CESifo WORKING PAPERS

10712
2023

October 2023

The Economics of Attention

George Loewenstein, Zachary Wojtowicz

CESifo

Impressum:

CESifo Working Papers
ISSN 2364-1428 (electronic version)
Publisher and distributor: Munich Society for the Promotion of Economic Research - CESifo GmbH
The international platform of Ludwigs-Maximilians University's Center for Economic Studies and the ifo Institute
Poschingerstr. 5, 81679 Munich, Germany
Telephone +49 (0)89 2180-2740, Telefax +49 (0)89 2180-17845, email office@cesifo.de
Editor: Clemens Fuest
https://www.cesifo.org/en/wp
An electronic version of the paper may be downloaded
· from the SSRN website: www.SSRN.com
· from the RePEc website: www.RePEc.org
· from the CESifo website: https://www.cesifo.org/en/wp

CESifo *Working Paper No. 10712*

The Economics of Attention

Abstract

Attention is a pivotal resource in the modern economy and plays an increasingly prominent role in economic analysis. We summarize research on attention from both psychology and economics, placing a particular emphasis on its capacity to explain numerous documented violations of classical economic theory. We also propose promising new directions for future research, including attention-based utility, the recent proliferation of attentional externalities introduced by digital technology, the potential for artificial intelligence to compete with human attention, and the significant role that boredom, curiosity, and other motivational states play in determining how people allocate attention.

JEL-Codes: D830, D900, D910, I000.

Keywords: attention, motivation, behavioural bias, information, learning, education, artificial intelligence, machine learning, future of work.

George Loewenstein
Department of Social and Decision Sciences
Carnegie Mellon University
Pittsburgh / PA / USA
gl20@andrew.cmu.edu

Zachary Wojtowicz
Department of Economics & Department of Negotiations, Organizations, & Markets
Harvard University, Cambridge / MA / USA
zwojtowicz@fas.harvard.edu

We thank Michael Posner, Alex Imas, Joshua Schwartzstein, Russell Golman, Matthew Rabin, David Hirshleifer, Peter Andre, Ben Enke, Colin Camerer, Nick Chater, Agnes Festre, Angela Duck-worth, and Peter Landry for their insightful com-ments and suggestions.

1. *Introduction*

At the dawn of an industrial revolution wherein millions would eventually flock from farm to factory, Adam Smith and his contemporaries established economic science around the idea that physical factors of production—the classical trinity of "land, labor, and capital"—were the primary resources driving the wealth of nations. Over the ensuing centuries, successive generations of economists have elaborated on this perspective by emphasizing the importance of additional intangible factors—most notably technology, human capital, and information—that came to play an increasingly prominent role in subsequent eras of economic development. In this review, we join a growing chorus of contemporary economists who argue that the mental resource of attention should be added to the list of core productive factors studied by the discipline.[1] The reasons are threefold:

1. Attention has become one of the most pivotal resources constraining both production and consumption in the modern economy.
2. Accounting for attention resolves many outstanding puzzles in economic theory, especially those identified by behavioral economists.
3. Without a firm grasp on the role of attention, economic science will be ill-prepared to grapple with the effects of artificial intelligence and other novel technologies that function, essentially, to augment, absorb, redirect, or replace human attention.

Incorporating attention into economic science is natural given that it possesses the same key properties that distinguish more established productive resources—*e.g.*, it is in short supply and can be put to a variety of competing productive uses, thereby generating opportunity costs. At the same time, viewing attention as a *bona fide* resource represents an important conceptual advance because doing so extends economic science to the explicit study of mental, rather than just physical, production. An analysis of attention also provides a more nuanced understanding of other intangible productive factors that have become pillars of economic thinking, such as human capital, information, and technology. Attention is arguably equally—if not more—fundamental than each of these, given that it constrains both their creation and application.

One goal of this review is to distill what psychologists have learned about attention over the past 150 years into a form that will be useful to economists. We organize this effort around the following definition, which both synthesizes contemporary psychological perspectives on attention and highlights its similarities to traditional economic factors of production.

DEFINITION: ***Attention*** *is the selective allocation of a scarce, rivalrous mental resource to some information–processing tasks to the exclusion of others. Although most such allocation happens automatically (and often without awareness), an agent must have the potential to exercise control over a mental resource for its allocation to be considered attentional.*

As we detail at length in Section 2, this definition is expansive enough to capture attention's sensory, perceptual, and cognitive margins while at the same time being sufficiently concrete to map onto formal models of limited atten-

[1] See Festré and Garrouste (2015), for a historical review of attention in economics.

tion that have already been adopted by economists, which we review in Section 5.

Attentional mechanisms help focus our limited cognitive capacities on information we expect to be important; however, doing so necessarily involves deprioritizing, or in some cases altogether ignoring, other information. Understanding the determinants of what people pay attention to (and, by necessity, ignore) helps to explain a wide range of currently pressing phenomena, such as why the explosion of freely available information occasioned by the advent of the Internet has not resulted in a consummately more well-informed society—indeed, why almost the opposite seems to have occurred. An attentional perspective suggests that the answer to this puzzle may lie in the fact that the internet has enabled people to focus their limited attention more selectively on content that is highly stimulating (Berger and Milkman, 2012; Vosoughi, Roy and Aral, 2018) but uninformative (Gagnon-Bartsch, Rabin and Schwartzstein, 2018; Schwartzstein, 2014; Hanna, Mullainathan and Schwartzstein, 2014; Sunstein, 2018).

The limits of human attention have become increasingly important in the face of what is often referred to as the "information explosion." As Herbert Simon (1971) expressed it in a frequently cited passage:

> "In an information-rich world, the wealth of information means a dearth of something else: a scarcity of whatever it is that information consumes. What information consumes is rather obvious: it consumes the attention of its recipients. Hence a wealth of information creates a poverty of attention and the need to allocate that attention efficiently..."

How people allocate attention, the mechanisms that enable them to do so, and the economic consequences that follow are the central issues we address.

As a complement to superb prior reviews that cover formal economics models of attention (Gabaix, 2019; Caplin, 2016), our treatment places a greater emphasis on translating the vast literature on attention spread across the behavioral sciences into the language of economics. While we review theoretical developments in economics, we provide a more intuitive and less mathematical overview than offered in prior reviews.

Economists' recent interest in attention is timely not only as a result of its coincidence with the information explosion, but also because a large and growing fraction of both labor (*e.g.*, computer programming) and leisure (*e.g.*, social media use) activities in the modern economy rely almost entirely on the application of mental, rather than physical, resources. Globally, the average person now spends about six and a half hours on the internet each day,[2] and one third of U.S. adults report that they are online "almost constantly."[3] Many of today's most profitable businesses, such as internet search and social media, generate revenue through "user engagement," which effectively means attracting and redirecting individuals' attention. Increasingly, attention has become a commodity that can be bought, sold, and even "stolen" (*c.f.*, Wu, 2018; McFedries, 2014; Hari, 2023).

While many new technologies *draw* on attention and seek to attract it, other technologies, such as machine learning,

[2] www.datareportal.com/reports/digital-2023-global-overview-report

[3] www.pewresearch.org/fact-tank/2021/03/26/about-three-in-ten-u-s-adults-say-they-are-almost-constantly-online/

either *complement* or *substitute* for human attention. Which of these forces dominates in each sector of the economy will determine their evolving consequences for consumer welfare and, perhaps even more importantly, labor demand (see, *e.g.*, Acemoglu and Restrepo, 2018*b*). The rapid development of artificial intelligence, in particular, presents the very real possibility that many forms of mental production will no longer be the exclusive domain of human minds. A tighter conceptual grip on the role that attention (and mental resource allocation more generally) plays in the economy may prove decisive for understanding and addressing the consequences of these momentous developments.

At a more basic research level, treating attention as a core economic resource promises substantial opportunities for intellectual "gains from trade" between economics and companion sciences. On the one hand, a resource framing facilitates the task of translating the vast existing literature on attention spread across the brain and behavioral sciences into terms that clarify its relevance to economics. On the other hand, this framing also suggests ways that the toolkit economists have developed to study other allocation problems can potentially contribute new insights, as well as integrative theoretical perspectives, to psychology, neuroscience, and other disciplines which have, until recently, been the main sources of our understanding of attention (for an exposition of this particular point, see Wojtowicz and Loewenstein, 2023).[4]

[4]The influence of economic thinking on psychology can already be seen, for example, in the "resource-rational" perspective (Lieder and Griffiths, 2020; Griffiths, Lieder and Goodman, 2015), which explicitly explores how assigning costs to various cognitive operations changes the optimal mental strategies people employ when thinking through problems.

Attention is also important because of its bi-directional relationship with memory, a topic of increasing interest to economists (Bordalo, Gennaioli and Shleifer, 2017; Enke, Schwerter and Zimmermann, 2020). Attention not only selects what information we take in through our senses in the first place, but also which internal experiences we transform into long-term learning and which memories we recall in a given situation (Craik and Lockhart, 1972; Chun and Turk-Browne, 2007).

Lastly, establishing attention as a scarce mental resource and clarifying its properties relative to other productive factors helps to lay the groundwork for an explicit analysis of attentional externalities and property rights. Despite the fact that (to the best of our knowledge) neither of these corollaries of a resource-based view of attention has been thoroughly explored, both bear acutely on contemporary policy discussions, especially those surrounding internet privacy and the regulation of digital advertising.

1.1. Outline of the review

Section 2 begins with an overview of research on attention from the brain and behavioral sciences, translating findings and theoretical perspectives, where possible, into the language of economics. Section 2.4, in particular, surveys the three main categories of mechanisms that direct attention:

1. *Bottom-up:* Selective processes that arise automatically in response to intrinsic properties of external stimuli and operate outside of volitional control.

2. *Top-down:* Selective processes that depend upon a person's cognitive state—their goals, memories, and beliefs. Top-down processes include,

but are not limited to, volitional control.

3. *Motivational:* Visceral feeling states, such as boredom and curiosity, that arise automatically yet influence a person's volitional control of attention by modifying the hedonic appeal of specific attentional foci.

Section 3 discusses "attention-based utility," the emerging insight that paying attention to certain external stimuli or internal thoughts directly impacts utility. In some contexts, such as fine dining, attention merely enhances consumption utility. However, in others, such as viewing an embarrassing photograph of oneself, it is almost entirely responsible for one's hedonic experience. Attention-based utility is different from belief-based utility and leads to a variety of unique predictions, which we discuss. Section 4 rounds out our overview of the psychology of attention by describing various methods that have been used to measure it.

Turning to economics, Section 5 reviews a variety of theoretical frameworks that economists have used to model attention, such as rational inattention, salience, and sparsity. Section 6 then considers attention's many implications for foundational concepts in economic analysis, including: consumption, risk, time, social preferences, strategic interaction, information and learning, human capital development, performance, and contracting.

Section 7 addresses attention's implications for specific topics of interest to economists: finance, consumer behavior, productivity, firm behavior, health, addiction, and public policy. Following the lead of Gabaix (2019), we place a particular emphasis on the potential for models that incorporate attention to organize many non-classical economic phenomena—especially those studied by behavioral economists—within a common explanatory framework.

Section 8 draws upon the preceding material to propose future directions for research into the economics of attention. Subsection 8.1 discusses attentional externalities, property rights, and markets, then considers how artificial intelligence and other digital technologies are transforming the role of human attention in the economy. Subsection 8.2 suggests promising new directions for theory. In particular, we advocate for a more complete theoretical analysis of mental production that takes account of the many economic tasks that compete for attention. Section 9 concludes.

2. *The Psychology of Attention*

The prominent early psychologist William James described attention as a "taking possession by the mind, in clear and vivid form, of one out of what seem several simultaneously possible objects or trains of thought. Focalization, concentration, of consciousness are of its essence" (1890, page 404). As for its function, James asserted that attention "implies withdrawal from some things in order to deal effectively with others" given that "without selective interest, experience is an utter chaos" (page 403).

While many intuitively agree with James' insight that attention arises from fundamental limitations on our capacity to acquire and process information, it is less clear what those limitations are and at what stage (or, more precisely, stages) of cognition they occur. As becomes apparent upon closer inspection, the task of developing a detailed theory of attention—what people choose to pay attention to, what people are capable of paying attention to, how attention affects learning, *etc.*—frequently reduces to the problem of understanding the cognitive limitations that give rise to the need for selective attention in the first place.

Fortunately for economists, psychologists and neuroscientists have spent the last century investigating attention though the methodical application of cleverly designed laboratory experiments. To get a sense of how this work has sharpened our understanding, consider an early study by Fairbanks, Guttman and Miron (1957), which showed that if two passages of prose are presented to different ears at the same time, experimental participants are only able to follow one at a time; however, if a single passage is delivered at double-speed, they have little trouble understanding it. Typical of the myriad studies that have been done, this suggests that, at least in the auditory domain, attentional constraints bind less on the total rate of information processed than on the number of separate input streams being parsed.

Another workhorse experimental paradigm, the "Stroop task" (Stroop, 1935), demonstrates the potential for conflict when attention involves disentangling multiple sensory judgements. In the task, participants are presented with color words printed in either congruent or incongruent colors (*e.g.*, the word "green" written in either green or red letters). People have little trouble reporting the written words, even when they appear in text of a conflicting color. However, their performance significantly declines if they must report the text's color when it conflicts with what is written.

This finding is taken as evidence that parsing a text's semantic meaning occurs more rapidly in the brain than identifying its color, creating a predominant response tendency that must be suppressed in order to complete the task successfully (Botvinick et al., 2001). Stroop's experiment highlights two further recurring themes: (1) attention is just as important for filtering *out* irrelevant, incorrect, or potentially misleading information as it is for filtering *in* relevant, correct, and revealing information; and (2) attention is imperfect at both types of filtering.

In the remainder of this section, we selectively review research on attention with a special focus on its implications for economics. (Section 2.8 summarizes this discussion with a list of what we see as the most important features of attention for economics.) Perhaps the single most important take-away is that attention does not reflect a single constraint, but rather a cascading series of constraints occurring at different levels of processing. Despite this conclusion, however, we discuss when and why attention can be productively modeled in reduced form as a unitary resource.

2.1. *Attentional Metaphors*

Metaphors can have a profound impact on how we conceptualize topics of scientific study, not only because they draw our focus—*attention*—to different features of phenomena, but also because they serve as substitutes for fully-specified scientific models which, like their formal cousins, generate intuitions, furnish predictions, and guide empirical exploration. A handful of intuitive metaphors have powerfully shaped scientific work on attention in psychology (and still govern most thinking about attention in other academic disciplines). We discuss the strengths and weaknesses of each in turn.

Perhaps the earliest and most prominent metaphor conceives of attention as a "bottleneck" that restricts the rate at which sensory data can pass through low-level perceptual processing into higher-level mental representations (Broadbent, 1958). Although useful, and in fact still widely used (*e.g.*, Tishby, Pereira and Bialek, 2000), the bottleneck metaphor breaks down in two interrelated ways.

First, although a bottle's neck does constrain the rate at which liquid can flow out at any point in time, all of the bottle's contents will pass through it eventually. In contrast, attention necessarily involves a process of selection: some information gets through, but much—and, in fact, typically most—gets lost.

Second, the bottleneck metaphor suggests both that the information is homogeneous and that it enters the bottleneck in an indiscriminate order. The essence of attention, by contrast, is that it *selects* which information makes it through a particular stage of processing. Attention, therefore, always involves some degree of discretion, whether exercised deliberately or automatically.

Another popular metaphor conceives of attention as a "spotlight" (Posner, 1980) that illuminates select stimuli and leaves other information "in the dark." A common elaboration of this metaphor casts attention as a "zoom lens" with a width that can be varied depending on the task to be performed (Eriksen and St James, 1986). Both metaphors highlight the notion that people have some capacity to direct the focus—and potentially also the breadth—of their attention.

Departing from the bottleneck, spotlight, and zoom lens metaphors, Kahneman (1973)—who specialized in attention research prior to his pioneering work in behavioral economics—likened attention to a limited *resource* that can be flexibly allocated, and to some degree expanded or contracted, in response to the unique demands of a situation. In addition to combining multiple strengths of prior metaphors, Kahneman's model of attention as a resource pool has the advantage that it naturally maps onto the conceptual approach of economics.

Highlighting this point, Kahneman (1970) found that experimental subjects reallocated their attention between simultaneous tasks to reflect variations in the incentives accompanying them. In one experiment, subjects worked simultaneously on a primary and secondary task, but were only paid for either task if they performed the primary task perfectly. Kahneman observed that "the primary task was fully protected, and excess capacity was available on a second-by-second basis for the execution of the secondary task. One could hardly ask any control unit to do any better" (pages 123-124).

