept that the major conclusions of these studies are true" (2011: 57). But in retrospect, it appears that many of these seemingly solid, empirical findings are in fact not as clear-cut and conclusive as previously thought (Felin et al., 2019; for more, see Chater et al., 2018).

In this chapter we set these issues aside and specifically discuss how assumptions about perception are essential for the rationality literature, focusing both on rational expectations and particularly the concept of bounded rationality. We argue that the underlying assumptions about perception (and what should be visually obvious) need to be carefully revisited, as these

apply to varied forms of bounded rationality, judgment and decision making. Thus we make the perceptual assumptions of existing work more explicit and provide the broad outlines of an alternative.

What do we see and why? What's obvious?

Perhaps the simplest question regarding perception is, *what* do organisms (humans included) see and *why*? Or put differently, what is perceptually obvious and why? Humans and other organisms continually encounter stimuli and objects that make up or constitute their visual scene, environment or situation.[5] Some things in the visual scene (somehow) become salient and obvious, while other things remain in the background, perhaps outside awareness. And to complicate things even further, different organisms—or even two different people or organisms looking at the very same visual scene—may also differ in what they perceive. What is it, then, that we see and become aware of, and why?

A simple way to answer the question of "what do we see?" is to point to the physical objects that actually constitute any visual scene itself: the things in front of and surrounding an organism. To provide a practical illustration, you as the reader of this chapter are right now encountering a visual scene. This sentence and the book chapter you are reading are part of your visual scene. But if you lift up your gaze and look around, you will also see other things. If you are in an office, there is likely to be a desk close by, perhaps a lamp or different forms of lighting, some number of chairs, maybe a whiteboard, perhaps art or office decorations on the wall, or some number of books on the shelf. And if you direct your gaze out the window, you might see any number of other things: people walking by on the street, nearby buildings, trees and vegetation, or the sky. In short, your immediate surroundings are teeming with potential things to see, many of them obvious. But the central question here is: why—among the many things right in front of (and around) us—do we see or become aware of *certain* things, and not others?

Before addressing this question, a simple response to the "what do we see?" question is: we see what is actually there. At first glance this approach provides a very straightforward (and in fact prominent) account of perception. It suggests that there should be no mystery when it comes to perception. Perception simply records the physical things in front of (and around) us: a chair, books, computer screen, clouds, and so forth. As put by Marr in his book *Vision*, vision is a "true description of what is there" (1982: 29–30; cf. Hoffman et al., 2015). Perception then is seen as a catalogue of actual objects, things and stimuli in front of us. This in fact is the implicit assumption of wide swaths of vision science, such as ideal observer theory (Geisler, 2011), psychophysics (Kahneman, 1966; for a recent review, see Kingdom and Prins, 2016), and Bayesian approaches to vision (Kersten et al., 2004; Yuille and Kersten, 2006). More generally, this veridical approach to perception is the foundation of many (if not most) contemporary theories of vision and perception (for a review, see Hoffman et al., 2015).

One problem with this veridical, catalogue, or camera-view of perception is that it is impractical (Chater et al., 2018). Listing or capturing all of these stimuli and objects not only is not necessary or useful, but also impractical and impossible. This idea in fact metaphorically provides the visual equivalent of bounded rationality, which is that listing and accounting for all the obvious visual things in front of us would both take too much time and also defeat the very purpose of perception (or rationality) itself. Or put differently, everything is not recognizable or computable or listable, given limited resources or time. This then might yield a conception of perception as a defective camera, compared to a more omniscient ideal that somehow captures everything. But beyond this problem, a more essential issue is that the camera-view of

perception doesn't tell us *which* of the many possible things in our visual scenes are salient and why. That is, why do we become aware of certain objects or stimuli and not others? Again, the problem is that visual scenes are teeming with "things:" potential objects, stimuli and cues. The fact that we miss some things, even obvious ones, might of course be the basis of calling humans blind (Simons and Chabris, 1999). Or more productively, it might be the basis of developing a theory of *why* we become aware of some things and not others.

This is where Kahneman (2003) and the behavioral program of research build on psychophysics, which focuses on salience as a function of the actual nature of particular stimuli or cues themselves. What is seen by organisms is tied to the actual, physical nature of environments confronted by organisms and agents. As put by Kahneman, "the impressions that become accessible in any particular situation are mainly determined, of course, by the *actual properties* of the object of judgment," and "physical salience [of objects and environments] *determines* accessibility" (2003: 1453, emphasis added). Importantly, some stimuli, impressions and objects are more readily accessible than others. Here Kahneman argues that these perceptual objects become salient and accessible because they have particular characteristics, such as their "size, distance, and loudness" (2003: 1453). To simplify and illustrate: a large, proximate, and "loud" stimulus or object is more readily seen, and thus obvious, compared to a small, distant, and "quiet" object. Kahneman calls these "natural assessments" (Kahneman, 2003; also see Kahneman and Frederick, 2002; Tversky and Kahneman, 1983). Visually salient objects are more readily and quickly attended to because of these stimulus characteristics. Stimulus characteristics make certain things "stand out" and become more prominent and thus visually accessible. The list of stimulus characteristics (beyond size, etc.) also includes "more abstract properties such as similarity, causal propensity, surprisingness, affective valence, and mood" (Kahneman, 2003, p. 1453). Thus this program of research offers some practical predictions arguing that certain, actual characteristics of stimuli (again, size being a particularly salient one) determine whether we see them or not.

Though the heuristics program of research disagrees with Kahneman about whether biases in fact are rational heuristics (see Gigerenzer and Goldstein, 1996; Gigerenzer and Todd, 1999), there are surprising commonalities between these two behavioral programs of research. Namely, the emphasis in the heuristics program of research is also on perception and the nature of stimuli themselves. The central construct of the heuristics program of research is an environment or perceptual "cue." Thus in their summary of the heuristics stream of research, Gigerenzer and Gaissmaier (2011) emphasize varied factors related to environmental and perceptual cues. These include "the number of cues," "cue weighting," "the correlation of cues," "cue validity," "cue addition," "the search through cues," "positive cues," "cue value," "cue ordering," "cue redundancy," "cue correlation," "cue integration," "cue combination," " cue favoring," and so forth (also see Gigerenzer and Goldstein, 1996).