2.2. Foundations of Attention

One noteworthy commonality between the bottleneck, spotlight, and resource pool metaphors is that they conceive of attention as a unitary construct. In a variety of applications—especially, as we will elaborate below, those of greatest interest to economists—this simplification is warranted and indeed the most productive way to model attention. Strictly speaking, however, an individual's total attentional capacity is a composite of many qualitatively distinct sub-capacities (Posner and Petersen, 1990; Narhi-Martinez, Dube and Golomb, 2022). As Chun et al. (2011) observe, "information processing is modulated by task goals across all stages of sensation, object recognition, memory, emotions, and decision-making" (page 74).[5] The authors conclude that "we

[5]such a multi-process perspective is supported by a long line of diverse research. For example,

should therefore abandon the view of attention as a unitary construct or mechanism, and consider attention as a characteristic and property of multiple perceptual and cognitive control mechanisms" (page 74). In what follows, we provide an overview of these complexities to help economists make informed decisions about what aspects of attention are likely to be relevant in specific economic contexts and which can, conversely, be assumed away.

Attention is multifaceted because the human perceptual and cognitive apparatus consists of various distinct, interlocking faculties, each of which is subject to biophysical constraints. To use an economic metaphor, the brain is less of a single factory assembly line and more of an interlinked cottage industry of asynchronous productive activities, some of which create the intermediate goods needed by others. The human sensory system, for example, consists of diverse, physically distinct subsystems that are dedicated to the detection of light, sound, temperature, pain, position, smell, and pressure, to name but a few (Bear, Connors and Paradiso, 2020). The brain also consists of a variety of specialized tissue areas—neural "circuits"—that instantiate different algorithms ranging from the highly specific (*e.g.*, identifying faces; Kanwisher and Yovel, 2006) to the highly general (*e.g.*, holding an abstract unit of information in mind; Miller, 1956; Baddeley, 1992). To the degree that these distinct information-gathering and processing capacities can be independently redirected, each gives rise to a separate choice about how it should in fact be directed and, correspondingly, a separate margin of attention.

Biophysical limitations not only restrict our ability to gather information about the outside world (sensation) and transform it into manageable representations (perception), but also constrain the amount of information we can hold in mind at any given time and the kinds of operations we can perform on it (higher-order cognition). One of the central—and indeed defining—insights of cognitive psychology has been that higher-order mental processes, such as performing arithmetic or solving a logic puzzle, draw on a common pool of scarce but highly flexible serial mental resources, such as working memory and cognitive control, that give rise to constraints on internal attention. In what follows, we provide a brief primer on how attention operates at a variety of levels: sensation, perception, working memory, cognitive control, and long-term memory.

Sensation

Consider, for the purpose of illustration, the human visual system. Visual sensation begins when light strikes photoreceptors located on the interior of the eye, but here already a scarce information-processing resource—concentrated pits of cone cells in the middle of each retina known as the *fovea centralis*—gives rise to a cognitive resource-allocation decision and corresponding form of attention. While it would certainly be useful if the entire visual field were maximally sharp, the brain economizes on information-processing costs by concentrating acuity at the center of a mobile eye which can be redirected, or *foveated*, toward stimuli of interest. This enables us to dynamically train our information-gathering capacity on useful stimuli, but it also en-

fifty years ago Allport, Antonis and Reynolds (1972) showed that, while experimental subjects cannot simultaneously attend to two concurrent auditory speech messages, they can attend to one such message and simultaneously process non-verbal tasks such as processing visual scenes or sight-reading music.

cumbers us with the need to continually direct and redirect our gaze, giving rise to a particular margin of attention known as *foveal visual attention.* In addition, we can, at least temporarily, modulate information-processing intensity in the brain and, consequently, increase acuity at other points in the visual field—a capacity known as *covert visual attention* (Carrasco, 2011).

Although foveal and covert visual attention furnish some of the most obvious examples of sensory attention (and indeed form the basis of the "spotlight" and "zoom lens" metaphors discussed above), attentional margins exist for all other sensory resources as well. In much the same way that the positioning of our eye determines the orientation of our *fovea centralis*, the positioning of our head, and hence ears, determines our direction of highest auditory acuity. Although humans lack the capacity to move our ears independently of our head, non-human animals will literally "prick up their ears" to monitor novel, alarming, or otherwise interesting sounds. Hearing also features an analogue of visual covert attention: the so-called "cocktail party effect," which refers to our remarkable ability to focus auditory processing on a particular stimulus and separate it from a noisy background, for instance when one tracks a single conversation at a boisterous party (Arons, 1992).[6]

The domain of touch furnishes yet another example, as tactile acuity is greatest on the fingertips, where receptor density is highest and neural processing most concentrated (Johnson and Phillips, 1981). Running one's fingertips over a surface to get a better sense of its texture therefore represent an act of selective attention in as much as it precludes our ability to simultaneously touch, and therefore gather tactile information about, other objects.

[6]Confusingly, the "cocktail party effect" is also used to describe the phenomenon of having one's name suddenly burst out of the hubbub of unattended background conversation (Cherry, 1953). In this form, the cocktail party effect plays a key role in debates about how much processing there is of unattended stimuli (*c.f.*, Treisman, 1960; Lavie, 2005), as it indicates that at least some baseline monitoring and categorization occurs for unattended—in this case auditory—stimuli.

Perception

As the above examples from the domains of vision, hearing, and touch illustrate, sensory attention constitutes the first layer of selective interest that William James described as being necessary to tame the "utter chaos" of sense-experience. However, not all information that strikes our sensory organs is selected for further processing. For example, visual data reaching the brain is transferred to a temporary buffer known as "iconic memory," where it persists in a nearly complete form for about 150ms (Sperling, 1960; Coltheart, 1980). During this brief window, attentional mechanisms select a subset of the visual scene for further process, which is re-coded, assigned semantic categories (*e.g.*, handwritten characters are identified as either digits or letters), and transferred to a more permanent buffer. Analogous sensory buffers exist for both hearing ("echoic memory"; Darwin, Turvey and Crowder, 1972) and touch ("haptic memory"; Bliss et al., 1966).

All information not selected for processing at this stage is irretrievably lost, meaning that perceptual attention filters out much of what we sense, which already filters out much of what we could, in principle, have taken in. Moreover, what little of the entire external cacophony makes it through these attentional processes only reaches "us" in a highly edited form. Partially due to the limitations just discussed, the sensory information we collect is inherently noisy and incomplete, meaning that our brain must continually fill in blanks, resolve ambiguities, and regularize improbable observations to generate a coherent picture of the world. Our perceptual representations therefore do not literally "re-present" the data our senses gather, but rather constitute the brain's best guess as to what is going on "out there," formed by synthesizing sensory information with expectations generated by our current model of the external environment (Firestone and Scholl, 2016).

The fact that perception tries to construct a coherent picture of the world accounts for why we do not even notice the sizable patches of our visual field where no information is collected (known as "blind spots"; Durgin, Tripathy and Levi, 1995), can only see perceptually multi-stable optical illusions, such as the Necker cube, one way at a time (Brascamp et al., 2018), and are subject to attentional blindness. This latter effect refers to the fact that people fail to notice obvious stimuli in their environment, such as, fancifully, a gorilla walking across a basketball game when preoccupied with counting passes (Simons and Rensink, 2005) or, more prosaically but also more fatefully, a traffic light when talking on the phone while driving (Strayer and Johnston, 2001). Because perceptual processes edit raw sensory information before it reaches the conscious mind, people tend to be unaware of the biases they introduce and consequently overlook the need to enact counter-measures (Loewenstein, Moore and Weber, 2006).

The idea that biases similar to those occurring in perception extend to higher-order judgments, especially ones of economic relevance, has been foundational to behavioral economics since its earliest days (e.g., Kahneman et al., 1982) and underlies many recent attempts to develop general theories of the phenomena it has uncovered (*e.g.*, Chater et al., 2020). Khaw, Li and Woodford (2021), for example, have recently argued that small-stakes risk aversion arises from a process of psychometric regularization similar to one Wei and Stocker (2017) developed to explain biased judgements of line inclination.

Working Memory

In a pioneering paper, Miller (1956) noted that the average individual's memory span (number of distinct items they are capable of recalling in order) and univariate absolute judgment span (number of stimulus categories they are capable of mapping into distinct behavioral responses) are both about seven units long, regardless of the type of information being encoded (letters, tones, colors, *etc.*). Although Miller was careful to point out that one's memory span could be greatly extended through the practice of "recoding" information into chunks (*e.g.*, recognizing "cellardoor" as the two words "cellar" and "door" instead of a string of arbitrary letters), this observation led researchers to conjecture the existence of an approximately seven-item *working memory* resource that temporarily stores information and serves as the interface between thought, perception, long-term memory, and action.

Subsequent research has expanded this picture in various ways, for example by demonstrating that the efficiency of working memory varies slightly depending on the complexity of the chunks (Simon, 1974; Gobet et al., 2001), and uncovering the existence of separate, modality-specific stores for visual and auditory information (the "phonological loop" and "visuospatial sketch pad" of Baddeley, 1992). While the precise details of working memory's architecture and limitations are a subject of ongoing research (and not our focus), the basic fact that our brain can only represent and manipulate a limited store of information at any given time is an important constraint that gives rise to further cognitive margins of attention.

One of the most notable features of working memory is that its contents can be sourced either externally (through sensory perception) or internally (by recalling long-term memories, engaging the imagination, or combining other representations). Hence, working memory supports a wide variety of high-level cognitive tasks that are both externally and internally directed. The selective allocation of working memory to information-processing operations within one's own mind gives rise to *internal attention* and determines some of its key limitations.

These limitations mean that one cannot, in general, perform more than one complex mental calculation at a time. Indeed, what at first appear to be violations of this general rule—*e.g.*, a chess grand-master playing, and winning, dozens of games simultaneously—invariably reflect, upon closer inspection, the brain's ability to "automate" familiar tasks so they no longer tax internal attention. In the case of chess, for example, expert players encode past experience into their perceptual faculty (Chase and Simon, 1973) and learn to "see" advantageous board positions, allowing them to intuitively avoid bad moves and concentrate their working memory on explicitly simulating only the most promising lines of play.

Cognitive Control

Attention is tightly connected to another capacity known as *cognitive control*, which refers to the brain's ability to divert information processing away from default, habitual, or automatic trajectories to ones that are tailored to the unique demands of a specific situation (Posner, 1975; Botvinick and Cohen, 2014). Cognitive control plays a crucial role in attention because it enables an individual to coordinate other mental resources—and thereby redirect other forms of attention—when pursuing explicit, intentional goals.

Cognitive control is required, for example, to resolve conflicting behavioral responses in the Stroop task, which explains both why participants react more slowly on trails in which response must be resolved and why people begin to make errors only above a certain threshold of difficulty, when the task exceeds their limited capacity for control (Posner, 1975; Cohen, Dunbar and McClelland, 1990). Cognitive control and working memory are closely related and operate in tandem to execute acts of higher-order cognition, with the former steering the maintenance and manipulation of information in the latter's various stores (Baddeley, 1992).

Like working memory, cognitive control is a flexible capacity that supports nearly all processes of deliberative thought. Also like working memory, our ability to exercise cognitive control is limited (Shenhav et al., 2017), making it one of the key scarce resources underlying limitations on internal attention. Indeed, given that cognitive control is used to direct other finite-capacity mental processes, its limitations play a central role in shaping how other attentional restrictions manifest themselves. In behavioral economics, the concept of controlled processing appears in many guises, for instance as the factor that distinguishes between "System I" and "System II" thinking (Kahneman, 2011) and supports the "cognitive reflection" needed to override prepotent response tendencies (Frederick, 2005).

Long-term Memory

Attention also plays a critical role in the formation and retrieval of long-term memories, which can be divided into two main categories: *implicit* and *explicit.* Implicit memory refers to information that can be stored and recalled without effort. It includes basic motor skills (*e.g.*, how to tie a shoe) and semantic associations (*e.g.*, the word "dog" automatically activating related concepts such as "cat" and "bone"). Explicit memory, by contrast, refers to information that can be retrieved with concerted effort. It includes both episodic memory (personal experiences, such as the arc of one's high school prom) and semantic memory (factual details, such as a friend's telephone number).

First and foremost, information can only be retained if it first makes it into one's mind, which means that sensory and perceptual attention play a key role in determining what is even available to remember. Second, the process of encoding memory is enhanced when information is "rehearsed" in working memory, a process which also draws upon cognitive control and, hence, internal attention (see, *e.g.*, Craik and Lockhart, 1972; Baddeley, 1992). Lastly, attending to recently stored explicit memories alters the process of consolidation and can therefore strengthen, change, or damage them (Forcato, Fernandez and Pedreira, 2014).

Research on explicit memory also suggests that such information is organized in clusters, with related items stored in close connection according to semantic similarities—*e.g.*, "incidents that happened while vacationing in Paris"—in much the same way that resources tend to be arranged in physical environments—*e.g.*, food in a natural landscape. Experiments on semantic memory retrieval suggest that people use attention to search through these "patches" of information in much the same way that animals forage for food, *i.e.*, by searching within a patch until it becomes depleted below a given threshold, then moving on to a new patch (Hills, Jones and Todd, 2012; Hills, Todd and Jones, 2015).

Research in psychology has shown that mood impacts the memory retrieval process, a phenomenon known as "mood-congruent memory" (Bower, 1981). As discussed by Kőszegi, Loewenstein and Murooka (2022), this can create a self-reinforcing cycle in which positive and negative moods trigger thoughts and memories that reinforce those states. A wide range of otherwise anomalous phenomena, such as self-handicapping, information avoidance, disproportionately aggressive responses to perceived slights, and dropout from education and job search, can all be understood as measures that individuals take to avoid slipping into a negative equilibrium.

2.3. One Constraint or Many?

At the outset of this review, we defined attention as "the selective allocation of a scarce, rivalrous mental resource to some information–processing task to the exclusion of others." According to our definition, attention is, strictly speaking, the *process* by which mental resources are allocated, *not the resources themselves.* Although this conceptual distinction is important to bear in mind when thinking about the structure of attention, we will, as a linguistic shorthand in keeping with common usage, also occasionally use "attention" to refer to the thing (or things) being allocated.

Even when reified in this way, however, attention is not a single, homogeneous substance. As the foregoing discussion makes clear, the human central nervous system consists of a variety of "scarce, rivalrous mental resources"—functionally (and often physiologically) distinct information-processing capacities, such as working memory or the *fovea centralis*, that can each be allocated independently and therefore give rise to distinct margins of attention. For example, when someone says "pay attention," they might mean "look at me" (sensory attention), "what I'm about to show you may trick the senses" (perceptual attention), or "stop daydreaming and focus on what I'm saying" (internal attention). Depending on the application, it may be necessary to disentangle these distinct attentional categories and study their influences separately.

Despite these nuances, there are two general cases in which attention does act as a homogeneous resource and, accordingly, can be modeled in reduced form as a single constraint. The first arises when only one margin of attention is relevant to the phenomena under study. For example, in an analysis of shopping behavior, foveal visual attention (whether the consumer will notice a product given its position on a shelf) may be the dominant binding constraint driving deviations from the classical, full-information model. Focusing on one margin of attention in a particular application is consistent with how other constraints are typically treated in economics, where most factors are held fixed by implicit or explicit *ceteris paribus* assumptions.

The second general case arises when multiple sub-components of attention operate together in such tight coordination that they effectively function as a single system, usually because they are all directed at a common goal that itself makes homogeneous demands on the resources in question. For example, as described in preceding subsections, cognitive control is necessary to maintain and manipulate information in working memory; however, when jointly applied to certain tasks (*e.g.*, holding visual *or* auditory information in mind, but not both simultaneously), the specific limitations of each resource become less important, and the two can be jointly modeled as a single system (see Baddeley, 1992).

This specific example is particularly important because the joint operation of cognitive control and working memory largely defines what we have been referring to as internal attention—our limited ability to *think* about the world, as distinct from our ability to *interface* with it. Internal attention is especially pivotal for a wide range of economic decision-making operations, such as enumerating possible risks, planning, and updating beliefs, and is therefore the constraint that most acutely restricts the rationality of economic agents in many circumstances. This fact, combined with the observation that internal attention can be conceived of as a single attentional constraint in the circumstances just described, helps explain why many economic problems do seem well-described by a single attentional resource.

2.4. Determinants of Attention Allocation

In this section, we review three broad classes of attentional determinants: bottom-up ("exogenous," stimulus-driven), top-down ("endogenous," internal state-driven), and motivational (a new, hybrid category that we introduce which serves as an interface between the other two and shares features with both).