Cues within the heuristics program of Gigerenzer then serve the equivalent function to Kahneman's stimulus characteristics and natural assessments. Thus in many ways, the ecological rationality sub-area of behavioral economics—pioneered by Gigerenzer and others—links with the areas of psychophysics and inverse optics which focus on perception as a function of stimulus intensity, similarity, repetition, exposure, thresholds, and signal detection (see Kingdom and Prins, 2016). This is also the basis of Bayesian views of perception (Knill and Richard, 1996), which have also had a strong influence on the bounded rationality and cognition literatures (e.g., Chater et al., 2010; Oaksford and Chater, 2007). And a similar type of emphasis on stimuli and cues can also readily be found in other areas of psychology and cognitive science, such as the situation construal and situation perception literatures (e.g., Rauthmann et al., 2014; also see Chater et al., 2018; Funder, 2016). In sum, the behavioral program in psychology and

economics implicitly makes the assumption that the nature of stimuli (Kahneman, 2003) or the nature of cues (Gigerenzer and Gaissmaier, 2011) determines perception and obviousness. In the case of Kahneman, what we see is a function of (for example) how large or proximate something is. And in the case of Gigerenzer and others, cues are simply given and their varied structure (ordering, aggregation, combination, etc.) are essential for salience and perceptual awareness.

In an important sense these conceptions of rationality don't—ironically, similar to the rational expectation model of economics—meaningfully require any assumptions about the organism itself. That is, the architecture of cognition is general (Anderson, 2013). The models assume an objective conception of the environment (which has particular visual or statistical features), and organisms then have some kind of delimited, bounded, or biased view of their environment, or a view that is proximate and good enough to satisfice. This environmental focus is also captured by Simon who argued that "an ant [or human being], viewed as a behaving system, is quite simple. The apparent complexity of its behavior over time is largely a reflection of the complexity of the environment in which it finds itself" (1981: 63–65; also see Anderson, 2013). The arguments, then, are species-independent and universal (Simon, 1980), as suggested by Simon's reference to organisms in general, whether we are talking of ants or human beings. This also can be related to behavioral models in psychology that similarly encouraged scientists to move away from studying organisms but environments instead. Schwartz, for example, argued that "if you want to know why someone did something, do not ask. Analyze the person's immediate environment until you find the reward" (1978: 6). Furthermore, the universality of these arguments is reflected in how broadly these models of bounded rationality are applied, across different species and even computers. Simon argued that "since Homo Sapiens *shares some important psychological invariants* with certain nonbiological systems—the computers—I shall make frequent reference to them also" (1990: 3, emphasis added). Thus the notion of bounded rationality is more generally applied to any form of search and foraging (Abbott et al., 2015; Fawcett et al., 2014; Gershman et al., 2015).

An important wrinkle with the behavioral program of research is the fact that humans and other organisms seem to be visually blind to things that should be readily obvious—obvious given the nature of the stimuli or cues. That is, something that is large, and right in front of an organism, directly in its visual field, should be obvious (as predicted by the theory). But somehow organisms, humans included, are seemingly blind to any number of large things. Our visual scenes feature various obvious things—obvious in terms of their characteristics—but somehow we nonetheless appear to miss them. The highly-cited, classic example of this is Simons and Chabris's (1999) study of inattentional blindness, where a person dressed in a gorilla suit walks across a visual scene and many experimental subjects never see the gorilla. This is surprising, because the gorilla has many of the hallmarks of a stimulus or cue that in fact ought to make it highly salient, including the fact that it is large. Of course, in some sense these types of findings question the very idea that perception is a function of stimulus characteristics (cf. Felin et al., 2019). Next we provide an alternative way of viewing these types of findings, which we think can account for them, and also shed light on the question of bounded rationality in the context of judgment and decision making in economics.

To summarize and briefly return to the subheading of this section of our chapter—what do we see and why?—the predominant emphasis in the behavioral program has been on the nature of stimuli and cues in the immediate environment of organisms. This argument certainly is, in some ways, an improvement over rational expectations, which, in effect, presume visual omniscience. The bounded rationality literature seems to have provided a psychologically more realistic conception of perception and rationality. But next we seek to suggest some extensions

and alternatives. In short, we argue that the question of "what do organisms see and why" can be answered differently and that this has important implications for how we think about human rationality and decision making in economic and social settings.

Perception and rationality

Insights from psychology and biology

In this section we consider some alternative ways to understand perception and rationality. We specifically discuss two key points: (1) perception and the organism-environment relationship; and (2) seeking or "looking for" rationality.

Before proceeding, it is worth noting that that we strongly concur with Gigerenzer and Selten's notion that "visions of rationality do not respect disciplinary boundaries" (2001: 1). This interdisciplinarity certainly was evident in the pioneering work of Herbert Simon, whose oeuvre included everything from psychology, management to computer science and beyond. And, of course, behavioral economics is strongly anchored on Kahneman's (2003) emphasis on and contributions in psychophysics (cf. Kahneman, 1966)—along with providing extensive links to psychology (Thaler, 2015)—and the attendant implications of all this for judgment and decision making. Thus we also draw insights from other literatures, specifically from the psychology of perception and biology.

Perception and the organism-environment relationship

In the literature on bounded rationality there is a strong emphasis on the nature of environments and their role in shaping or determining behavior. The argument is that we can "discover, by a careful examination of some of the fundamental structural characteristics of the environment... the mechanisms used in decision making" (Simon, 1956: 130). This focus on the environment is reflected in the aforementioned comment by Simon, namely, that the "apparent complexity of [organism] behavior over time is largely a reflection of the complexity of the environment in which it finds itself" (1969: 65–66; also see Simon, 1990). This is also evident in the analogy between visual scenes and environments, the idea that agent behavior is guided "by what they happen to see at a given moment" (Kahneman, 2003: 1469). For example, Kahneman extensively uses evidence from perceptual priming to make this point (2011: 52–68), and it is this literature that argues that "the entire environment-perception-behavior sequence is automatic, with no role played by conscious choice in producing the behavior" (Bargh and Chartrand, 1999: 466). The emphasis on the environment is equally explicit in the literature on ecological rationality, though the emphasis is somewhat different. Gigerenzer and Gaissmaier (2011) argue that environments (and their structures) are characterized by specific factors: the uncertainty, redundancy, sample size and variability of cues. The upshot is that environments are treated as objective and species-general (for a recent discussion, see Chater et al., 2018), thus leading to universal models that are said to account for rationality across species (cf. Gershman et al., 2015; Simon, 1990).

From a biological point of view, the notion that environments are general and can be objectively characterized is problematic. This is because cues and stimuli are *specific* to organisms (Koenderink, 2014). That is, what an organism attends to (or as we'll discuss, looks *for*) depends on the nature of the organism itself. This creates a confound in the organism-environment distinction. Certainly, scholars are likely to admit that organisms differ, as do their respective environments. But the problem is that these differences have not been meaningfully articulated

or discussed (Chater et al., 2018).[6] And this species-specificity also fundamentally changes how we think about perception, and by extension, rationality.

The fields of ethology and comparative biology offer the best evidence for the fact that environments are species-specific rather than general (Tinbergen, 1963; for a recent review, see Burkhardt, 2018). Each organism has its own, unique "Umwelt" (surrounding world), where awareness and perception are a function of the nature of the organism itself (Uexküll, 2010). To provide a specific example, frogs may not see a juicy cricket or locust (their food) even if it is directly in front of them (Ewert, 1987). Thus an analysis of what *ought* to be salient or valuable to an organism based on any *general* stimulus characteristics will not tell us what it is actually aware of. We might of course label the frog blind or biased, but this merely creates a black box rather than meaningfully explaining what the frog sees and why. Thus the *a priori* selection of what should be obvious—in the presence of any number of other stimuli in a scene—cannot generate a scientific explanation. It turns out that frogs are visually attuned to movement and thus will snap as soon as the cricket or locust jumps. This highlights that what "stimulates"—or which cues become salient and naturally assessed (cf. Kahneman, 2003)—has less to do with the stimulus itself (or the objective or general "amount" of some cue (Gigerenzer and Gaissmaier, 2011). Rather, awareness of particular stimuli has more to do with the nature of the organism (Ewert, 1987). Only those stimuli or cues that are species-specific "light up," or are processed and attended to, while many other things are ignored.[7]

The notion that stimuli are specific to organisms changes the way we need to study the organism-environment relationship. It means that the mechanisms behind the organism-environment interaction are unique to each species, thus raising questions about species-general models (Chater et al., 2018), including extensions into the domain of bounded rationality.[8] This work was pioneered by ethologists, comparative biologists, like Niko Tinbergen and Konrad Lorenz, whose work was linked to Jakob von Uexküll. Uexküll metaphorically conceived of the species-specific environment as "a soap bubble around each creature to represent its own world, filled with the perception which it alone knows" (2010: 117). He argued that "every animal is surrounded with different things, the dog is surrounded by dog things and the dragonfly is surrounded by dragonfly things"—that is, "each environment forms a self-enclosed unit, which is governed in all its parts by its meaning for the subject" (2010: 5). These biological models didn't somehow disagree with broader evolutionary processes that might impact species at the level of populations. But this literature was highly attuned to the more proximate, immediate considerations that shape species behavior and perception (Tinbergen, 1963), and thus also provide useful insights for human settings. Thus the goal here isn't to engage in any form of "species chauvinism" (Winter, 2012)—in fact, quite the opposite—rather to merely point out species-specific factors that impact perception.

Seeking or "looking for" rationality

As we've discussed above, perceptual relevance and meaning for the behavioral program are driven by environmental characteristics, by the inherent and objective nature of objects and stimuli. Our suggested alternative focuses on the relevance and meaning that organisms themselves bring to encounters with environments. Perception, in some sense, is driven by what an organism has "in mind," what it considers relevant and meaningful for specific purposes.[9] Not only are environments specific, as discussed above, but organisms have species-specific factors that direct their perception and behavior toward certain ends and toward the selection of certain stimuli.

A powerful way to understand organism awareness and perception is by studying what the organism is searching or looking for. This "looking for"-activity is guided by a species-specific "Suchbild" (Uexküll, 2010; cf. Chater et al., 2018), a German word for search or seek image. Search images are the equivalent of what an organism has in mind, in terms of an "answer" that the organisms is looking for to satisfy its search. Frogs, for example, when hungry, are looking for certain, line-like features that move in their environment. Their behavior is motivated and directed by this search-image, and awareness is directed toward highly specific things (or what might be called answers). This "looking for"-activity comes at the expense of any number of other, obvious things that an organism might have right in front of it.

In the case of humans, the relevant search image is given by what is in the head or mind of the human actor when encountering a visual scene or situation. If you are searching for your keys, you are keenly attuned to key-like stimuli or features. Relevance and meaning are provided by the question that you have in mind, and the task that you are engaged in. This Suchbild or question might be seen as the most basic form of a heuristic. As noted by Polanyi, "the simplest heuristic effort is to search *for* an object you have mislaid" (1957: 89). Note that this "search for"-heuristic is fundamentally different from the heuristics that emphasize, say, the nature of stimuli themselves or the number of cues (Gigerenzer and Gaissmaier, 2011).[10] When scanning a room for your keys, you are ignoring vast numbers of stimuli (including obvious ones) and selectively directing awareness toward possibly relevant cues based on the "key search image" you have in mind. Note that the keys are not somehow inherently visually salient, as they are small and thus do not attract attention or awareness due to their size (as suggested by psychophysics). In searching for keys—or anything else for that matter—we ignore an indefinite number of other, perhaps obvious and large, things around us. We also do not individually "attend to" each item in our visual scene to decide whether it is the key or not. Rather, we only focus on and select key-like visual stimuli. We concentrate on the problem, question and task at hand: searching for keys. This type of motivated searching or "looking for"-activity is impossible to account for from the perspective of psychophysics or a world-to-mind oriented view of perception. In psychophysics there is no meaning or relevance (Felin, Koenderink, and Krueger, 2017; Koenderink, 2012), there are only objective stimuli and cue characteristics (Chater et al., 2018; Gigerenzer and Gaissmaier, 2011).

Any number of empirical findings from the cognitive sciences can readily be re-interpreted with this Suchbild-oriented or "looking for"-lens, especially any work that purports to provide evidence of human blindness (e.g., Simons, 1999); Simons and Rensink, 2005). That is, the *reason* that humans miss large changes or objects in their visual scene is, simply, because they have something else in mind. To put this colloquially: humans miss certain things because they are looking for other things. The problem with the empirical studies of human blindness is that they often deliberately *distract* experimental subjects (asking them to engage in some irrelevant task or answer a particular question), and then point out something that is large and blatantly obvious but missed, such as a gorilla (Felin, Felin, Krueger, and Koenderink, 2019). In other words, in these perceptual experiments, humans are effectively given a question or Suchbild of what to look for (whether counting basketball passes or engaging in other tasks), which distracts them, and therefore they miss large changes or objects. Visual scenes, of course, are teeming with many blatantly obvious things. But no progress will be made in understanding perception and rationality without focusing on the Suchbilds that direct human perception, or without a focus on the things that human actors are looking for.