The psychology literature has drawn a distinction between top-down and bottom-up control, in different guises, for over a century. William James (1890), for example, differentiated between "willed" attentional focus, which is under the deliberate control of the individual, and "ideo-motor" control, which responds to external factors. An example of the latter would be our tendency to instantaneously and automatically orient to surprising or alarming stimuli. In more recent years, Posner (1980) drew a parallel distinction between "endogenous" and "exogenous" processes. Other labels conveying the same dichotomy include "voluntary" versus "reflexive" and "goal-" versus "stimulus-driven" attention (Corbetta and Shulman, 2002).[7]

All of these labels, however, are meant to convey that the primary difference between these two categories is the direction of causal determination. Bottom-up mechanisms are set in motion automatically by features of stimuli themselves, whereas top-down mechanisms incorporate an agent's current internal state—specifically, their memories, goals, and beliefs—into attentional selection and therefore can be said to emanate from "within" them.

A few other characteristics distinguish the two categories. First, top-down processes are slower and take as much as an order of magnitude longer to enact than bottom-up ones (Müller and Rabbitt, 1989), especially when they arise from deliberation (Wolfe, Alvarez and Horowitz, 2000). Second, once directed, top-down processes tend to sustain focus for longer. For this reason, top-down attention has also been referred to as "sustained" and bottom-up as "transient" (Carrasco, 2011).

Top-down and bottom-up processes compete with one another in the sense that the activation of one process tends to interfere with and slow down the other. In one study documenting this tension, Pinto et al. (2013) asked experimental subjects to search for a randomly selected letter that was embedded in a diamond shape outline amid other random letters presented in circles. When one of the circles was presented in a different color (which presumably attracted attention via bottom-up processes), top-down attention to, and identification of, the diamond-embedded letter was significantly delayed.

Bottom-Up

Bottom-up mechanisms automatically guide attention to aspects of the environment that are *salient*—etymologically, those that "leap out" at us from the broader background of potential foci. In the much-studied domain of vision, salience draws attention to both "high-level" objects (*e.g.*, people, faces, or text Calvo and Nummenmaa, 2008; Judd et al., 2009) and locations that feature distinctive "low-level" qualities (*e.g.*, brightness, orientation, color, or motion Treisman and Gelade, 1980). Salience tends to highlight contrasts, rather than absolute characteristics: a slow-moving dot will attract attention when surrounded by many fast-moving dots, but a fast-moving dot will attract attention when surrounded by many slow-moving ones.

Bottom-up mechanisms also draw attention to stimuli of social or personal significance. For example, people reflexively orient visual attention in the same direction as others (Milgram, Bickman

[7]This commonplace and seemingly straightforward distinction is, in some cases, somewhat ambiguous. Norman and Shallice (1986) pose the example of an individual paying attention to actions they are taking. There are at least three ways that execution of a task could be interpreted as automatic: (1) the task can be executed without awareness of the performance (*e.g.*, walking along a short stretch of flat safe ground); (2) the action could be not only performed but also initiated without deliberate attention or awareness (*e.g.*, brushing off an insect); and (3) the action could be an "orienting response" in which attention is automatically and involuntarily drawn to a stimulus such as a sudden loud noise.

and Berkowitz, 1969; Gallup et al., 2012) and, as noted earlier, reliably overhear their own name mentioned in a neighboring conversation at a party (Arons, 1992).

In economics, bottom-up attention has been hypothesized to drive a variety of classical choice theory violations (Rubinstein, 1988; Kőszegi and Szeidl, 2013; Bordalo, Gennaioli and Shleifer, 2012, 2013). The intuition underlying such models is that certain "salient" dimensions of choice problems attract disproportionate attention and therefore exert undue influence on decision making (see Section 5 for an overview).

Top-Down

In contrast to bottom-up mechanisms, which respond to properties of the external environment, top-down mechanisms incorporate an agent's cognitive state—goals, beliefs, and memories—into the process of attentional selection. Top-down influences operate at every stage of information processing by modifying the behavior of antecedent operations (Gilbert and Sigman, 2007). In particular, top-down mechanisms have been shown to modify the operation of bottom-up attention, enhancing the salience of goal-congruent perceptual features such as motion, color, and luminance Treue and Trujillo (1999); Motter (1994); Chelazzi et al. (1993): if one were warned to look out for tigers on safari, orange colors and striped patterns would become more visually salient Navalpakkam and Itti (2007).

In the context of human cognition, top-down attention also includes an individual's volitional control over what information they take in and process. Deliberately redirecting one's gaze, straining to hear a single voice among many, or thinking about a riddle are all examples of such control. Considerable existing work in economics has focused on this type of top-down attention because it can be viewed as a type of preference-based choice and therefore modeled using tools from consumer theory.

Although not explicitly about attention as such, this literature began with the work of Stigler (1961), who introduced the idea that people pay costs to acquire information (in the context of search), and will gather information to the extent—and only to the extent—that it improves decision making. While it has always been implicitly understood that limited human attention is the primary constraint generating such costs, recent work has sought to explicitly model these psychological microfoundations. In modern "rational inattention" models, for example, agents select among informative signals by weighing the expected utility benefits of enriching decision making against a presumed cost of deploying attention to refine their beliefs about the world (See Section 5).

Motivational

The psychological literature has long distinguished between top-down and bottom-up influences and generally taken them to be an exhaustive scheme for grouping attentional mechanisms. In ongoing research, however, we propose a third category of determinant: *motivational* (Wojtowicz, Chater and Loewenstein, 2019; Wojtowicz and Loewenstein, 2020; Wojtowicz, Chater and Loewenstein, 2022).

Motivational determinants are feeling states that incentive us to reallocate our attention in specific ways by altering the relative hedonic appeal of various foci. Notable examples include curiosity, boredom, flow, and mental effort. These states solve a problem first identified by Simon (1967): the need to efficiently allocate mental resources without using up those very same resources. Along with bottom-up processes, motivational states make up our "attentional autopilot" system, which ensures that we default to a reasonably efficient mental resource allocation even when we invest little, if any, deliberative thought into the allocation problem itself.

Attention-directing motivational states share many properties with other affective feeling states, such as pain, hunger, and the sex drive. First, all such states are exogenous in the sense that an individual cannot merely will themselves to feel or not feel a particular state merely through thought alone (although one can, of course, strategically engage in behaviors to occasion them under some circumstances).[8] Second, like other feeling states such as hunger, attention-directing motivational states arise from a combination of internal and external cues that are learned over time. For example, curiosity about a gift might depend both on one's internal state of knowledge (*e.g.*, awareness that the giver tends to put a lot of though into presents) and external cues (*e.g.*, a conspicuously large package).

While the motivational feeling states associated with cognition are bottom-up in the ways just discussed, they also interact with top-down determinants in the sense that they operate by biasing volitional attentional choice. Boredom, for example, motivates us to change our focus of attention by increasing the hedonic cost of maintaining attention (Wojtowicz, Chater and Loewenstein, 2019). Conversely, the psychological state of flow—a pleasurable state of total absorption in a task or activity—incentivizes us to maintain focus by increases the hedonic benefit of doing so. Curiosity likewise motivates us by making specific foci hedonically appealing (and all others aversive Wojtowicz, Chater and Loewenstein, 2022; Wojtowicz and Loewenstein, 2020; Chater and Loewenstein, 2016; Loewenstein, 1994).

Motivational determinants can conflict with people's other goals and priorities, leading to attentional self-control problems. To list but a few examples: boredom can make it difficult to sustain the practice necessary to master a new language or musical skill; flow can lead people to spend more time than they would like watching television or scrolling through social media; and curiosity can make it difficult to ignore news or gossip that one knows are unimportant and potentially even immiserating. We discuss the economic implications of attentional self-control problems in ensuing sections.

2.5. *Attentional Coordination*

The ability to coordinate attention between people is indispensable for many aspects of social behavior—indeed, for many of the basic practices that constitute what we call social, let alone economic, life. Consider theater performances, weddings, lectures, team sports (from both the perspective of spectators and the performers themselves), political rallies, book clubs, funerals, and judicial proceedings. All require complex forms of attentional coordination, such as *joint* or *shared attention*: the ability for multiple agents to focus on the same object.

Attentional coordination is so essential to human activity that some have argued it represents one of our species' core evolutionary innovations. The cooperative-eye hypothesis holds that, as compared to other primates, humans evolved a highly visible eye featuring distinctive, colored or darkened irises contrasted against a white sclera specifically to ex-

[8]If one did have volitional control over affective states, one could simply choose not to experience negative ones, obviating their beneficial function.

pose the direction of our gaze to others (Tomasello et al., 2007). Freely (and, indeed, unavoidably) sharing information about our attentional state in this way not only enables more complex forms of real-time coordination such as those necessary to support joint intentionality (Tomasello et al., 2005) and other forms of social cognition (Stephenson, Edwards and Bayliss, 2021), but also reveals the attentional priorities of each looker.

Such mechanisms for coordinating attention facilitate the interpersonal transmission of cultural values and other forms of information, especially between adults and young children (Dawson et al., 2004). Developmental research, for example, has shown that joint mother-child attention accelerates word learning (Tomasello and Farrar, 1986). Conversely, autism spectrum disorder is marked by failures of social and joint attention, which lead to a variety of downstream challenges (Dawson et al., 2004).

Shared attention, in particular, is one of the principle mechanisms by which groups establish common knowledge: a state of belief wherein every member of a group knows a fact, but also knows that everyone else knows that fact, and so on. Common knowledge is indispensable to many economic institutions, and it serve as a core theoretical assumption in many theories, especially game-theoretical models of strategic interaction. Many social practices that establish common knowledge among groups—such as pledging allegiance to the flag, chanting a religious prayer, or requiring that every member of a scientific discipline learn the same analytic framework from the same graduate textbook—do so by coordinating attention in a way that not only verifies a set of facts to each individual, but also makes it clear that these facts are known by all (Chwe, 2013).

Attentional coordination is also a central *raison d'être* for firms and other hierarchical organizations. A defining feature of such institutions is their capacity to utilize vast quantities of information by distributing attentional responsibilities across many individuals (Marschak and Radner, 1972) and effecting a bidirectional flow of information "up" command hierarchies and of coordinating instructions back "down" to subordinates Simon (1944).

2.6. Other People's Attention

The ability to command attention is a significant resource, which may explain why social ostracism—being ignored—is one of the more severe punishments a society can deliver (Eisenberger, Lieberman and Williams, 2003). It should therefore not come as a surprise that people can become habituated to seeking out the attention of others, no matter the cost.

Although the desire to seek attention is as old as civilization itself (Braudy, 1997), new technologies have created novel types of fame (*e.g.*, the "influencer") and new challenges for those who seek to cultivate it. A large number of articles in the popular media, often focused on the negative effects of social media, refer to the phenomenon of "addiction to likes," and some empirical research provides support for the intuitive notion that people can become habituated to receiving attention from others (Meshi, Morawetz and Heekeren, 2013; Lindström et al., 2021).

At the same time, attention from others can often result in negative feelings—*e.g.*, of embarrassment or shame—when one feels the impression is negative. These feelings can be exacerbated by people's tendency to overestimate how much attention other people are paying to them, a phenomenon known as the "spotlight effect" (Gilovich, Medvec and Savitsky, 2000). The spotlight effect seems to result, in part, from a failure of perspective-taking—an inability to recognize that most other people are, in fact, largely focused on *themselves* (Savitsky, Epley and Gilovich, 2001).

2.7. Attentional Disorders

The experiences of those who experience attentional disorders sheds light on the central role that attention plays in supporting daily functioning. The most obvious of these is Attention-Deficit Hyperactive Disorder (ADHD), which is characterized by "difficulty maintaining focus on one task or play activity... not listening when spoken to (including when there is no obvious distraction)," and "not following or finishing instructions" (the DSM 5, First, 2013). Anxiety disorder is likewise associated with aberrant patterns of attention, including, not surprisingly, increased attention to threat-related stimuli (Bishop et al., 2004), especially when they are presented *outside of the focus of attention* (Bishop, Duncan and Lawrence, 2004). Finally, the social consequences of autism spectrum disorder (ASD) appear to result, in part, from deficits of attention (Landry and Bryson, 2004; Townsend, Harris and Courchesne, 1996), especially to social cues (*c.f.*, Liss et al., 2006; Leitner, 2014), including those that facilitate shared attention (Madipakkam et al., 2017). Landry (2021) proposes a unified account of both ADHD and ASD in which the former arises from a systematic tendency to underestimate or overestimate, respectively, the opportunity costs of attention and task-switching.

2.8. Summary: Features of Attention

Having introduced the reader to some of the details of how attention operates, we summarize the foregoing in six properties that, we believe, are most important for integrating attention into economic analysis. In what follows, we list and briefly comment on each.

Property 1. Attention is a scarce and valuable resource.

This is *the* key feature of attention. It has the important implication that attention is subject to economic laws and, by extension, amenable to standard methods of economic analysis (alongside more traditional resources, such as land, labor, and capital).

Property 2. Attention reflects the joint effects of myriad constraints operating at different levels of processing in different sensory and neural systems.

A key question for economists is whether, in each given application, to model attention in reduced form as a single, unified resource. As we have argued in the foregoing, this simplification is justified in some circumstances, but should be applied with an awareness of the underlying structure of attention and a sensitivity to the possibility that more granular modeling may be appropriate in some contexts.

Property 3. Attention is flexible and can be applied to a wide range of different uses at each point in time.

One can, for example, read a book or hold a conversation, but not both simultaneously. Because attention is limited in supply and can be put to many competing uses of varying productivity, we are compelled to make consequential choices—whether explicitly or implicitly—about how we should in fact direct it.

Property 4. Most attention is "use it or lose it"—it cannot be stored across time.

In this sense, attention is usually best conceptualized as a flow, rather than a stock, variable. Given that opportunities for how to use attention are constantly in flux, this feature has the important implication that a decision about how to best allocate attention must be made anew in every moment; if the attention-allocation decision is made poorly, the potential value of attention in that interval is irrevocably lost.[9] To a first approximation, therefore, most attention can be modeled as a constant flow, rather than a stock: you can redirect activity to different parts of the brain, but the overall amount of processing—and, crudely, attention—can be treated as effectively constant.

Property 5. Attention is directed by bottom-up and top-down mechanisms, and by motivational mechanisms (which arise automatically but influence the volitional control of attention using hedonic feeling states).

An implication for economics is that models which assume attention is either completely under volitional control or purely the result of exogenous features (*e.g.*, as a result of "salience") will fail to do justice to the existence of, or interactions between, these different forms of attentional control.

Property 6. Explicitly deliberating about how to direct attention reduces the amount of attention ultimately available for productive use.

Attention can be used to explicitly think through the relative merits of potential uses of attention. However, doing so competes for the same limited cognitive resources that one could apply to productive activities, meaning that deliberately allocating attention has real opportunity costs. Bottom-up and motivational mechanisms are, as a result of this property, designed to help guide attention more-or-less automatically. These "attentional auto-pilot" mechanisms exist, by their very design, to bias our attention allocation in predictable ways. As we will discuss at length in ensuing sections, these mechanisms help to explain a range of non-classical economic behaviors.

3. *Attention-Based Utility*

Much of what matters to people—*i.e.*, determines their subjective well-being and, accordingly, drives decision-making—happens "in the mind." Whereas expected utility theory holds that beliefs matter to agents only to the degree that they inform choice and, through it, subsequent consumption, economists have recently begun to study the fact that people have preferences over states of beliefs themselves.

This insight, frequently referred to as *belief-based utility* (Loewenstein, 1987; Geanakoplos, Pearce and Stacchetti, 1989; Caplin and Leahy, 2001; Brunnermeier and Parker, 2005), has played an especially important role in accounting for paradoxical phenomena such as information avoidance (*e.g.*, Sicherman et al., 2016; Golman, Hagmann and Loewenstein, 2017) and the long-term persis-

[9] Although this is a sensible simplification for the vast majority of applications, the total amount of attention mobilized at any point in time is, in fact, somewhat elastic (see, *e.g.*, Kahneman, 1973). The brain, in fact, has some capacity to temporarily intensify certain types of information processing by increasing the firing rate of relevant neural populations (as in the example of covert attention, mentioned above; Carrasco, 2011). Extended periods of neural activation can outpace the body's ability to deliver energy to and clear toxins from a particular location (Attwell and Laughlin, 2001; Wiehler et al., 2022). In contrast to structural constraints, these *metabolic constraints* have a greater degree of temporal flexibility; for example, glucose that is not consumed by neural activity at one moment will remain in the bloodstream to be used at a later time. However, overall metabolic consumption in the brain is approximately constant (Clarke, 1999).

tence of biased beliefs (*e.g.*, Eil and Rao, 2011; Möbius et al., 2014).