What humans have "in mind" can be accounted for in many ways. Perception might be directed by a problem or question, such as the aforementioned example of looking for one's keys. Or perception might be directed by a task, such as getting to some location (or counting

basketball passes (Simons and Chabris, 1999). But again, it's hard to argue that people are "blind to the obvious" (Kahneman, 2011: 23–24), as visual scenes are teeming with obvious things. And perhaps most relevant to the economic context (discussed further in the next section) is the idea that perception might be directed by a hypothesis or theory that a human has in mind. This is aptly captured by Popper who argued that "we learn only from our hypotheses what kind of observations we ought to make: whereto we ought to direct our attention: wherein to take interest" (1966: 346). This also goes for science: that is, salience is given by what we are theoretically looking for. As noted by Einstein, "whether you can observe a thing or not depends on the theory which you use. It is the theory which decides what can be observed" (Polanyi, 1971: 604). Thus whether we are talking about the labs of behavioral economics, or encounters with visual scenes in the real world, we have implicit questions or theories about what these respective situations or scenes are about, and these then direct our perception and awareness. In all, the upshot of this discussion is that organism- and theory-dependent factors structure awareness and perception, with important implications for how we think about rationality, judgment and decision making in economic and social settings as well.

Rationality and the perception of value

Opportunities and caveats

Next we discuss the economic implications of the arguments above. We also provide some important caveats. Our overall goal with this concluding section is to link the aforementioned discussion of perception and obviousness to central questions of rationality and belief heterogeneity in economic settings, as well as the idea of economic value. We make two points.

First, axiomatic assumptions about the human mind are important. As put by Simon, "nothing is more fundamental in setting our research agenda and informing our research methods than our view of the *nature* of the human beings whose behavior we are studying" (1985: 303). Thus if our theoretical "priors" about human nature are largely focused on the "prevalence of bias in human judgment" (Kahneman, 2011), then we are likely to simply focus on this, at the expense of other things. But the cost of this is that we will likely miss many other, more positive aspects of rationality and the human mind. Thus the psychology that behavioral scholars have imported into economics has been relatively one-sided—perhaps deliberately "putting in a stake" at the very opposite extreme from omniscience: rampant bias and blindness. The concern is that these bias-oriented priors—a form of scientific confirmation bias—will lead to the construction of studies that continue to show further instances of bias and blindness, deviations from omniscience. But as mentioned at the outset, providing evidence of shortfalls from omniscience is all too easy and convenient (cf. Thaler, 2015). Much of the evidence for bias may reflect a bias on the part of scholars toward fun, surprising and easy studies that prove irrationality (Krueger and Funder, 2004). This work has also led to a widespread public perception that bias and blindness are rampant problems and key features of the human mind, as suggested by popular books written by cognitive scientists (e.g., Chater, 2018; Chabris and Simons, 2010). Now, of course, humans make mistakes and errors. But the obsession with those errors has led to a rather one-sided sampling of psychology in the context of economics. Furthermore, the focus on biases and irrationality will not allow us to account for the fact that we live in the best of times, at least when it comes to any number of objective, measurable dimensions, including radical declines in poverty across the globe, exponential growth in human knowledge and staggering technological and economic progress (e.g., Pinker, 2018).

The behavioral program sees itself as an heir to Adam Smith's program of research in economics, in reintroducing a more realistic version of psychology to economics (Thaler, 2016; also see Ashraf, Camerer, and Loewenstein, 2005). But it's hard to see how the rich ways in which Smith delved "into the sentiments and mind of actors" can be squared with the strong focus on bias and irrationality. A careful re-reading of *The Theory of Moral Sentiments* or *The Wealth of Nations* shows that Smith's program of research was far more expansive and positive (Rothschild, 2013). His assumptions about human nature and the mind certainly didn't suggest any form of omniscience on the part of economic agents, as behavioral scholars rightly have pointed out. But Adam Smith certainly was not as error-oriented when discussing human nature and the human mind. In fact, he sought to endow economic actors with the same theoretical and creative capacities that we as scientists have. Adam Smith's program of research might be summarized as an effort to develop—as put by economic historian Emma Rothschild—"a theory of people with theories" (2013: 157). This suggests a radically different agenda from one that focuses on the "prevalence of bias in human judgment" (Kahneman, 2011; Thaler, 2015). This type of sentiment was also channeled by Edith Penrose in *American Economic Review* when she argued: "For the life of me I can't see why it is reasonable (on grounds other than professional pride) to endow the economist with this unreasonable degree of omniscience and prescience and not entrepreneurs" (1952: 813). Of course, no one is arguing that omniscience is psychologically or cognitively a defensible view. But allowing human agents a modicum of rationality, of a very specific type, given the uncertain and fast-paced situations they find themselves in, provides a useful way forward.

Thus an important next step is to develop models that assume that the human agents we study might in fact have some of the same theoretical capacities that we scientists do. Namely, humans have the ability to theorize, to ask questions, to pose and solve problems. There are major strands of psychology to support this view. For example, the work of William James (1912) is filled with psychological insights about rationality and how individuals navigate uncertain environments and the role that their beliefs play in doing so. More generally, there is important research in psychology and the cognitive sciences on the generative capacities of humans in the presence of impoverished stimuli and uncertain environments (Spelke et al., 1992; for a review, see Felin, Koenderink, and Krueger, 2017). All of this psychological and cognitive research deserves to be integrated into the context of judgment and decision making in economic settings. Glimmers of this approach can in fact be found in some pockets of economics and adjacent fields like management. For example, Karni and Vierø (2013) discuss the role of "growing awareness" (what they call reverse Bayesianism) in uncertain, economic environments. Eric Van den Steen (2016) discusses the role of beliefs and managerial vision in markets and in the strategy of firms. And Felin and Zenger (2017) highlight how heterogeneous managerial beliefs and theories shape markets, the emergence of firms and the origins of economic value. Firms, from this perspective, can be seen as representing a unique beliefs or "point of view" about what to do and how to structure production (Coase, 1937; King et al., 2010). Others have looked at the role of entrepreneurial judgment (Foss and Klein, 2015) or attention (Ocasio and Joseph, 2017) in the context of markets and organizations. And scholars within the domain of bounded rationality have discussed such concepts as creativity (Viale, 2016) and the wisdom of heuristics in guiding behavior in uncertain settings (Grandori, 2010).

Of course, in some sense, our arguments might be seen as creating a caricature of behavioral economics and the emphasis it places on the negative aspects of human nature and mind. There are important exceptions to our characterization. Herbert Simon's work in particular is brimming with insights that deserve more careful attention, beyond what we have discussed

here. For example, throughout much of Simon's work there is an emphasis on problem-solving and goals (Simon, 1964). The specification of problems and goals indeed seems to provide a possible foundation for the type of organism-oriented conception of perception and rationality that we have discussed in this chapter. However, unfortunately the literature on problem-solving and goals has not been meaningfully incorporated into discussions of bounded rationality in cognitive science or behavioral economics (Chater, 2018; Kahneman, 2003, 2011; Thaler, 2016).

A second implication of our arguments about perception relates to the informal $500 bill-axiom we discussed at the beginning of this chapter. In some sense, the $500 provides an intriguing litmus test for explaining rational expectations and bounded rationality. The $500 bill, of course, is a rather strange example, because it hardly provides a useful proxy for discussing the vast set of possible objects and assets that might have value in economics settings. After all, the $500 bill is clearly labeled: we know what it is worth. In most economic cases of interest, value is scarcely obvious. Most things of (possible) value are rarely labeled, and there is likely to be significant disagreement about their worth. The set of possible uses for objects and assets is, quite simply, unlistable and unprestatable (Felin et al., 2016). And importantly, most of the valuable assets and activities we observe in markets require (or were the result of) some form of long-run organization and production. Thus casual references to market efficiency, using the $500 bill as an example, vastly oversimplify the economic problem. And experiments that show that humans miss obvious things, while interesting, miss the opportunity to develop theories of how truly novel value is identified, produced and organized in the first place. Thus a focus on heterogeneous perceptions, beliefs, hypotheses and theories can provide a powerful tool for explaining value in firms and markets.

When economists do in fact focus on beliefs, the focus is usually on self-fulfilling prophecies where *irrational* beliefs and delusions lead to bubbles or market collapse (e.g., Gennaioli and Shleifer, 2018; Shiller, 2015). The human psychology that is applied to study markets is about "animal spirits," wrong-headed beliefs, and illusions, which are largely used to explain negative outcomes (Akerlof and Shiller, 2010; Shiller, 2017). This type of work of course has its place. But what about the obverse? That is, what about cases where beliefs appear to be delusional (perhaps even to a large number of market constituents, including experts), or where there is significant heterogeneity and ambiguity, but these beliefs and ideas nonetheless become realities and generate value (cf. Soros, 2013; van den Steen, 2016)?[11] These types of heterogeneous beliefs and opinions ought to be at the very heart of understanding markets and value creation.[12] It seems that the fascination with delusion or bias has led us to lose track of the type of heterogeneity that animates markets and provide the underlying engine of economic growth. That is, despite biases and irrational beliefs, we nonetheless witness continued technological progress and ongoing economic growth. A central problem is that public markets and many investors have a hard time assessing uniqueness and value (Benner and Zenger, 2016; Zuckerman, 1999), thus raising questions about the obviousness of value and more general market efficiency and rationality. Again, beliefs that appear to be delusional or wrong-headed (to some, including experts and savvy market actors), somehow generate what later becomes obvious economic value. Some beliefs, ones that objectively looked impossible, become realities as new organizations are formed and certain market actors gravitate toward and invest in what (to others) appear to be excessively risky and implausible investments. Of course, there are no "rules for riches" here. But we think that our earlier discussion of heterogeneous perception and beliefs might provide some useful, scientific and empirical starting points for this type of analysis for understanding the origins and nature of economic value.

Conclusion

The aim of this chapter has been to discuss different forms of rationality—rational expectations and bounded rationality—and to make explicit the underlying assumptions that are made regarding perception, obviousness, and economic value. We discuss how insights from biology and the psychology of perception might provide the preliminary foundations of an alternative. We specifically emphasize the species-specific nature of both environments and what organisms are "searching for," suggesting central mechanisms for explaining judgment and decision making in uncertain environments. We conclude by offering some high-level remarks and possible extensions to our argument, specifically by focusing on perception, belief heterogeneity and the origins of value in markets.

Acknowledgments

An early version of this chapter was presented at the 2018 University of Oxford workshop "Science, Humanity and Meaning." The authors appreciate helpful conversations with and feedback from George Ellis, Thomas Fink, Seth Jenson, Stuart Kauffman, Aaron Reeves, Riccardo Viale, and Mark Wrathall. This chapter extends joint work published in *Psychonomic Bulletin and Review* and *Perception* with Jan Koenderink and Joachim Krueger. Any errors are our own.

Notes

1 Of course, value may not be obvious to everyone immediately, in the short run. But in the long-run—as agents search, adapt, compete, and learn (e.g., Bray and Savin, 1986; Lucas, 1986)—even semi-efficient markets will ensure that obvious value will be competed away as agents interact.

2 For more macroeconomic discussions of value and "bills left on the table," see Clemens (2011) and Olson (1996).

3 In his book on behavioral psychology and economics, Richard Thaler recounts what the psychologist Thomas Gilovich said to him: "I never cease to be amazed by the number of convenient null hypotheses economic theory has given you" (2015: 97). Of course, the notion that something is easy or convenient should not be seen as a put-down, just as Thaler argues that his comment about neoclassical economics isn't a put-down (2015: 1579). Both omniscient and behavioral approaches to rationality have certainly been useful and led to progress in our understanding of economic activity.

4 The research on bounded rationality has generated varied, proximate literatures and concepts including "computational rationality" (Gershman et al., 2015), "algorithmic rationality" (Halpern and Pass, 2015), "Bayesian rationality" (Oaksford and Chater, 2007), resource-rational analysis (Griffiths et al., 2015), and bounded awareness (Chugh and Bazerman, 2007). These literatures are closely related and roughly feature similar underlying assumptions about perception (for a recent discussion, see Chater et al., 2018; Felin, Koenderink, and Krueger, 2017).