What people believe powerfully affects their utility, but what people *think about* internally and *pay attention to* externally can be equally, if not more, important than the portfolio of beliefs they in some sense "hold" but have not called to mind at any given moment. For example, everyone implicitly knows they must eventually die—an obviously horrible thought if you value your life—but most people rarely think about it unless they are reminded, for example by the sudden passing of a loved one. It is not the implicit knowledge of one's mortality—which everyone has all the time—but active contemplation that occasions negative feelings, and, often, efforts at self-distraction (a hypothesis known as "terror management"; Greenberg, Pyszczynski and Solomon, 1986).

Many phenomena that have been attributed to *information avoidance* may instead reflect *attention avoidance*. For example, the ostrich effect observed in investors (whereby they are more likely to seek information about their portfolio when the market is up than down) has been attributed to their desire to not receive adverse news about their investments. However, (Sicherman et al., 2016) observe the investor ostrich effect *on weekends*, when the market is closed and there is no new information to be gained from logging in. Only the desire to pay disproportionate *attention* to good news can make sense of this phenomenon. Quispe-Torreblanca et al. (2020) further show that investors are more likely to log into their accounts when the last stock they purchased is doing well than when it is performing poorly, controlling for the overall market and the performance of their overall portfolio. They argue that investors could only pull off this selective login strategy if they already knew how the stock was performing, consistent with attention-based utility. Moreover, experimental subjects who own individual stocks are selectively more likely to answer questions about an investment in exchange for pay if the investment has performed well (Quispe-Torreblanca et al., 2020).

The pleasures and pains of paying attention to particular topics can lead to over- and under-investment in learning about them (Bolte and Raymond, 2022), with examples such as over-planing vacations and under-planning living wills. In a book titled *Don't Even Think About It: Why Our Brains Are Wired to Ignore Climate Change*, Marshall (2015) attributes humanity's failure to take action on the environment to, in effect, attention avoidance.

Although the insights and research findings motivated by the two hypotheses overlap significantly, attention-based utility has one enormous advantage over belief-based utility: attention, unlike beliefs, is limited in supply. Hence, as we have been arguing from the outset of this review, it lends itself well to analysis using the conventional tools of constrained optimization. Belief-based utility, by contrast, has always suffered the conceptual difficulty that it is not clear what constraints limit people from believing whatever is most pleasant (besides the practical consequences of doing so; see Brunnermeier and Parker, 2005; Loewenstein and Molnar, 2018; Bolte and Raymond, 2022).

Activities become more appealing when they pull attention away from alternative foci that are negative—*i.e.*, when they serve as a welcome distraction. This may help explain the huge demand for pastimes, such as television, movies, drugs, alcohol, gambling, tattoos, and extreme sports, especially among those whose lives are relatively impoverished, either materially or otherwise.

The idea that attention directly impacts utility has important implications for information-disclosure policies, especially those, such as mandatory calorie labels at fast food restaurants and dramatic, gruesome labels on cigarette packaging, that are intended to discourage self-destructive behavior. Often, such efforts direct consumers' attention to information that they almost surely already know. According to attention-based utility, to whatever degree these measures accomplish their intended goal, they do so precisely because they impose real, hedonic costs on consumers, forcing them to confront—and hence affectively react to—future consequences they would otherwise ignore (see Loewenstein and O'Donoghue, 2006; Thunström, 2019; Sunstein, 2019; Butera et al., 2022).

4. Measuring Attention

A wide range of different methods have been used to measure attention. In early studies of decision making, for example, experimental subjects were presented with matrices of alternatives varying on different attributes, but could only access specific information by, for example, uncovering opaque flaps or opening envelopes while their behavior was recorded by the experimenter (Payne, 1976). With the advent of computers, equivalent methods have been programmed using software such as "mouselab," which covers each piece of information with an opaque box that becomes translucent once participants hover their cursor over it (Johnson et al., 1989).

A variety of "eye-tracking" methods enable researchers to dynamically monitor visual attention to different parts of a computer monitor or ambient physical environment. This data can be used to make inferences about what information participants are paying attention to (see Russo and Rosen, 1975, for one of the earliest examples).[10] Eye tracking has been used to study, among other things: learning (Knoepfle, Wang and Camerer, 2009) and strategic behavior (Devetag, Di Guida and Polonio, 2016) in games; the determinants of moral behavior (Fiedler and Glöckner, 2015); choices between simple consumer goods (Krajbich, Armel and Rangel, 2010); and whether the expected utility model is a good representation of risky choice (Arieli, Ben-Ami and Rubinstein, 2011).

Another ingenious techniques to track the focus of attention, the "flicker paradigm" (Rensink, O'regan and Clark, 1997), exploits *change-blindness* (Simons and Levin, 1997): our tendency to overlook even fairly dramatic changes, such as someone's shirt becoming another color, when they are introduced into a visual stimulus. In the flicker paradigm, an image and a modification of it are alternated with a blank screen in the middle. It takes individuals a surprisingly long time to detect substantial changes to the image, but changes to more conspicuous features are detected faster, which can be used as a technique to measure visual salience.[11] For example, if the clothing of

[10] A limitation of these methods is that how long someone's gaze focuses on a particular piece of information (or one exposes information with one's computer mouse) can indicate different things. Lingering on a particular piece of information is generally viewed as a proxy for the importance an individual places on that piece of information. However, it could also indicate that the decision maker has difficulty assimilating that information into the decision he/she is making. By the same token, quickly moving on from a bit of information could mean that its importance is so evident that the decision maker can instantly assimilate it into the decision.

[11] Loewenstein, Moore and Weber (2006) conducted an experiment in which participants were paid for accurately judging the fraction of people who would detect what changed in a flicker paradigm

an individual is varied, people have trouble detecting the difference; but if the individual's race or gender was changed, they would likely notice.

Although most empirical methods target the *focus* of attention, some research has also sought to measure the *intensity* of attention (see subsection 2.2 above). Drawing on earlier work by Hess and Polt (1964), Hess (1965), and (Goldwater, 1972), Kahneman (1973), in his book *Attention and Effort*, used pupil dilation to gauge the intensity of focus people applied to different tasks on a second-by-second basis. Kahneman cites research showing that pupil dilation is sensitive to both between-tasks and within-task variations—it can be used to rank the attention required by different tasks and by versions of the same task that differ in difficulty. Combining both measures (eye tracking and pupil dilation), Wang, Spezio and Camerer (2010) studied strategic information transmission in a sender-receiver game and found that the combination of lookup information and pupil dilation could help predict an unobservable private information state better than either measure alone.

Finally, economists and psychologists have also used people's recall (or accurate recognition) of specific information as a proxy for what they paid attention to (*e.g.* Craik et al., 1996; Graeber, Zimmermann and Roth, 2022; Hartzmark, Hirshman and Imas, 2021).

5. Attention in Economic Theory

Over the last two decades, economists have developed a variety of theoretical frameworks for studying the implications of attention. Most existing frameworks fall into two broad categories: "attentional choice," which focuses on how attention constrains people's ability to gather and integrate decision-relevant information, and "attentional learning," which focus on how attention shapes the process by which people gather and process information when forming beliefs.

Our aim is to provide readers with a flavor of the different approaches that have been proposed to date within each category, their chief differences, and (perhaps most importantly) their similarities. In last and final Section of the review (8.2), we note that, because existing theories have clustered around a limited range of core aspects of economic decision-making, a variety of fruitful directions for future theory are still open for exploration.

5.1. Attentional Choice

Most existing economic theories of attention focus on decision makers' limited ability to acquire and process information when they are selecting among consumption bundles or another fixed set of options. The first two frameworks we cover—*rational inattention* and *sparse maximization*—both explicitly incorporate attention by modeling choice as a two-stage process: First, a decision maker allocates costly attention to informational sources they expect to have the highest instrumental value; next, they select the action expected to maximize utility in light of what they learned in the first stage. This approach is convenient because both stages can be modeled as standard expected utility maximization problems.

Such models describe choice "as-if" people allocated attention with a high degree of goal-oriented sophistication. They therefore best describe situations in which either: (1) top-down determi-

setup. Participants were willing to pay to learn what actually was changing, but those who received the information dramatically overestimated the percentage—a "curse of knowledge" (Camerer, Loewenstein and Weber, 1989) they apparently did not anticipate.

nants dominate; or (2) in which bottom-up and motivational determinants are well-calibrated to an agent's rational goals. Note, as discussed earlier, that this approach combines attentional constraints operating at different levels of processing—sensation, perception, and cognition—together in a single reduced-form cost function.[12]

Aggregating different attentional constraints into a single reduced-form representation may or may not be warranted for all applications and contexts. Handel and Schwartzstein (2018), for example, point out that the effectiveness of policy interventions will, in general, depend on the specific attentional frictions in play. Insurance purchasers might make sub-optimal choices because they are unable to assimilate information about multiple plan features (*e.g.*, deductible, copay, *etc.*) or because their attention is drawn to a particular feature (*e.g.*, the lowest deductible), each of which implies different configurations of mistakes and suggests different interventions. Drawing such distinctions is often critical for predicting behavior out of sample or crafting effective policy.

The third framework we cover, *salience theory*, proposes that certain features of choice problems predictably attract more attention than others and consequently exert a disproportionate influence on decision making. In contrast to rational inattention and sparse maximization, the salience function that maps choice problems to attentional distortions is presumed to be fixed—perhaps by "bottom-up" processes—and is not modeled explicitly in terms of a constrained maximization process. In this respect, salience theory focuses more on describing the *effects* of attention in reduced form rather than examining the *process* by which it is allocated.

[12]Rational inattention models typically assume that agents pay a fixed, per-unit cost to deploy attention. The model can be adapted, with slight modification, to a fixed attentional budget, in which the "price" emerges as a shadow price of attention at the optimum. While much of the core technical machinery remains the same, some of the model's implications change when agents face fixed attentional constraints.

Rational Inattention

In a paper titled "The Implications of Rational Inattention," Sims (2003) proposed what has become the most well-developed approach to studying the effects of limited attention in economics (see Maćkowiak, Matějka and Wiederholt, 2021, for a recent review). Such models assume that, in order to gather and process information, agents pay a cost that is proportional to how much these activities reduce their uncertainty about the true state of the world. In the rational inattention framework, "uncertainty" is formalized as the Shannon entropy, or expected number of digits needed to specify a random variable's true realization (see Cover and Thomas, 1999, for a comprehensive introduction to information theory).

Sims (2003) originally studied this model as a way of explaining puzzles in macroeconomic data—such as the smooth, lagged propagation of shocks between variables—which otherwise require implausible frictions to accommodate. Subsequent authors have built upon this approach, solving the model for various continuous action spaces (*e.g.* Mackowiak and Wiederholt, 2009; Maćkowiak and Wiederholt, 2015) and applying it to a variety of topic areas, such as monetary policy (Paciello and Wiederholt, 2014), price rigidities (Mackowiak and Wiederholt, 2009), consumption and savings (Luo and Young, 2010), and mutual fund investing (Kacperczyk, Van Nieuwerburgh and Veldkamp, 2016). Mutual information constraints help explain why, for example, a variety of economic variables that classical theory predicts will be distributed continuously, such as seller prices or portfolio allocations, instead take discrete values Matějka (2016); Jung et al. (2019).

In the context of discrete choice, Matějka and McKay (2015) established that the rational inattention framework provides an attentional micro-foundation for the popular multinomial logistic stochastic choice rule. Recent work has shown that this conceptual link can be used to infer an individual's underlying attentional cost function and consideration sets from from the choices they make (Caplin and Dean, 2015; Caplin et al., 2020; Caplin, Dean and Leahy, 2019).

The rational inattention framework has been so widely applied, in part, because it does not specify the origin or nature of the attentional cost function, which can therefore be interpreted as a reduced-form representation of many different sensory, perceptual, and cognitive frictions. In fact, the results of Matějka and McKay (2015) do not even specify whether the marginal cost of attention arises directly, as a per-unit cost, or indirectly, as the shadow price of a fixed mutual information budget.

One strong claim that the rational inattention framework does make, however, is that attentional costs are always positive. In practice, certain forms of attention seem to elicit negative costs—that is, pleasant hedonic sensations—sometimes to a degree that it becomes difficult to disengage focus. This suggests that, although rational inattention models capture a wide variety of attentional determinants in a single framework, they may not be the appropriate tool when certain attentional mechanisms—most notably motivational feeling states—are responsible for a behavior of interest.

Sparse Maximization

Gabaix (2014) presents another framework for studying the impact of attention on consumer choice and equilibrium theory. In his model, a *sparse maximizer* is assumed to pay an attentional cost that scales with the amount of variation in decision-relevant variables (*e.g.*, prices, qualities) that they observe. The framework makes agents' attention allocation decisions tractable by assuming they take a first-order approximation to their utility function around a "default" action.

Incorporating attentional costs in this way introduces a variety of novel implications—*e.g.*, money illusion, asymmetry in the Slutsky matrix, and sensitivity of equilibrium allocation to price level. The relative simplicity and portability of this framework has enabled applications to optimal taxation (Farhi and Gabaix, 2020), dynamic macro (Gabaix, 2016), and game theory (Gabaix, 2012).

Salience

Salience theory posits that dimensions of an economic choice which exhibit greater variation between options will attract more attention and, consequently, exert a disproportionate influence on decision making (an idea introduced by Leland, 1994). Bordalo, Gennaioli and Shleifer (2012) formalize this idea in the domain of risky choice, arguing that states which result in payoffs that differ greatly from each other will be relatively over-weighted. The core insight of the model is that outcomes are evaluated *relative* to one another, and therefore choice sets exert an influence on the relative ranking of gambles. This helps resolve a number of familiar puzzles, such as the Allais paradox, preference reversals, and certain forms of small-stakes risk-seeking.

Bordalo, Gennaioli and Shleifer (2013) extend the core idea of salience theory to the domain of consumer choice, specifically situations in which individuals must trade off multiple features of a good (*e.g.* price and quality). They argue that, for choice sets in which price exhibits greater variation, consumers will pay relatively greater attention to differences in price and vice-versa for sets in which quality is more dispersed. The fact that adding unchosen options influences the perceived dispersion of each dimension provides a potential explanation for both the decoy effect and people's context-sensitive willingness to pay for individual goods.

5.2. Attentional Learning

Attentional processes select the information people seek out, notice, remember, and recall, which in turn shapes the beliefs they ultimately form. As discussed at length in Subsection 6.6, attention is far from random and does not, therefore, generate a representative sample of the material it selects from in most situations. On the contrary, attention curates our picture of the world in ways that we consider useful *a-priori*. This not only makes possible, but in many instances virtually guarantees, the introduction of learning biases.

Schwartzstein (2014) studies the learning effects of limited attention using a framework specifically designed to capture the self-reinforcing nature of attentional curation. The influence of top-down determinants means that people's current belief state and model of the world influence which variables they attend to (and ignore). This introduces the potential for self-sustaining attentional equilibria that insulate people from precisely that evidence which could dispel their incorrect assumptions, helping to explain why certain types of false beliefs persist in the face of readily available information. In Schwartzstein's model, ignored information cannot be recalled at a later date; Gagnon-Bartsch, Rabin and Schwartzstein (2018) build on this approach by considering how attention biases memory as well.

Steiner, Stewart and Matějka (2017) propose a dynamic generalization of the rational inattention framework. They show how the dynamic model can be reduced to a sequence of static rational inattention choice problems, which therefore admit well-developed solution techniques (*e.g.*, those of Matějka and McKay, 2015). Steiner, Stewart and Matějka (2017) show that agents behaving in this fashion make choices according to a "dynamic multinomial logit" choice rule, which has consequences that include judgmental inertia in the face of new evidence.

Ba, Bohren and Imas (2022) develop a two-stage learning model in which attention generates both under- and over-reaction to information depending on context. In the first stage, individuals simplify complex environments by channeling attention to states they see as relevant a-priori. Then, in the second stage, these simplified representations are used to update beliefs. Simplification leads to over-reaction when the environment is complex and under-reaction when it is simple, explaining why field data tend to support the former, and laboratory experiments the latter, finding.

6. Economic Consequences of Attention: Foundational Topics

In this section, we discuss attention's implications for a variety of foundational topics in economics: (1) Consumption and Choice; (2) Risk Preferences; (3)

Time Preferences; (4) Social Preferences; (5) Strategic Interactions and Mechanism Design; (6) Information and Learning; (7) Human Capital Development; (8) Incentives and Performance; and (9) Contracting. Section 7 then reviews attention's implications for specific application areas, such as finance, health, and firm behavior.

In reviewing both foundational topics and specific application areas, a small number of recurring themes identify themselves as particularly relevant to economics. The first is *narrow bracketing*. If the prototypical economic agent's attentional capacity is too scant for them to fully incorporate multiple attributes within a single, relatively well-defined decision problem, then it is certainly too scant for them to simultaneously evaluate the full scope of their global utility maximization problem and all the complex interrelationships that arise between its component parts. This leads to narrow bracketing, or the general tendency for economic agents to make choices in isolation when their utility, in fact, depends on a broader set of considerations (*c.f.*, Read et al., 1999; Rabin and Weizsäcker, 2009). One particularly acute manifestation of narrow bracketing is *decision neglect*, the notion that we do not even consider the vast majority of decisions we could in principle make because they simply do not cross our minds.

Second, external information and internal lines of thought that are *salient* will, in general, tend to garner disproportionate attention, and hence have an outsized influence on economic behavior, while those that are non-salient will receive insufficient attention. This leads people to overweight, for example: certain categories of low-probability risks, such as shark attacks, that are viscerally imaginable and under-weight other, less dramatic threats, such as heart disease (Slovic and Weber, 2013); investors to pay too much attention to stocks that receive media coverage and too little attention to fees, and citizens to pay too much attention to identifiable victims and too little to those, such as prisoners and the elderly in care homes, who are "out of sight and out of mind."

A third theme, closely related to the first two, is that even when people do pay attention to information, they often fail to take account of a wide range of considerations that should moderate their interpretation of that information—*e.g.*, the correlation structure in multiple observations (e.g. Enke and Zimmermann, 2019) or selection effects in what they are exposed to (Enke, 2020). For example, people fail to adequately adjust for biases in advice they receive from conflicted advisors (Jin, Luca and Martin, 2022).

6.1. Consumption and Choice

Becker (1965) argued that consumption is best thought of as the output of a productive process which combines time with other inputs to "create" utility. Upon closer inspection, however, it is attention—and not just time *per se*—that drives most forms of consumption utility. In the economics literature, time and attention have have frequently been conflated because the former is necessary for the later; however, the reverse is not true, and "raw" time, absent the concerted application of cognitive resources, is insufficient on its own for many consumptive or productive processes.[13] In-

[13]In some instances, the relative interplay of attention and time required to complete a productive task may be quite intricate. When making tea, for instance, one can divert attention to another activity while a kettle is coming to boil (allowing "mere time" to effect its work), but only so long as one is vigilant enough to notice when the process is complete. Kettles incorporate features—such as spouts

deed, attention is required to engage in, and derive pleasure from, many activities that produce consumption utility, such as reading a book, watching a concert, or conversing with a friend.

To illustrate the distinction, consider a good that we literally consume: food. It takes attention not just to prepare food, but also to eat and enjoy it; the ability to savor a meal requires, at its essence, one to focus additional attention on the sensations it generates. Indeed, the high-end dining practice of "eating in the dark" plays on this effect, the premise being that eliminating vision focuses attention on, and therefore intensifies, other aspects of the gustatory experience. The degraded experience of eating while driving or working illustrates the opposite effect.

This explains why a global shock to one's attentional budget—*e.g.*, worrying about the looming prospect of being fired during an economic downturn—can have such a widespread and sizable impact on life satisfaction. Attention-absorbing events simultaneously crowd out many forms of consumptive attention, making it difficult to derive pleasure from other aspects of life. On the other hand, and consistent with attention-based utility (Section 3), individuals actively use "distracting" activities to crowd out negative thoughts.

People also must expend attention to make active, deliberate decisions, even about which activities to pay attention to. In particular, it takes attention to prospectively simulate the consequences of different courses of action or imagine what potential consumption experiences might be like, both core pillars of economic choice. Most extant work in economics therefore focuses on how attention constrains the process of choice itself.

The effects of limited attention are particularly pronounced when each alternative in a choice set features multiple attributes that must be integrated to form a composite evaluation. In such circumstances, aspects of how choice sets are presented ("framing effects") can influence the way that decision makers distribute attention over, and therefore weight, the various attributes. Such effects help explain the substantial differences that arise when individuals evaluate the desirability of alternatives jointly (*i.e.*, at the same time) versus separately (*i.e.*, in isolation of one another; Hsee et al., 1999). A similar mechanism may also help explain why within-subject and between-subject experimental designs Charness, Gneezy and Kuhn (2012) often yield different results (*e.g.* Fox and Tversky, 1995), as the two necessarily focus attention on different features of a decision.

6.2. *Risk*

Limited attention has widespread implications for how people evaluate and respond to risk. For example, well-documented salience effects (see Subsection 5.1) imply that people will be especially responsive to risks that feature the potential for extreme outcomes. This may help explain skewness preferences (Dertwinkel-Kalt and Köster, 2020) and, in turn, the enormous appeal of lotteries with huge jackpots (Grossman and Eckel, 2015).

Perhaps the most significant consequences of limited attention when it comes to risk, however, result from narrow bracketing. When presented with a series of gambles, for example, people naturally tend to evaluate them one-at-a-time, in isolation, rather than collectively, as a portfolio. This can lead

that "whiste"—to reduce the attentional overhead required to monitor them.

people to overlook correlations that tie the performance of assets together (e.g., Enke and Zimmermann, 2019). At the same time, narrow bracketing can lead people to under-appreciate the benefits of diversification—in particular, the overwhelming likelihood that many independent positive expected-value bets will generate a favorable aggregate return (a phenomenon Benjamin, Rabin and Raymond, 2016, have labeled the *non-belief in large numbers*).

Narrow bracketing also represents an essential antecedent to prospect theory (Kahneman and Tversky, 1979), key components of which—especially small-stakes risk aversion and differential risk-preferences for gains and losses—are patently inconsistent with the maximization of a global utility function defined over final wealth (see, *e.g.*, Rabin, 2000). Some recent work has suggested even deeper connections between limited attention and prospect theory. For example, Woodford (2012) and Khaw, Li and Woodford (2021) propose that small-stakes risk aversion and reference dependence are perceptual distortions that arise from our limited capacity to represent and process information. Glickman, Tsetsos and Usher (2018) moreover argue that attention may account for framing effects in risk-taking and Pachur et al. (2018) propose that our aversion to losses arises from the fact that they attract more attention than gains.

Oprea (2022) additionally provides evidence that the signature empirical patterns of prospect theory are not specific to risk, but arise from the impact of limited attention on people's ability to deal with the complexity of lotteries. Supporting this conclusion, Oprea shows that the fourfold pattern of risk preferences implied by prospect theory can be reproduced in deterministic decisions involving complexities parallel to those that exist for lotteries.

Taking (or not taking) a specific risk invariably shifts our attention and can result in a variety of hedonic consequences. For example, insuring against a risk not only gets rid of the potential for negative outcomes *per se*, but also obviates the need to worry about or plan around them (*c.f.*, Hsee and Kunreuther, 2000). Attention and associated anxiety may therefore be a significant driver of the demand for extended product warranties and insurance policies that cover low probability but highly specific and vivid risks, such as terrorist attacks. In other circumstances, by contrast, people seek out risks to focus attention on things that bring them pleasure (Golman, Gurney and Loewenstein, 2021). Such examples include betting on a sports team to amplify the hedonic impact of watching them play.

People also use betting, gambling, and other attention-absorbing risks to distract themselves from negative thoughts (*e.g.*, a failing marriage), however temporarily. In an insightful book about the slot machine industry, Schüll (2012) cites numerous cases of individuals who use slot-machine gambling to escape the misery of their lives—*e.g.*, a man who describes himself as being "after nothingness," a woman who states that the point of playing slots is "to stay in a zone 'where nothing else matters'" and another woman who plays slots as a "reliable mechanism for securing a zone of insulation from a 'human world' she experiences as capricious, discontinuous, and insecure" (pages 12-13).

Technology companies—especially video game designers and social media platforms—have leveraged the attention-absorbing power of variable rewards to great effect (Bhargava and Velasquez, 2021; Alter, 2017). Indeed, smartphones and other electronic devices have become so effective at demanding our attention that people take enormous risks to stay connected to them, most notably driving while distracted (Stutts et al., 2005).

6.3. Time

We only care about the future to the extent that we attend to it. Early in the history of research on intertemporal preferences (See Frederick, Loewenstein and O'donoghue, 2002, for an overview), Böhm-Bawerk (1889) proposed, essentially, that time discounting arises from our limited ability to focus on future events:

> "It may be that we possess inadequate power to imagine and to abstract, or that we are not willing to put forth the necessary effort, but in any event we limn a more or less incomplete picture of our future wants and especially of the remotely distant ones. And then there are all those wants that never come to mind at all."

If someone's attention is fully absorbed "in the now," they will be insensitive to the delayed consequences of their actions. Sexual arousal and other drives that focus attention on the immediate present (Loewenstein, 1996) have such an effect. Alcohol, which, according to a popular account (Steele and Josephs, 1990), narrows one's attentional focus, also leads to short-sighted behavior.

Even when we are not intoxicated or in a hot state, concerns in the immediate present tend to command more attention than those in the future, meaning that limitations on attention may be one—and possibly the primary—culprit responsible for "present bias" (Laibson, 1997; O'Donoghue and Rabin, 1999). Quite analogous to how disproportionate attention to large-magnitude outcomes leads to a skewness preference over gambles, the same effect leads to high rates of time discounting when immediate outcomes are concentrated and delayed outcomes are dispersed, as is often the case (Kőszegi and Szeidl, 2013; Dertwinkel-Kalt et al., 2022). More generally, the under-weighting of outcomes that are spread out over time, uncertain, or otherwise amorphous provides an alternative explanation of behaviors such as smoking and overeating (Rick and Loewenstein, 2008). On the other hand, future experiences can draw a greater cumulative amount of attention, and hence, generate anticipation, meaning that people sometimes want to accelerate negative events and delay positive ones (Loewenstein, 1987; Berns et al., 2006).

Many problems of self-control (*i.e.*, the inhibition of prepotent behaviors in favor of other actions one wishes to implement; see Loewenstein, 1996; Loewenstein, O'Donoghue and Bhatia, 2015) involve a conflict between momentary pleasures and delayed negative consequences. Such conflicts can be resolved in two ways, both of which require sustained attention.

First, one can directly resist temptation by engaging cognitive control. For example, quitting bad habits, such as smoking, slouching, or over-eating, involves preventing oneself from "mindlessly" succumbing to the target behavior (Wansink and Sobal, 2007), often by deliberately redirecting attention to its negative consequences (Mann and Ward, 2007). As detailed in Section 2.2, cognitive control is one of the key resources underlying internal attention, meaning that actively resisting temptation competes with other uses of attention. In one striking demonstration of this effect, Ward et al. (2017) showed that the mere presence of a smartphone reduced performance on tests of cognitive ability.

Second, one can strategically avoid cues that trigger temptation in the first place (Laibson, 2001; Bernheim and Rangel, 2004; Duckworth, Milkman and Laibson, 2018). However, doing so typically involves making a large upfront attentional investment in restructuring one's routine, social life, and physical environment, as well as ongoing attention to monitoring for situations where further cues might present themselves.

6.4. Social Preferences

Attention has a significant impact on the activation and expression of social preferences. First, note that narrow bracketing plays an equally important role in social preferences as it does for risk or time: people's other-regarding behavior is frequently activated by circumstances that draw attention to proximate opportunities to "do the right thing," rather than the result of a global utilitarian calculation of where personal effort would have the highest marginal benefit. In dictator games, for example, experimental participants voluntarily give a significant fraction of their endowment away to equally affluent strangers who the experiment has drawn their attention to, but neglect the possibility that they could save the money for donation to those in dire need. More generally, no matter what one's underlying social preferences may be, altruism (or spite) will, in general, appear artificially high toward people one's attention is drawn to and artificially low toward those who one's attention is not drawn to.

As a result, expressions of social preference will be highly sensitive to superficial factors that influence who we pay attention to. For example, individual people are more viscerally imaginable than large demographics and hence tend to garner disproportionate sympathy and support, a phenomenon known as the "identifiable victim effect" (Schelling, 1968; Small and Loewenstein, 2003; Bohnet and Frey, 1999). Conversely, populations which are "out-of-sight" and hence, for attentional reasons, "out-of-mind"—*e.g.*, the incarcerated, malnourished, refugees, or inhumanly-raised livestock—tend to receive insufficient social consideration. The invisible nature of systemic problems and slow-moving crises, such as climate change, can also blind people to the need for action (Marshall, 2015).

Attention also plays an essential role in spreading and enforcing norms. First, drawing attention to both injunctive and descriptive norms—what others approve of and what others actually do, respectively—can impact pro-social behavior, for example by reducing littering Cialdini, Reno and Kallgren (1990). Second, being observed by others changes behavior, especially social behavior, in complex ways. In a meta-study of dictator games, for example, Engel (2011) find that de-anonymizing the dictator shifts people who would otherwise give nothing *and* people who would have given a greater-than-equal split to equality. Finally, people do not like to dwell on their *own* moral failings, and this distaste alone seems to prevent a certain measure of antisocial behavior. For example, Dana, Weber and Kuang (2007) show that subjects are significantly less generous in variants of the dictator game that feature "moral wiggle room," or enough ambiguity that their actions cannot be directly perceived as unfair, either by themselves or others.

6.5. Strategic Interactions

As Schelling (1980) pointed out when introducing the concept of a *focal point*, people must use actions that feature "some kind of prominence or conspicuousness" (page 57)—*i.e.*, that are *salient*—to coordinate behavior in absence of a previous agreement or the capacity to communicate. Subsequent work by Li and Camerer (2022) has shown that people use bottom-up visual salience (as calculated by a machine learning algorithm that predicts where people will freely look when presented with an image) to select focal points in pure coordination games.

Another line of research has applied attention-measurement techniques (discussed in Section 4) to uncover the search and thought strategies that people employ when playing economic games (*e.g.*, Brocas et al., 2014). For example, Camerer et al. (1993) tracked the order in which participants revealed information in a sequential bargaining game and found that it was the opposite of that predicted by the sub-game perfect equilibrium strategy of backward induction (see also Johnson et al., 2002).

While revealing, most research on attention in games is correlational in nature. However, some cleverly designed experiments do help isolate the causal role of attention. For example, Devetag, Legrenzi and Warglien (1999) find that people often violate iterated dominance in the standard dominance-solvable games but, when prompted to state a belief about what the other player will do, are more likely play the iterated dominant strategy. This suggests that drawing attention to what the other party will do makes people more likely to recognize the existence of the other player's dominating strategy, to believe that they would play it, and to respond accordingly.

6.6. Information & Learning

People can only learn from information they collect, process, and remember. As a result, attentional mechanisms are central to what people do (and do not) learn.

Experimental participants frequently fail to exploit information that is freely presented to them, even when researchers painstakingly attempt to clarify its significance. Simonsohn et al. (2008), for example, show that experimental participants pay close attention to events that affect them personally, but mostly ignore those that affect others, even when the latter are equally relevant for decision making. In a similar vein, Hartzmark, Hirshman and Imas (2021) show that investors react more strongly to news about stocks that they hold than stocks that they do not hold.

Unbiased learning generally requires that people attend to all, or at least a representative subset of, relevant data (Hanna, Mullainathan and Schwartzstein, 2014). When misapplied, selective attention can therefore lead to persistent inferential errors (Schwartzstein, 2014; Gagnon-Bartsch, Rabin and Schwartzstein, 2018). As discussed in Subsection 2.4, an individual's current understanding of the world is critical for determining where they direct attention. The bi-directional relationship between beliefs and attention opens up the possibility that people attend selectively to information that reinforces their current perspective and, moreover, overlook precisely the information which would dispel mistaken beliefs. Understanding the equilibria of this process is important for identifying which erroneous beliefs are "stable" (Gagnon-Bartsch, Rabin and Schwartzstein, 2018).

Motivational states also play a significant role in determining what information people pay attention to. Curiosity, in particular, leads to a huge demand for non-instrumental information (Wojtowicz, Chater and Loewenstein, 2022; Wojtowicz and Loewenstein, 2020; Golman et al., 2022). By contrast, boredom is a significant impediment to both individual instances of information acquisition and many longer-term processes of learning.