5 Depending on one's theoretical sub-field, there are significant differences in how scholars treat situational perception versus scene statistics versus visual fields versus, and so forth (cf. Chater et al., 2018). For the purposes of this chapter, we simply utilize the language and intuition developed by Simon (1955) and Kahneman (2003), though we also build some links to existing vision research that provides an alternative (Koenderink, 2012).

6 Intriguingly, there is a brief, early recognition of this by Herbert Simon (cf. Felin, Koenderink and Krueger, 2017). Simon argues that "we are not interested in describing some physically objective world in its totality, but only those aspects of the totality that have relevance as the 'life space' of the organisms considered" (1956: 130). Our question, then, has to do with this "life space," and specifically its unique features relative to the organism in question. This organism-specific line of argument has subsequently not received attention (see Chater et al., 2018).

7 An additional bit of evidence for species-specificity comes from the idea of supernormal stimuli (Barrett, 2010; Hoffman et al., 2015). Supernormal stimuli are stimuli that are disproportionately attractive or salient to specific species. Thus certain birds may try to hatch a volleyball, because of its large size, preferring it over their own eggs. Or, a specific beetle in Australia (*Julodimorpha bakewelli*) nearly became extinct as discarded beer bottles became a supernormal stimulus for the male beetle, who tried to copulate with the bottle (the nodules or glass beads on the bottle were highly attractive to the beetle). Thus species have built-in instincts for specific perceptual aspects of their environments.
8 For related points, about embodied cognition, see Gallese et al. (Chapter 23 in this volume).
9 We are of course using "in mind" merely as informal shorthand for any number of endogenous, species-specific factors behind perception and behavior. Our discussion of "Suchbild" provides an overall way of capturing this notion. Though, as we discuss, this Suchbild (or what is "in mind," what an organization might be looking for) captures a number of disparate factors such as internal drives and motivations, as well as the questions, problems or tasks that organisms impose on environments.
10 Perhaps the closest idea to this might be the so-called "one reason"-heuristic suggested by Gigerenzer and colleagues (1999). However, the one reason heuristic is also explicitly tied to cue characteristics—such as cue order, or other ideas like stopping rules—and thus is hard to directly square with the more Suchbild-oriented approach suggested in this chapter.
11 Interestingly, some scholars have recently begun to recognize this issue under the guise of discussing the role of "narratives," which shape the attention, motivations, predictions and behavior of economic actors (see Akerlof and Snower, 2016).
12 The idea of knowledge as "justified true belief" and the social processes of belief justification (Goldman, 1999) create an interesting puzzle for value creation in the context of uncertain economic environments. That is, economic value is inherently created where there are disparate and conflicting beliefs about what the relevant possibilities and facts are (for further discussion, see Felin and Zenger, 2017). Thus the social mechanisms and "scaling" of beliefs (from some subjective state to a more objective one)—and where justification happens on the basis of working toward belief realization and mobilizing others—provide an interesting opportunity for future work.

References

Abbott, J. T., Austerweil, J. L., and Griffiths, T.L. 2015. Random walks on semantic networks can resemble optimal foraging. *Psychological Review*, 122(3), 558–569.

Akerlof, G. A., and Shiller, R. J. 2010. *Animal spirits: How human psychology drives the economy, and why it matters for global capitalism*. Princeton, NJ: Princeton University Press.

Akerlof, G. A., and Snower, D. J. 2016. Bread and bullets. *Journal of Economic Behavior & Organization*, 126, 58–71.

Akerlof, G. A., and Yellen, J. L. 1985. Can small deviations from rationality make significant differences to economic equilibria? *American Economic Review*, 75(4), 708–720.

Alchian, A. A. 1950. Uncertainty, evolution, and economic theory. *Journal of Political Economy*, 58(3), 211–221.

Anderson, J. R. 2013. *The architecture of cognition*. New York: Psychology Press.

Arrow, K. 1986. Rationality of self and others in an economic system. *Journal of Business*, 59, 385–399.

Arrow, K., and Debreu, G. 1954. Existence of an equilibrium for a competitive economy. *Econometrica*, 22, 265–290.

Ashraf, N., Camerer, C. F., and Loewenstein, G. 2005. Adam Smith, behavioral economist. *Journal of Economic Perspectives*, 19(3), 131–145.

Bargh, J. A., and Chartrand, T. L. 1999. The unbearable automaticity of being. *American Psychologist*, 54(7), 462.

Barrett, D. 2010. *Supernormal stimuli: How primal urges overran their evolutionary purpose*. New York: WW Norton & Company.

Benner, M. J., and Zenger, T. 2016. The lemons problem in markets for strategy. *Strategy Science*, 1: 71–89.

Braddick, O. 2018. Illusion research: An infantile disorder? *Perception*, 47(8), 805–806.

Bray, M. M., and Savin, N. E. 1986. Rational expectations equilibria, learning, and model specification. *Econometrica: Journal of the Econometric Society*, 54(5), 1129–1160.

Buchanan, J. M. 1959. Positive economics, welfare economics, and political economy. *The Journal of Law and Economics*, 2, 124–138.

Burkhardt, R. W. 2018. *Patterns of behavior, Konrad Lorenz, Niko Tinbergen, and the founding of ethology*. Chicago: University of Chicago Press.

Chabris, C., and Simons, D. 2010. *The invisible gorilla: And other ways our intuitions deceive us*. New York: Random House.

Chater, N., Felin, T., Funder, D. C., Gigerenzer, G., Koenderink, J. J., ... Stanovich, K. E. 2018. Mind, rationality, and cognition: An interdisciplinary debate. *Psychonomic Bulletin & Review*, 25(2), 1–34.

Chater, N., Oaksford, M., Hahn, U., and Heit, E. 2010. Bayesian models of cognition. *Wiley Interdisciplinary Reviews: Cognitive Science*, 1(6), 811–823.

Chugh, D., and Bazerman, M. H. 2007. Bounded awareness: What you fail to see can hurt you. *Mind & Society*, 6(1),1–18.

Clark, J. M. 1918. Economics and modern psychology. *Journal of Political Economy*, 26(1), 1–30.

Clemens, M. A. 2011. Economics and emigration: Trillion-dollar bills on the sidewalk? *Journal of Economic Perspectives*, 25(3), 83–106.

Coase, R. H. 1937. The nature of the firm. *Economica*, 4(16), 386–405.

Crandall, C. S., and Sherman, J. W. 2016. On the scientific superiority of conceptual replications for scientific progress. *Journal of Experimental Social Psychology*, 66, 93–99.