Limited attention has also been invoked to explain situations in which people fail to adequately account for a variety of factors that should, logically, moderate their judgments. For example, people insufficiently account for biases in informational sources—*e.g.*, being informed that they are only hearing one side of an argument (Brenner, Koehler and Tversky, 1996), or are being selectively exposed to information (Jin, Luca and Martin, 2022; Enke, 2020), *e.g.*, as a result of receiving advice from a conflicted advisor (Cain, Loewenstein and Moore, 2005). Likewise, people pay insufficient attention to "nuisance" variables Graeber, 2023, such as changes in a firm's profitability or valuation resulting from market conditions, when evaluating executive performance (Bertrand and Mullainathan, 2001).

Finally, information does not feature free disposal: that which is seen cannot generally be "unseen," no matter how uncomfortable or painful it might be. Given that thinking about certain facts can negatively impact utility (see Section 3), this can lead people to actively avoid learning in certain contexts (Golman, Hagmann and Loewenstein, 2017).

6.7. Human Capital Development

The fact that attention constrains people's ability to learn in general implies that it also constrains their ability to both accumulate and apply human capital in particular. In fact, it could be argued that attention is the *only* factor restricting the acquisition of human capital in many circumstances: if people could instantaneously absorb and process information without bound, acquiring knowledge that has already been developed—such as calculus, Latin, or the contents of this paper—would be effectively costless.

Some obstacles to learning, such as boredom, do not directly reflect biophysical constraints, but rather feelings our mind itself creates. Much of the effort put into education, for example, involves overcoming boredom and harnessing states like curiosity or flow (Wojtowicz, Chater and Loewenstein, 2019; Wojtowicz and Loewenstein, 2020; Markey and Loewenstein, 2014). Indeed, it is often the psychic cost of boredom—and *not* economic opportunity costs—that holds one back from the daily practice necessary to master an instrument or learn a new language. Indeed, boredom not only makes it difficult to practice at all, but even more specifically to practice the most mind-numbing, but effective, aspects of music: scales, conjugation, and other rudiments that serve as the foundation for mastery.

Even when people are motivated to learn, they can only absorb and process information at a limited rate. This often involves the need for "hands-on" experience and other methods of delivering knowledge that cater to low-bandwidth attentional limitations built into the human cognitive apparatus. The need to prepackage knowledge in this way requires massive expenditures of labor and capital. Institutions of higher education, for example, spend enormous sums of money building campuses and hiring professors to teach classes, in part because in-person instruction helps students maximize the efficiency of their attention.Professors, in turn, expend significant labor creating presentations that communicate information through the relatively high-bandwidth sensory channel of visual processing (*e.g.*, "infographics" Tufte, 1985) that could, were it not for human attentional limitations, otherwise be communicated in a "raw" form (*e.g.*, a table).

Technical mastery—especially that of physical skills—typically involves the transfer of behavioral control from attention-intensive "controlled" cognitive processes to attention-non-intensive "automatic" ones (Schneider and Shiffrin, 1977). When confronted by a new task, such as the video game Tetris, the brain initially recruits a diversity of cognitive resources, but, over time, learns to employ them with dramatically greater efficiency, resulting in improved performance while using fewer structural *and* metabolic resources (Haier et al., 1992). This enable experts to perform at a high level of skill even when their focus is split between multiple tasks, *e.g.* playing the piano while reading sheet music and singing at the same time. Interestingly, perhaps because people lack introspective access to the process of automation, they tend to underestimate both the speed and extent of automation, a misprediction that can lead to under-investment in human capital (Koriat, Sheffer and Ma'ayan, 2002; Billeter, Kalra and Loewenstein, 2011; Horn and Loewenstein, 2021).

6.8. Performance & Incentives

Classical economic theory holds that people perform better when they are adequately incentivized to do so. This assumption is of special significance for behavioral economics because many of its critics have argued that people will not succumb to sub-optimal patterns of behavior "when it counts"—*i.e.*, when incentives are large enough to make it worth people's while to expend significant attention and effort (Massey and Thaler, 2013; Camerer and Hogarth, 1999; but, see Parco, Rapoport and Stein, 2002). Whether increased stakes improve performance is relevant to discussions of executive compensation, exemplified by the claim that top managers receive insufficient performance-contingent incentives to maximize firm performance (*e.g.* Jensen and Murphy, 1990).

The logic behind such claims is that attention and effort are costly; hence, incentives are required to induce people to focus and try their hardest. Performance, in turn, is assumed to be positively related to both attention and effort. However, a fairly large literature in psychology (reviewed in Mesagno and Beckmann, 2017), and smaller set of studies in economics (Ariely et al., 2009; Enke et al., 2021), challenges this view by documenting the phenomenon of "choking" under pressure.

Most prominent theories of choking involve, centrally, attention. For example, "distraction theories" postulate that choking occurs because high incentives, for one reason or another, direct attention away from the task at hand toward thoughts that are either unhelpful or actively deleterious to performance, *e.g.* how one appears to others (Mesagno, Harvey and Janelle, 2012) or the consequences of failure (Baumeister and Showers, 1986). Another set of theories postulate that choking is especially pronounced for tasks that are well practiced and hence best executed using trained automatic processes; according to these theories, the brain automatically interprets high stakes as a situation in which it is worthwhile to allocate top-down attentional resources, interrupting well-practiced routines (Masters, 1992).

6.9. Contracting & Mechanism Design

In light of the Coase theorem (Coase, 1960) and other classical efficiency results, it is noteworthy that individuals fail to spontaneously solve many economic and social problems using contracts. Limitations on attention seem to be a key driver of *contracting costs* and may help to explain the relatively infrequent penetration of formal agreements into many areas of economic and social life. Klein (1980) identifies two main reasons that contracts are often incomplete: (i) uncertainty over the contingencies that may arise and (ii) costs associated with verifying which states of a contract actually obtain. Attention plays a role in both.

In a classical world, agents consider and form beliefs about every possible contingency, then contract to coordinate actions for mutual gain. In reality, however, attention is required to simulate possible futures and identify relevant contractual contingencies (let alone evaluate their impact, calculate transfers, *etc.*), making it impossible to include every possible eventuality.

This explains why many outcomes that are revealed to be hugely consequential in retrospect—such as pandemic provisions during Covid—are either missing or ambiguously specified. These omissions are not always made in good faith; sophisticated parties may strategically omit terms from a contract in order to avoid drawing attention to certain contingencies, risks, or unfair practices (Hermalin, Katz and Craswell, 2007; Gabaix and Laibson, 2006).

What's more, even outcomes which are observable in principle may not be observable in practice, given that contracting parties (and courts) have limited attention. For example, managers can watch some workers some of the time, but not all workers all of the time. This has the important implication that attentional costs—and therefore the psychology and economics of attention itself—play a significant role in determining the form and extent of enforcement, even for features that agents recognize as important ahead of time.

In this sense, limited attention is an unspoken assumption of nearly all principle-agent models, given that, with infinite quantities of this resource, managers could not only monitor subordinates perfectly, but actually perform most tasks themselves rather than delegate them to others. As just one example of how attention constrains contract feasibility, Sugaya and Wolitzky (2023) develop a model in which enforcement of public coordination through personalized sanctions (*e.g.*, a fine for noncompliance) is costly because it requires precise monitoring of—and, in most natural settings, attention to—individual-level behavior. They show that such costs render certain enforcement mechanisms, such as collective grim trigger, ineffective.

Attention also constrains the practical feasibility of auctions and other allocative mechanisms in important ways. For example, even when it is in principle possible for people to verify the strategy-proofness of an auction, cognitive limitations mean that agents may not be able to do so in practice. Moreover, certain strategies to construct mechanisms that are *obviously strategy proof* (in the formal sense of Li, 2017), such as the use of ascending price auctions, achieve greater cognitive simplicity by breaking down complex strategic interactions into a series of simpler choices. However, this too imposes attentional costs of a different sort: the need to wait through an auction. The efficiency of *direct revelation mechanisms*, moreover, relies on the assumption that every participant reports a complete and accurate preference order, but constructing and communicating such a record of one's preferences also demands significant attention from participants. These and other attentional costs may explain why mechanisms are popular for infrequent, high-stakes outcomes, such as medical residency, but have not penetrated deeply into more mundane areas of economic life.

7. Economic Consequences of Attention: Application Areas

In this section, we discuss the consequences of attention for a variety of economic topics: (1) finance; (2) consumer behavior; (3) productivity; (4) firm behavior and organization; (5) health and addiction; and (6) policy and public choice.

7.1. Finance

There are too many investment opportunities for any individual to fully consider or keep track of; hence attention plays a key role in investor behavior. For example, Peng and Xiong (2006) argue that limited attention leads people to focus on market and sector-level information instead of tracking individual firms. Indeed, Bhui and Jiao (2023) test for this behavior in the lab and find that people shift focus to more general financial categories when attentionally constrained.

Attention also leads people to take disproportionate account of specific assets (*e.g.*, those already in their possession) or considerations (*e.g.*, certain salient but low-value signals) and, conversely, ignore other assets (*e.g.*, those in foreign countries) or considerations (*e.g.*, the strategic motivations of others). In the words of Hirshleifer, "limited attention theories imply positive abnormal returns after neglected good news and negative abnormal returns after neglected bad news" (2015, page 141).

A variety of empirical studies have shown that retail investors are net buyers of "attention-grabbing" stocks that feature abnormal returns, volume, or media coverage (Seasholes and Wu, 2007; Barber and Odean, 2008; Engelberg and Parsons, 2011). Da, Engelberg and Gao (2011) show that internet search frequencies for individual stocks correlate with other measures of investor attention, and, more importantly, predict short-term gains but long-term losses. Inexperienced investors who trade using mobile applications seem to be especially attracted to attention-grabbing stocks, which tend to produce abnormally low returns after their moment in the spotlight has passed (Barber et al., 2021). Barber, Odean and Zheng (2005) further show that investors are influenced by salient, attention-grabbing features of mutual funds, such as front-end loads and commissions, relative to more important but less salient features, such as operating expenses. Choi, Laibson and Madrian (2010) provide parallel experimental evidence that individuals fail to take sufficient account of operating fees.

Empirical work on the financial consequences of attention has also shown that: (1) markets respond more slowly to information when attention is likely to be diffused, for example because many firms announce earnings on the same day (Hirshleifer, Lim and Teoh, 2009); (2) increased salience of a stock's purchase price substantially strengthens the disposition effect (Frydman and Wang, 2020); (3) increased investor attention leads to greater stock volatility, and, as a result, elevated risk premia (Andrei and Hasler, 2015); (4) increased media coverage of a firm leads investors to pay relatively more attention to firm-specific information than to market- and sector-level factors, which leads to less synchronicity between the firm's stock price and market- and sector-level prices (see, Peng and Xiong, 2006; Dong and Ni, 2014); and (5) lack of attention to selling, relative to buying, leads institutional investors to under-perform the market (Akepanidtaworn et al., 2021).

Theoretical models of financial attention have also been used to explain: (1) under-diversification (Van Nieuwerburgh and Veldkamp, 2010); (2) naive diversification (Gathergood et al., 2023); (3) home bias (Van Nieuwerburgh and Veldkamp, 2009); (4) style investing[14] (Peng and Xiong, 2006); and (5) return predictability (Hirshleifer, Lim and Teoh, 2011).

7.2. Consumer Behavior

Attention leads consumers to overweight certain product features and under-weight, or altogether ignore, others. For example, people are disproportionately sensitive to an appliances' upfront purchase price relative to its long-run energy costs (Hausman, 1979). In a similar vein, (Allcott, 2011) show that, although automobile purchasers generally *overestimate* future gas prices, they still pay very little attention to fuel efficiency when choosing a car.

Gabaix and Laibson (2006) argue that firms take advantage of consumer's limited attention by strategically obfuscating the price of add-ons, such as ATM overdraft fees and the cost of printer ink. According to their analysis, competition fails to eliminate such *shrouded attributes* because honest firms cannot match the "loss leader" prices that deceptive firms offer. Moreover, educating a rival's customers merely enables them to more effectively exploit these loss-leader prices, a form of cross-subsidization between naive and sophisticated buyers that enables deceptive firms to protect market share. Shrouding is, however, responsive to attention-based policy interventions; Stango and Zinman (2014) show, for example, that increasing attention to overdraft fees by asking overdraft-related questions in a survey substantially reduces the prevalence of over-drafting.

Consumers have a tendency to underweight nonsalient costs across a variety of other contexts, as well. Brown, Hossain and Morgan (2010), for example, find that retailers maximize profits by revealing add-on shipping charges when they are small but hiding them when they are large. Finkelstein (2009) found that drivers became less elastic with respect to changes in tolls following the introduction of electronic collection, to which states responded by raising tolls. Abaluck and Adams-Prassl (2021) develop a model in which consumers do not necessarily consider all options available to them, but become more likely to do so when changing prices "wake them up" to the need to re-consider their full choice set. They show that patterns of consideration can be recovered from choice data and provide the basis for welfare-improving interventions such as "smart defaults."

Empirical research has shown that attention moderates the impact of a particularly important class of add-on costs: taxes. A classic field study by Chetty, Looney and Kroft (2009) demonstrated, for example, that increasing the salience of sales taxes by embedding them in posted prices reduced alcohol sales by roughly 8% (Chetty, Looney and Kroft, 2009). Taubinsky and Rees-Jones (2018) experimentally elicited willingness to pay for different products—once without tax, then again with either standard sales tax or triple sales tax—and found that people drastically under-adjusted their reservation prices in response (see, also, Morrison and Taubinsky, 2021). Participants in the standard-tax condition only increased their reservation prices by 25% of the objective cost increase.

[14] "Style investing" refers to the allocation of funds between categories of assets such as large-cap stocks, value stocks, government bonds, dot-com stocks and venture capital.

Those in the triple-tax condition adjusted more fully, by 50%—presumably because they paid greater attention as the stakes increased—but still fell far short of full incorporation.

Another striking implication of limited attention is *left-digit bias*, or the tendency for consumers to over-weight the left-hand digits of product information. Lacetera, Pope and Sydnor (2012) showed, for example, that used car prices exhibit discontinuous drops at 10,000-mile odometer thresholds, along with smaller drops at 1,000-mile thresholds. Relatedly, Olenski et al. (2020) observe significantly higher rate of coronary-artery bypass grafting among patients admitted with acute myocardial infarction in the 2 weeks before their 80th birthday than for those admitted in the 2 weeks after because, despite the absence of clinical guidelines recommending a change in treatment at this age. They argue that doctors mentally reclassify such patients as being "in their 80s" rather than "in their 70s."

7.3. Productivity

Attention is an input into nearly every productive processes that requires human labor. Indeed, the rising prominence of digital technology has made attention and labor nearly synonymous in a growing number of jobs, especially those—such as computer programming or graphic design—that primarily involve interfacing with computers. This means that the joys and sorrows of work have become, for many, the pleasures and pains of maintaining focus.

Workplace boredom, in particular, is an extremely common challenge (Fisher, 1993; Chin et al., 2017), especially for repetitive tasks that nevertheless require high levels of sustained vigilance over time, such as tumor detection in mammography and baggage screening for air travel. As discussed in Section 2.4, boredom generates psychic disutility that increases the extrinsic rewards required to incentivize people to maintain focus *by its very design*, thus driving wages above the economic opportunity cost of time (Wojtowicz, Chater and Loewenstein, 2019). Boredom is not the only motivational state that does this, however; Toussaert (2018) showed that some experimental participants opted to eliminate the option of learning the ending of a salacious story so that they would not be distracted by curiosity while they worked on a paid task.

In education, a parallel insight has spawned a literature on educational achievement that distinguishes between intelligence and "cognitive endurance"—the ability to sustain attention and exert mental effort over time. Limited cognitive endurance has been linked to declining performance over time in fields ranging from medicine to school examinations (Balart, Oosterveen and Webbink, 2018; Brachet, David and Drechsler, 2012). Cognitive endurance predicts wages and educational outcomes such as college attendance, college quality, and college graduation, even after controlling for a fatigue-free measure of ability (Reyes, 2023). However, cognitive endurance can be improved through practice, with benefits for educational outcomes Kaur et al. (2021).

7.4. Firm Behavior & Organization

Organizations are comprised of humans and therefore inherit our psychological limitations. An organization's structure, management, and strategy are thus shaped by the need to effectively harness a group's collective mental resources and align them towards shared objectives. As Simon (1944) put it, "the major can influence the battle to the extent that his head is able to direct the machine-gunner's hand" (page 16). Early in the study of administrative behavior, Simon (1947) also pointed out that a manager's limited attention implied an "inability to take into consideration all the factors relevant to his choice" (page 101) and concomitant need to seek satisfactory, rather than fully optimal, decisions—an idea he referred to as *satisficing.*

Whereas presumptively optimal decision-making can be adequately characterized in terms of the outcome (the optimum), attentional limitations generally imply that the process by which administrators make decisions—*e.g.*, which options are considered in what order, how "satisfactory" is determined, *etc.*—will also influence organizational behavior. Cyert and March (1963) developed this and other insights of Simon regarding the *bounded rationality* of administrative decision makers into their hugely influential "Behavioral Theory of the Firm," which emphasized the importance of modeling an firm's internal structure—the processes, rules, and procedures by which it operates, but also the heterogeneous goals of its participants.

Marschak and Radner (1972) develop a branch of game theory—the "theory of teams"—specifically to the study the question of how firms divide attentional labor. Team theory focuses on strategic interactions in which each agent has aligned objectives but different information. Marschak and Radner (1972) apply this framework to analyze which organizational structures are both viable and desirable (in the sense of maximizing aggregate information-processing capacity and, accordingly, the quality of collective decision-making).

These perspectives have culminated in an "attention-based view of the firm," which, in the words of Ocasio (1997), proposes that "firm behavior is the result of how firms channel and distribute the attention of their decision-makers." The premise is that firm organization determines firm behavior largely through the way it structures attention and the flow of information. By the same token, it holds that firms tend to organize themselves in ways that maximize attentional and informational efficiency. As it turns out, many of the concepts developed to understand the psychology of individual-level attention have re-emerged in the study of organizations, most notably the distinction between top-down and bottom-up determinants (Ocasio, 2011) and the tight relationship between attention and learning Levinthal and March (1993).

7.5. *Health & Addiction*

Attention also plays a key role in many health-related behaviors. For example, patients frequently fail to follow drug and other treatment regimens because: (1) doing so reminds them of their condition (Kamaradova et al., 2016) or (2) they simply forget, meaning that attentional interventions can significantly boost adherence (*e.g.*, Bobrow et al., 2016). The same two mechanisms also appear to drive low rates of testing (and in some cases treatment) for diseases such as cancer and Parkinson's (Caplan, 1995; Kőszegi, 2003; Oster, Shoulson and Dorsey, 2013).

Attention, or a lack thereof, also factors into a variety of unhealthy habits, such as smoking, drinking, and overeating. First, inadequate attention to long-term negative consequences supports the maintenance of such habits. Interventions which focus attention on these realities can be highly effective (*e.g.* cigarette warning labels; Noar et al., 2017). However, it should be noted that such policies seem to be effective precisely because they impose attention-based utility costs on people, a fact that needs to be considered when calculating their welfare implications (e.g., Sunstein, 2019; Thunström, 2019).

Attention also impacts addiction in a variety of ways. Cue-theories of addiction posit that attention to cues associated with drug-taking trigger craving, and the accompanying, often irresistible, urge to imbibe the drug one is addicted to (Goldstein, 2001; Laibson, 2001; Loewenstein, 1999). This account of addiction helps to explain a wide range of addiction-related phenomena, such as why addicts often relapse after long periods of abstinence.

A number of studies have shown that addicts exhibit attentional biases in favor of drug-related cues in the environment (Robinson and Berridge, 1993). For example, substance abusers name color of words presented on a computer screen more slowly for drug-related than for neutral words—the "drug-Stroop test" (Cox, Fadardi and Klinger, 2006). Drug abusers are also more likely to notice when drug-related stimuli appear and disappear in the flicker paradigm discussed earlier Jones et al. (2003).

People can also become addicted to attentional stimuli themselves as evidenced by the growing problems of compulsive cellphone, internet, and video game use (Weinstein, 2010). And, it seems that people can likewise become addicted to the attention of others, leading to a variety of dysfunctional behaviors in response to the feeling that one's "star has fallen."[15]

[15] See Nick Duerden's discussion of pop stars' lives "after the spotlight moves on"; https://www.theguardian.com/music/2022/apr/16/pop-stars-spotlight-bob-geldof-robbie-williams-lisa-maffia

7.6. Policy and Public Choice

Policy makers have begun to realize that attentional interventions can be as, if not more, effective than incentives for influencing behavior. For example, simple, targeted, well-timed, attention-directing text messages can have a significant positive impact on savings (Karlan et al., 2016), medication adherence (Thakkar et al., 2016), school absenteeism (Smythe-Leistico and Page, 2018), and court nonappearance (Fishbane, Ouss and Shah, 2020; Zottola et al., 2022). Often, these policies are cheaper and have fewer unintended consequences than incentive-based approaches.

On the other hand, limited attention also blunts the impact of information-only interventions, in some cases decisively. Many disclosures are useless because consumers ignore them (Loewenstein, Sunstein and Golman, 2014). For example, Jensen, Potts and Jensen (2005) find that fewer than 3% of consumers read the privacy disclosures that are so ubiquitous on websites. More generally, the scarcity of attention implies that too much disclosure is not merely a nuisance, but can be affirmatively counterproductive when it distracts from other, more important, information (Lacko and Pappalardo, 2010).

Another general challenge is that topics and "facts" which naturally attract attention, and hence drive individual behavior, are not necessarily inherently important, as evidenced by the disproportionate virality of false news, conspiracy theories, and disinformation (Vosoughi, Roy and Aral, 2018). The fact that media platforms, celebrities, and politicians derive power from attention encourages them to steer the public conversation toward "hot-button" issues, distracting people from less salient, but often objectively more important, problems. Indeed, *insufficient* attention to boring, technocratic problems often poses a serious challenge. For example, politicians get little if any credit for problems that don't occur, which incentivizes them to "put out fires" rather than enact preventative measures that are often more effective over the long run.

8. *New Directions*

In this section, we turn to emerging topics in the economics of attention. The first subsection discusses how novel digital technologies are reshaping the economics of attention. We then introduce the concepts of attentional externalities and attentional property rights. The second subsection highlights some notable gaps in our current theoretical understanding of attention and proposes fruitful directions for future research.

8.1. *The Changing Landscape of Economic Attention*

The fact that attention responds, in some cases inescapably, to bottom-up mechanisms and motivational feeling states means, among other things, that the actions of others play a significant role in determining what people pay attention to. Technology companies in particular have come to exert an enormous influence on the structure of our modern attentional environment.

Today's commercial internet has been described as a "battle for clicks and eyeballs." Indeed, the primary source of revenue for most major internet technology companies has become the attention of their users (Evans, 2020; Flosi, Fulgoni and Vollman, 2013).[16] The commodification of attention incentivizes technology companies to provide whatever content maximizes the total amount of time users spend on their platforms, during which time they are susceptible to advertisements and generate data that firms can monetize (Wu, 2017; Zuboff, 2015).

At first glance, these new technologies might appear to strictly add value by enabling individuals to productively use "dead time"—*i.e.*, attention that would otherwise be wasted. However, (mis)directing attention can have a wide range of negative consequences for individuals: It can lead them to form incorrect beliefs (*e.g.*, by exposing them to misinformation), create opportunity costs when it directs attention away from superior attentional foci, and impose direct hedonic costs, consistent with attention-based utility.

Illustrating all three of these costs, a pop-up advertisement for a weight loss program might mislead a consumer about the benefits of the program, interrupt them from a rewarding task they had been focusing on, and provide a painful reminder of body insecurities. Much as processed foods are designed to maximize agribusiness profits with little or no consideration for their health or environmental externalities, companies purveying attentional products are motivated to attract attention with little or no consideration of costs (or foregone benefits) to the individual— the informational equivalent of "empty calories."

Attentional Externalities

To the degree that interacting parties fail to internalize some of the harmful or beneficial consequences of these attentional effects, their actions can be said to generate *attentional externalities.* These are well illustrated by the proliferation

[16] Wu (2017) chronicles the historical development of ad-supported media, including the prominent examples of newspaper journalism, radio shows, and television programs. In each case, paid advertisements are embedded into substantive content in such a way as to make it difficult to extricate them; consumers wishing to direct their attention to the content cannot avoid also giving attention over to paid placements.

of video screens displaying ads in elevators. A recent trade publication focusing on such adds stated that:

> "These days, people tend to ignore advertisements, therefore advertisers need to come up with new ways to catch people's attention. Standing and waiting for the elevator to arrive is the perfect time to try and grab the consumer's eye and plant the seed of advertising into their brains."[17]

Such ads impose a variety of costs and potential benefits on building occupants, who have no way of demanding compensation for the opportunity costs of lost attention (or the cost of taking the stairs to avoid being exposed to advertising).

In response to the considerable potential for individuals to impose attentional externalities on one another in public spaces, myriad social practices and institutions have arisen to manage which claims people are allowed to make on each other's attention. These institutions take a variety of forms that range from explicit rules, such as "quiet cars" on trains and quiet rooms in libraries, to implicit norms governing what constitutes acceptable behavior at particular places and times. The gradual evolution of such norms and conventions is, however, no match for the rapid entry of new forms of attentional externalities in many modern contexts.

Attentional Property Rights

The foregoing discussion naturally raises questions about whether people can be said to have *property rights* to their attention and what implications formally recognizing those rights might have. If, as we have argued, attention is a scarce and valuable resource endowed to each person by the very fact of having a mind, then it seems natural to grant them rights of ownership over their attention, in much the same way that we grant people natural rights of ownership over their physical bodies.[18]

According to the theory of Demsetz (1967), "property rights develop to internalize externalities when the gains of internalization become larger than the cost of internalization." Establishing and protecting such rights, however, turns out to be a daunting challenge. As Demsetz (1966) notes, "a private property right system requires the prior consent of 'owners' before their property can be affected by others." But, as discussed above, attention is only partially directed by conscious volition. The inability of agents to give meaningful "prior consent" over the allocation of their attention in a wide variety of frequently occurring and practically significant contexts thus presents a challenge to the promise of granting people property rights over their own attention. New technological developments make the explicit definition and protection of attentional property rights an increasingly pressing issue, but also commensurately more complex to address.

Technology and Attentional Complementarities

The interplay between limited attention and technological advances has

[17] https://www.awesomeinventions.com/elevator-ads/

[18] John Locke articulates a natural right to one's physical person as follows: "Every Man has a Property in his own Person. This no Body has any Right to but himself. The Labour of his Body, and the Work of his Hands, we may say, are properly his" (Locke, 2015, §§27). The brain is clearly a part of a person's body—thus, if one considers the operations of the brain, cognition, to be a form of "mental labor," then Locke's argument seems to imply a natural right to attention.

far-reaching implications for production as well as consumption. Many productivity-enhancing technologies operate by relaxing attentional constraints. Consider, for example, "telemedicine", which enables doctors to deploy their human capital at a distance over video chat. This reduces costs by solving the physical "coincidence of wants" inherent in a traditional, in-person clinical exam. A variety of other innovations, from self-driving cars to whistling kettles, similarly create value by extending or replacing human powers of attention.

When it comes to consequences for new technologies for employment, there is an especially pressing need to grapple with the implications of the recent rapid development of artificial intelligence (AI), which has already begun to spawn new technologies that augment, direct, or displace human attention across nearly every sector of the economy. Classical economic models based on assumptions of hyper-rational agents are ill-fitted to make sense of a technology that enhances these capabilities. To study the impact of *artificial* intelligence, therefore, one must first develop a clear picture of what factors limit *natural* intelligence.

Prior to the advent of AI, economists could take for granted the simple fact that every individual is endowed with one brain and a truly inimitable bundle of perceptual, cognitive, and motor capacities which earn them a "seat at the table" of economic production. The prospect that artificial intelligence (capital) may be able to displace large swaths of natural intelligence (labor) represents a categorical change in the balance of economic power, the effects of which are hard to describe, let alone predict, using current theory. The fact that the sophistication of AI seems to depend so critically on scale—in terms of both the vast quantities of data and computational power required to train state-of-the-art models—presents a particularly large threat to the democratizing force that a naturally quite equal distribution of mental resources has historically exerted.

Whether new AI technologies act as substitutes or complements for human labor will determine the future of economic inequality, both within industries and across the economy as a whole (Acemoglu and Restrepo, 2020, 2018*a*; Simon, 1965). An economics of mental resources in general, and attention in particular, can help clarify the likely trajectory of such impacts and help policymakers prepare for the potential impacts of wide-spread labor reorganization caused by AI. Many of these technologies can be better understood as *attention saving* than *labor saving*, with important consequences for how they should be intuitively understood and responded to.

8.2. New Directions for Theory

Most existing frameworks—including those outlined in Section 5—provide targeted accounts of how specific attentional margins constrain specific, economically relevant behaviors or mental operations. This approach has been instrumental to developing portable models that can be used to study the impacts of limited attention in a variety of specific settings. In reality, however, attention is, as we have discussed, multidimensional, and nearly everything an economic agent does requires, and therefore competes for the use of, their finite attentional resources.

If economists want to more fully embrace attention as a key central resource constraining judgment and choice, models that incorporate tradeoffs over a broader range of activities would be valuable. As one example of the type of phenomena that can only be understood by considering the interactions that span an agent's global attentional allocation problem, Banerjee and Mullainathan (2008) develop a model in which money stresses at home reduce productivity at work, creating a feedback loop that reinforces the poverty trap (*c.f.*, Kaur et al., 2021).

Models of human capital formation and skill-development, more generally, could productively incorporate deeper insights about how automation works, as well as its implications for the dynamics of attentional constraints. Models that focus on decisions people make about whether and how to develop their own human capital should also take account of peoples' often incorrect insights about the speed with which automation occurs.

As discussed in our overview of attention-based utility (Section 3), paying attention to certain stimuli, thoughts, or activities generates utility directly, implying that consumer theory can be applied to attentional budgeting. This, in turn, immediately raises a host of questions, such as which attentional "goods" are complements or substitutes, normal or inferior, *etc.*

Attention is used for more than just consumption, however. Many applications of attention are not exclusively driven by the desire to *consume* utility directly, but rather to *produce* "intermediate goods," such as knowledge (*e.g.*, by reading this paper), social capital (*e.g.*, by feigning interest in a friend's bizarre dream), or high-quality choices (*e.g.*, by engaging in extensive product research) that can be used to generate utility in the future. As hinted at in Subsection 6.1, recasting Becker's 1965 theory of time production in terms of attention could help clarify the structure of how these demands compete with one another.

A more general theory of attentional budgeting could even help sharpen our understanding of the isolated contexts already being modeled using existing methods. For example, Caplin and Dean (2015) propose a method for using revealed preference analysis to elicit an individual's "attentional cost function." As discussed in Section 2.4, however, many types of attentional costs are largely determined by the *opportunity cost* associated with one's executive resource, and are therefore not a fixed entity, but rather change depending on one's immediate and global circumstances. While a local cost function can be elicited in a particular context (*e.g.*, during an experimental session at a particular place and time), such measures may not always generalize. Indeed, some activities, like solving sudoku puzzles, are pleasurable in some circumstances (*e.g.*, a rainy day at the family cabin) but highly aversive in others (*e.g.*, the stands of a World Cup final), meaning that the revealed "cost" of engaging in them may entirely switch signs between different contexts.

Almost all existing economic models dealing with attention either assume that people have complete control over the focus of attention (as in rational inattention models) or that they have no control (as in salience models).[19] The reality is, as discussed in Section 2.4, that in most situations the focus of attention is jointly directed both by a combination of top-down, bottom up, and motivational factors. Clearly, many important appli-

[19]An exception is a model of attention-based utility proposed by Golman and Loewenstein (2018) that incorporates both top-down and bottom-up influences. In the model, attention is directed toward (or away from) 'information gaps' that are pleasurable (or unpleasant) to think about. The model has implications for information-seeking and avoidance (Golman et al., 2022) and for risk- and ambiguity-aversion and seeking (Golman, Gurney and Loewenstein, 2020).

cations, such as situations in which consumers attempt to resist firms' attempts to capture their attention, require a consideration of more than one, and possibly all of, these determinants. The significant role that bottom-up mechanisms and motivational feeling states play in attention allocation complicates the theoretical project of understanding attention allocation because it means that, in contrast to firm-level production and investment decisions for which one can simply assume that agents equate the expected marginal productivity of resources across potential uses, an accurate global theory of attention requires a consideration of the influence of these additional psychological determinants. Although this means that the standard economic toolkit used to study resource allocation cannot be immediately applied without modification, it also opens up the potential for theory to reveal novel vectors for welfare-improving policies and interventions.