Denrell, J., Fang, C., and Winter, S. G. 2003. The economics of strategic opportunity. *Strategic Management Journal*, 24(10), 977–990.

Evans, G. W., and Honkapohja, S. 2005. An interview with Thomas J. Sargent. *Macroeconomic Dynamics*, 9(4), 561–583.

Ewert, J. P. 1987. Neuroethology of releasing mechanisms: Prey-catching in toads. *Behavioral and Brain Sciences*, 10(3), 337–368.

Felin, T., Felin, M., Krueger, J. I., and Koenderink, J. 2019. On surprise-hacking. *Perception*, 48(2), 109–114.

Felin, T., Kauffman, S., Mastrogiorgio, A., and Mastrogiorgio, M. 2016. Factor markets, actors and affordances. *Industrial and Corporate Change*, 25(1), 133–147.

Felin, T., Koenderink, J., and Krueger, J. I. 2017. Rationality, perception, and the all-seeing eye. *Psychonomic Bulletin & Review*, 24(4), 1040–1059.

Felin, T. , and Zenger, T. R. 2017. The theory-based view: Economic actors as theorists. *Strategy Science*, 2(4), 258–271.

Foss, N. J., and Klein, P. G. 2015. Introduction to a forum on the judgment-based approach to entrepreneurship: Accomplishments, challenges, new directions. *Journal of Institutional Economics*, 11(3), 585–599.

Frank, R. H., and Bernanke, B. 2007. *Principles of microeconomics*, 3rd ed. London: McGraw-Hill Irwin.

Frydman, R., and Phelps, E. S. (Eds.) 2013. *Rethinking expectations: The way forward for macroeconomics*. Princeton, NJ: Princeton University Press.

Funder, D. C. 2016. Taking situations seriously: The situation construal model and the Riverside Situational Q-Sort. *Current Directions in Psychological Science*, *25*(3), 203–208.

Geisler, W. S. 2011. Contributions of ideal observer theory to vision research. *Vision Research*, 51(7), 771–781.

Gennaioli, N., and Shleifer, A. 2018. *A crisis of beliefs: Investor psychology and financial fragility*. Princeton, NJ: Princeton University Press.

Gershman, S. J., Horvitz, E. J., and Tenenbaum, J. B. 2015. Computational rationality: A converging paradigm for intelligence in brains, minds, and machines. *Science*, 349(6245), 273–278.

Gigerenzer, G., and Gaissmaier, W. 2011. Heuristic decision making. *Annual Review of Psychology*, 62, 451–482.

Gigerenzer, G., and Goldstein, D. G. 1996. Reasoning the fast and frugal way: Models of bounded rationality. *Psychological Review*, 103(4), 650–669.

Gigerenzer, G., and Selten, R. 2001. Rethinking rationality. In *Bounded rationality: The adaptive toolbox*. Cambridge, MA: MIT Press.

Gigerenzer, G., Todd, P. M., and the ABC Research Group (Eds.) 1999. *Simple heuristics that make us smart*. Oxford: Oxford University Press.

Goldman, A. I. 1999. *Knowledge in a social world*. Oxford: Oxford University Press.

Grandori, A. 2010. A rational heuristic model of economic decision making. *Rationality and Society*, 22(4), 477–504.

Griffiths, T. L., Lieder, F., and Goodman, N. D. 2015. Rational use of cognitive resources: Levels of analysis between the computational and the algorithmic. *Topics in Cognitive Science*, 7(2), 217–229.

Halpern, J. Y., and Pass, R. 2015. Algorithmic rationality: Game theory with costly computation. *Journal of Economic Theory*, 156, 246–268.

Hoffman, D. D., Singh, M., and Prakash, C. 2015. The interface theory of perception. *Psychonomic Bulletin & Review*, 22(6), 1480–1506.

James, W. 1912. *The sentiment of rationality and other essays*. London: Longmans, Green and Company.

Kahneman, D. 1966. Time-intensity reciprocity in acuity as a function of luminance and figure-ground contrast. *Vision Research*, 6(3–4), 207–215.

Kahneman, D. 2003. Maps of bounded rationality: Psychology for behavioral economics. *American Economic Review*, 93(5), 1449–1475.

Kahneman, D. 2011. *Thinking, fast and slow*. New York: Farrar, Straus and Giroux.

Kahneman, D., and Frederick, S. 2002. Representativeness revisited: Attribute substitution in intuitive judgment. In T. Gilovich, D. Griffin, and D. Kahneman (Eds.), *Heuristics and Biases: The Psychology of Intuitive Judgment*, Cambridge: Cambridge University Press.

Karni, E., and Vierø, M.L. 2013. "Reverse Bayesianism": A choice-based theory of growing awareness. *American Economic Review*, 103(7), 2790–2810.

Kersten, D., Mamassian, P., and Yuille, A. 2004. Object perception as Bayesian inference. *Annual Review of Psychology*, 55, 271–304.

King, B. G., Felin, T., and Whetten, D. A., 2010. Perspective—Finding the organization in organizational theory: A meta-theory of the organization as a social actor. *Organization Science*, 21(1), 290–305.

Kingdom, F. A. A., and Prins, N. 2016. *Psychophysics: A practical introduction*. New York: Academic Press.

Koenderink, J. 2012. Geometry of imaginary spaces. *Journal of Physiology*, 106, 173–182.

Koenderink, J. 2014. The all-seeing eye. *Perception*, 43, 1–6.

Knill, D. C. and Richards, W. 1996. *Perception as Bayesian inference*. Cambridge: Cambridge University Press.

Krueger, J. I., and Funder, D. C. 2004. Towards a balanced social psychology: Causes, consequences, and cures for the problem-seeking approach to social behavior and cognition. *Behavioral and Brain Sciences*, 27(3), 313–327.

Lieder, F. and Griffiths, T. L. 2019. Resource-rational analysis: Understanding human cognition as the optimal use of limited computational resources. *The Behavioral and Brain Sciences*, 43, 1–85.

Lieder, F., Griffiths, T. L., Huys, Q J., and Goodman, N. D. 2018. The anchoring bias reflects rational use of cognitive resources. *Psychonomic Bulletin & Review*, 25(1), 322–349.

Lucas Jr, R. E. 1986. Adaptive behavior and economic theory. *Journal of Business*, 59(4), S401–S426.

Marr, D. 1982. *Vision: A computational investigation into the human representation and processing of visual information*. New York: Henry Holt and Co: Inc.

Melnikoff, D. E., and Bargh, J. A. 2018. The mythical number two. *Trends in Cognitive Sciences*, 22(4), 280–293.

Miller, J. B., and Sanjurjo, A. 2018. Surprised by the hot hand fallacy? A truth in the law of small numbers. *Econometrica*, 86(6), 2019–2047.

Muth, J. F. 1961. Rational expectations and the theory of price movements. *Econometrica: Journal of the Econometric Society*, 29(3), 315–335.

Oaksford, M., and Chater, N. 2007. *Bayesian rationality: The probabilistic approach to approach to human reasoning*. Oxford: Oxford University Press.

Ocasio, W., and Joseph, J., 2017. The attention-based view of great strategies. *Strategy Science*, 3(1), .289–294.

Olson, M. 1996. Big bills left on the sidewalk: Why some nations are rich, and others poor. *Journal of Economic Perspectives*, 10(2), 3–24.

Penrose, E. T. 1952. Biological analogies in the theory of the firm. *American Economic Review*, 42(5), 804–819.

Pinker, S. 2018. *Enlightenment now: The case for reason, science, humanism, and progress*. London: Penguin.

Polanyi, M. 1957. Problem solving. *British Journal for the Philosophy of Science*, 8, 89–103.

Polanyi, M. 1971. Genius in science. *Archives de Philosophie*, 34, 593–607.

Popper, K. 1966. *Objective knowledge: An evolutionary approach*. Oxford: Oxford University Press.

Ramscar, M. 2016. Learning and the replicability of priming effects. *Current Opinion in Psychology*, 12, 80–84.

Rauthmann, J. F., Gallardo-Pujol, D., Guillaume, E. M., Todd, E., Nave, C.S., ... Funder, D. C. 2014. The situational eight DIAMONDS: A taxonomy of major dimensions of situation characteristics. *Journal of Personality and Social Psychology*, 107(4), 677.

Rogers, B. 2014. Delusions about illusions. *Perception*, 43, 840–845.

Rogers, B. 2019. Where have all the illusions gone? *Perception*, 48(3), 193–196.
Rothschild, E. 2013. *Economic sentiments*. Cambridge, MA: Harvard University Press.
Schwartz, B. 1978. *The psychology of learning and behavior*. New York: W.W. Norton.
Shiller, R .J. 2015. *Irrational exuberance*. Princeton, NJ: Princeton University Press.
Shiller, R. J. 2017. Narrative economics. *American Economic Review*, 107(4), 967–1004.
Simon, H. A. 1955. A behavioral model of rational choice. *The Quarterly Journal of Economics*, 69(1), 99–118.
Simon, H. A. 1956. Rational choice and the structure of the environment. *Psychological Review*, 63(2), 129.
Simon, H. A. 1964. On the concept of organizational goal. *Administrative Science Quarterly*, 9(1), 1–22.
Simon, H. A. 1979. *Models of thought*. New Haven, CT: Yale University Press.
Simon, H. A. 1980. Cognitive science: The newest science of the artificial. *Cognitive Science*, 4(1), 33–46.
Simon, H. A. 1981. *Sciences of the artificial*. Cambridge, MA: MIT Press.
Simon, H. A. 1985. Human nature in politics: The dialogue of psychology with political science. *American Political Science Review*, 79, 293–304.
Simon, H. A, 1990. Invariants of human behavior. *Annual Review of Psychology*, 41(1), 1–20.
Simon, H. A. 1991. Organizations and markets. *Journal of Economic Perspectives*, 5(2), 25–44.
Simons, D. J., and Chabris, C. F., 1999. Gorillas in our midst: Sustained inattentional blindness for dynamic events. *Perception*, 28(9), 1059–1074.
Simons, D. J., and Rensink, R. A. 2005. Change blindness: Past, present, and future. *Trends in Cognitive Sciences*, 9(1), 16–20.
Soros, G. 2013. Fallibility, reflexivity, and the human uncertainty principle. *Journal of Economic Methodology*, 20(4), 309–329.
Spelke, E. S., Breinlinger, K., Macomber, J., and Jacobson, K. 1992. Origins of knowledge. *Psychological Review*, 99(4), 605–632.
Stanovich, K. E., West, R. F., and Toplak, M. E. 2016. *The rationality quotient: Toward a test of rational thinking*. Cambridge, MA: MIT Press.
Thaler, R. H. 2015. *Misbehaving: The making of behavioral economics*. New York: WW Norton.
Thaler, R. H. 2016. Behavioral economics: Past, present, and future. *American Economic Review*, 106(7), 1577–1600.
Thaler, R. H. 2017. Behavioral economics. *Journal of Political Economy*, 125(6), 1799–1805.
Thaler, R., and Sunstein, C. 2008. *Nudge: the gentle power of choice architecture*. New Haven, CT: Yale University Press.
Tinbergen, N. 1963. On aims and methods of ethology. *Zeitschrift für Tierpsychologie*, 20(4), 410–433.
Todd, P. M., and Gigerenzer, G. 2003. Bounding rationality to the world. *Journal of Economic Psychology*, 24(2), 143–165.
Tversky, A., and Kahneman, D. 1983. Extensional versus intuitive reasoning: the conjunction fallacy in probability judgment. *Psychological Review*, 90(4), 293–315.
Uexküll, J. von 2010. *A foray into the worlds of animals and humans*, trans. J. D. O'Neil. Minneapolis, MN: University of Minnesota Press.
van Buren, B., and Scholl, B. J. 2018. Visual illusions as a tool for dissociating seeing from thinking: a reply to Braddick. *Perception*, 47(10–11), 999–1001.
van den Steen, E. 2016. A formal theory of strategy. *Management Science*, 63(8), pp.2616–2636.
Viale, R. 2016. Brain-based bounded creativity. In L. Macchi, M. Bagassi, and R. Viale, (Eds.), *Cognitive unconscious and human rationality*. Cambridge, MA: MIT Press.
Winter, S. G. 2011. Problems at the foundation? Comments on Felin and Foss. *Journal of Institutional Economics*, 7(2), 257–277.
Yuille, A., and Kersten, D. 2006. Vision as Bayesian inference: Analysis by synthesis? *Trends in Cognitive Sciences*, 10(7), 301–308.
Zuckerman, E. 1999. The categorical imperative: Securities analysts and the illegitimacy discount. *American Journal of Sociology*, 104(5), 1398–1438.