9. *Conclusion*

Our goal in this review has been to demonstrate that conceptualizing attention as a *bona fide* productive mental resource helps to bridge economics and other disciplines like psychology and artificial intelligence, organize results from behavioral economics, and identify fruitful new avenues for economics research. Separating out physical production from mental production and, accordingly, physical resources from mental resources will help to make sense of this modern "economics of attention."

REFERENCES

Abaluck, Jason, and Abi Adams-Prassl. 2021. "What do consumers consider before they choose? Identification from asymmetric demand responses." *The Quarterly Journal of Economics*, 136(3): 1611–1663.

Acemoglu, Daron, and Pascual Restrepo. 2018*a*. "Low-skill and high-skill automation." *Journal of Human Capital*, 12(2): 204–232.

Acemoglu, Daron, and Pascual Restrepo. 2018*b*. "The race between man and machine: Implications of technology for growth, factor shares, and employment." *American Economic Review*, 108(6): 1488–1542.

Acemoglu, Daron, and Pascual Restrepo. 2020. "The wrong kind of AI? Artificial intelligence and the future of labour demand." *Cambridge Journal of Regions, Economy and Society*, 13(1): 25–35.

Akepanidtaworn, Klakow, Rick Di Mascio, Alex Imas, and Lawrence Schmidt. 2021. "Selling fast and buying slow: Heuristics and trading performance of institutional investors." National Bureau of Economic Research.

Allcott, Hunt. 2011. "Consumers' perceptions and misperceptions of energy costs." *American Economic Review*, 101(3): 98–104.

Allport, D Alan, Barbara Antonis, and Patricia Reynolds. 1972. "On the division of attention: A disproof of the single channel hypothesis." *Quarterly journal of experimental psychology*, 24(2): 225–235.

Alter, Adam. 2017. *Irresistible: The rise of addictive technology and the business of keeping us hooked.* Penguin.

Andrei, Daniel, and Michael Hasler. 2015. "Investor attention and stock market volatility." *The review of financial studies*, 28(1): 33–72.

Arieli, Amos, Yaniv Ben-Ami, and Ariel Rubinstein. 2011. "Tracking decision makers under uncertainty." *American Economic Journal: Microeconomics*, 3(4): 68–76.

Ariely, Dan, Uri Gneezy, George Loewenstein, and Nina Mazar. 2009. "Large stakes and big mistakes." *The Review of Economic Studies*, 76(2): 451–469.

Arons, Barry. 1992. "A review of the cocktail party effect." *Journal of the American Voice I/O Society*, 12(7): 35–50.

Attwell, David, and Simon B Laughlin. 2001. "An energy budget for signaling in the grey matter of the brain." *Journal of Cerebral Blood Flow & Metabolism*, 21(10): 1133–1145.

Ba, Cuimin, J Aislinn Bohren, and Alex Imas. 2022. "Over-and Underreaction to Information." *Available at SSRN.*

Baddeley, Alan. 1992. "Working memory." *Science*, 255(5044): 556–559.

Balart, Pau, Matthijs Oosterveen, and Dinand Webbink. 2018. "Test scores, noncognitive skills and economic growth." *Economics of Education Review*, 63: 134–153.

Banerjee, Abhijit V, and Sendhil Mullainathan. 2008. "Limited attention and income distribution." *American Economic Review*, 98(2): 489–93.

Barber, Brad M, and Terrance Odean. 2008. "All that glitters: The effect of attention and news on the buying behavior of individual and institutional investors." *The review of financial studies*, 21(2): 785–818.

Barber, Brad M, Terrance Odean, and Lu Zheng. 2005. "Out of sight, out of mind: The effects of expenses on mutual fund flows." *The Journal of Business*, 78(6): 2095–2120.

Barber, Brad M, Xing Huang, Terrance Odean, and Christopher Schwarz. 2021. "Attention induced trading and returns: Evidence from robinhood users." *Journal of Finance, forthcoming.*

Baumeister, Roy F, and Carolin J Showers. 1986. "A review of paradoxical performance effects: Choking under pressure in sports and mental tests." *European Journal of Social Psychology*, 16(4): 361–383.

Bear, Mark, Barry Connors, and Michael A Paradiso. 2020. *Neuroscience: exploring the brain, enhanced edition: exploring the brain.* Jones & Bartlett Learning.

Becker, Gary S. 1965. "A Theory of the Allocation of Time." *The economic journal*, 493–517.

Benjamin, Daniel J, Matthew Rabin, and Collin Raymond. 2016. "A model of nonbelief in the law of large numbers." *Journal of the European Economic Association*, 14(2): 515–544.

Berger, Jonah, and Katherine L Milkman. 2012. "What makes online content viral?" *Journal of marketing research*, 49(2): 192–205.

Bernheim, B Douglas, and Antonio Rangel. 2004. "Addiction and cue-triggered decision processes." *American economic review*, 94(5): 1558–1590.

Berns, Gregory S, Jonathan Chappelow, Milos Cekic, Caroline F

Zink, Giuseppe Pagnoni, and Megan E Martin-Skurski. 2006. "Neurobiological substrates of dread." *Science*, 312(5774): 754–758.

Bertrand, Marianne, and Sendhil Mullainathan. 2001. "Are CEOs rewarded for luck? The ones without principals are." *The Quarterly Journal of Economics*, 116(3): 901–932.

Bhargava, Vikram R, and Manuel Velasquez. 2021. "Ethics of the attention economy: The problem of social media addiction." *Business Ethics Quarterly*, 31(3): 321–359.

Bhui, Rahul, and Peiran Jiao. 2023. "Attention constraints and learning in categories." *Management Science*.

Billeter, Darron, Ajay Kalra, and George Loewenstein. 2011. "Underpredicting learning after initial experience with a product." *Journal of Consumer Research*, 37(5): 723–736.

Bishop, Sonia J, John Duncan, and Andrew D Lawrence. 2004. "State anxiety modulation of the amygdala response to unattended threat-related stimuli." *Journal of Neuroscience*, 24(46): 10364–10368.

Bishop, Sonia, John Duncan, Matthew Brett, and Andrew D Lawrence. 2004. "Prefrontal cortical function and anxiety: controlling attention to threat-related stimuli." *Nature neuroscience*, 7(2): 184–188.

Bliss, James C, Hewitt D Crane, Phyllis K Mansfield, and James T Townsend. 1966. "Information available in brief tactile presentations." *Perception & Psychophysics*, 1(4): 273–283.

Bobrow, Kirsten, Andrew J Farmer, David Springer, Milensu Shanyinde, Ly-Mee Yu, Thomas Brennan, Brian Rayner, Mosedi Namane, Krisela Steyn, Lionel Tarassenko, et al. 2016. "Mobile phone text messages to support treatment adherence in adults with high blood pressure (SMS-Text Adherence Support [StAR]) a single-blind, randomized trial." *Circulation*, 133(6): 592–600.

Böhm-Bawerk. 1889. "Capital and interest."

Bohnet, Iris, and Bruno S Frey. 1999. "The sound of silence in prisoner's dilemma and dictator games." *Journal of economic behavior & organization*, 38(1): 43–57.

Bolte, Lukas, and Collin Raymond. 2022. "Emotional Inattention."

Bordalo, Pedro, Nicola Gennaioli, and Andrei Shleifer. 2012. "Salience theory of choice under risk." *The Quarterly journal of economics*, 127(3): 1243–1285.

Bordalo, Pedro, Nicola Gennaioli, and Andrei Shleifer. 2013. "Salience and consumer choice." *Journal of Political Economy*, 121(5): 803–843.

Bordalo, Pedro, Nicola Gennaioli, and Andrei Shleifer. 2017. "Memory, attention, and choice." *The Quarterly journal of economics*.

Botvinick, Matthew M, and Jonathan D Cohen. 2014. "The computational and neural basis of cognitive control: charted territory and new frontiers." *Cognitive science*, 38(6): 1249–1285.

Botvinick, Matthew M, Todd S Braver, Deanna M Barch, Cameron S Carter, and

Jonathan D Cohen. 2001. "Conflict monitoring and cognitive control." *Psychological review*, 108(3): 624.

Bower, Gordon H. 1981. "Mood and memory." *American psychologist*, 36(2): 129.

Brachet, Tanguy, Guy David, and Andrea M Drechsler. 2012. "The effect of shift structure on performance." *American Economic Journal: Applied Economics*, 4(2): 219–46.

Brascamp, Jan, Philipp Sterzer, Randolph Blake, and Tomas Knapen. 2018. "Multistable perception and the role of the frontoparietal cortex in perceptual inference." *Annu Rev Psychol*, 69: 77–103.

Braudy, Leo. 1997. *The frenzy of renown: Fame and its history.* Vintage.

Brenner, Lyle A, Derek J Koehler, and Amos Tversky. 1996. "On the evaluation of one-sided evidence." *Journal of Behavioral Decision Making*, 9(1): 59–70.

Broadbent, DE. 1958. "Perception and communication."

Brocas, Isabelle, Juan D Carrillo, Stephanie W Wang, and Colin F Camerer. 2014. "Imperfect choice or imperfect attention? Understanding strategic thinking in private information games." *Review of Economic Studies*, 81(3): 944–970.

Brown, Jennifer, Tanjim Hossain, and John Morgan. 2010. "Shrouded attributes and information suppression: Evidence from the field." *The Quarterly Journal of Economics*, 125(2): 859–876.

Brunnermeier, Markus K, and Jonathan A Parker. 2005. "Optimal expectations." *American Economic Review*, 95(4): 1092–1118.

Butera, Luigi, Robert Metcalfe, William Morrison, and Dmitry Taubinsky. 2022. "Measuring the welfare effects of shame and pride." *American Economic Review*, 112(1): 122–68.

Cain, Daylian M, George Loewenstein, and Don A Moore. 2005. "The dirt on coming clean: Perverse effects of disclosing conflicts of interest." *The Journal of Legal Studies*, 34(1): 1–25.

Calvo, Manuel G, and Lauri Nummenmaa. 2008. "Detection of emotional faces: salient physical features guide effective visual search." *Journal of Experimental Psychology: General*, 137(3): 471.

Camerer, Colin F, and Robin M Hogarth. 1999. "The effects of financial incentives in experiments: A review and capital-labor-production framework." *Journal of risk and uncertainty*, 19: 7–42.

Camerer, Colin F, Eric J Johnson, Talia Rymon, and Sankar Sen. 1993. *Cognition and framing in sequential bargaining for gains and losses.* MIT Press.

Camerer, Colin, George Loewenstein, and Martin Weber. 1989. "The curse of knowledge in economic settings: An experimental analysis." *Journal of political Economy*, 97(5): 1232–1254.

Caplan, Lee S. 1995. "Patient delay in seeking help for potential breast cancer." *Public Health Reviews*, 23(3): 263–274.

Caplin, Andrew. 2016. "Measuring and modeling attention." *Annual Review of Economics*, 8: 379–403.

Caplin, Andrew, and John Leahy. 2001. "Psychological expected utility theory and anticipatory feelings." *The Quarterly Journal of Economics*, 116(1): 55–79.

Caplin, Andrew, and Mark Dean. 2015. "Revealed preference, rational inattention, and costly information acquisition." *American Economic Review*, 105(7): 2183–2203.

Caplin, Andrew, Dániel Csaba, John Leahy, and Oded Nov. 2020. "Rational inattention, competitive supply, and psychometrics." *The Quarterly Journal of Economics*, 135(3): 1681–1724.

Caplin, Andrew, Mark Dean, and John Leahy. 2019. "Rational inattention, optimal consideration sets, and stochastic choice." *The Review of Economic Studies*, 86(3): 1061–1094.

Carrasco, Marisa. 2011. "Visual attention: The past 25 years." *Vision research*, 51(13): 1484–1525.

Charness, Gary, Uri Gneezy, and Michael A Kuhn. 2012. "Experimental methods: Between-subject and within-subject design." *Journal of economic behavior & organization*, 81(1): 1–8.

Chase, William G, and Herbert A Simon. 1973. "Perception in chess." *Cognitive psychology*, 4(1): 55–81.

Chater, Nick, and George Loewenstein. 2016. "The under-appreciated drive for sense-making." *Journal of Economic Behavior & Organization*, 126: 137–154.

Chater, Nick, Jian-Qiao Zhu, Jake Spicer, Joakim Sundh, Pablo León-Villagrá, and Adam Sanborn. 2020. "Probabilistic biases meet the Bayesian brain." *Current Directions in Psychological Science*, 29(5): 506–512.

Chelazzi, Leonardo, Earl K Miller, John Duncan, and Robert Desimone. 1993. "A neural basis for visual search in inferior temporal cortex." *Nature*, 363(6427): 345–347.

Cherry, E Colin. 1953. "Some experiments on the recognition of speech, with one and with two ears." *The Journal of the acoustical society of America*, 25(5): 975–979.

Chetty, Raj, Adam Looney, and Kory Kroft. 2009. "Salience and taxation: Theory and evidence." *American economic review*, 99(4): 1145–77.

Chin, Alycia, Amanda Markey, Saurabh Bhargava, Karim S Kassam, and George Loewenstein. 2017. "Bored in the USA: Experience sampling and boredom in everyday life." *Emotion*, 17(2): 359.

Choi, James J, David Laibson, and Brigitte C Madrian. 2010. "Why does the law of one price fail? An experiment on index mutual funds." *The Review of Financial Studies*, 23(4): 1405–1432.

Chun, Marvin M, and Nicholas B Turk-Browne. 2007. "Interactions between attention and memory." *Current opinion in neurobiology*, 17(2): 177–184.

Chun, Marvin M, Julie D Golomb, Nicholas B Turk-Browne, et al. 2011. "A taxonomy of external and internal attention." *Annual review of psychology*, 62(1): 73–101.

Chwe, Michael Suk-Young. 2013. *Rational ritual: Culture, coordination, and common knowledge.* Princeton University Press.

Cialdini, Robert B, Raymond R Reno, and Carl A Kallgren. 1990. "A Focus Theory of Normative Conduct: Recycling the Concept of Norms to Reduce Littering in Public Places." *Journal of Personality and Social Psychology*, 58(6): 1015–1026.

Clarke, Donald D. 1999. "Circulation and energy metabolism of the brain." *Basic neurochemistry: Molecular, cellular, and medical aspects.*

Coase, Ronald Harry. 1960. "The problem of social cost." *The Journal of Law & Economics*, 3: 1–44.

Cohen, Jonathan D, Kevin Dunbar, and James L McClelland. 1990. "On the control of automatic processes: a parallel distributed processing account of the Stroop effect." *Psychological review*, 97(3): 332.

Coltheart, Max. 1980. "Iconic memory and visible persistence." *Perception & psychophysics*, 27: 183–228.

Corbetta, Maurizio, and Gordon L Shulman. 2002. "Control of goal-directed and stimulus-driven attention in the brain." *Nature reviews neuroscience*, 3(3): 201–215.

Cover, Thomas M, and Joy A Thomas. 1999. *Elements of information theory.* John Wiley & Sons.

Cox, W Miles, Javad S Fadardi, and Eric Klinger. 2006. "Underlying Implicit Cognition in Addiction." *Handbook of implicit cognition and addiction*, 253.

Craik, Fergus IM, and Robert S Lockhart. 1972. "Levels of processing: A framework for memory research." *Journal of verbal learning and verbal behavior*, 11(6): 671–684.

Craik, Fergus IM, Richard Govoni, Moshe Naveh-Benjamin, and Nicole D Anderson. 1996. "The effects of divided attention on encoding and retrieval processes in human memory." *Journal of Experimental Psychology: General*, 125(2): 159.

Cyert, Richard Michael, and James G March. 1963. "A behavioral theory of the firm."

Dana, Jason, Roberto A Weber, and Jason Xi Kuang. 2007. "Exploiting moral wiggle room: experiments demonstrating an illusory preference for fairness." *Economic Theory*, 33: 67–80.

Darwin, Christopher J, Michael T Turvey, and Robert G Crowder. 1972. "An auditory analogue of the Sperling partial report procedure: Evidence for brief auditory storage." *Cognitive Psychology*, 3(2): 255–267.

Dawson, Geraldine, Karen Toth, Robert Abbott, Julie Osterling, Jeff Munson, Annette Estes, and Jane Liaw. 2004. "Early social attention impairments in autism: social orienting, joint attention, and attention to distress." *Developmental psychology*, 40(2): 271.

Da, Zhi, Joseph Engelberg, and Pengjie Gao. 2011. "In search of attention." *The Journal of Finance*, 66(5): 1461–1499.

Demsetz, Harold. 1966. "Some aspects of property rights." *The Journal of Law and Economics*, 9: 61–70.

Demsetz, Harold. 1967. "Toward a Theory of Property Rights." *The American Economic Review*, 57(2): 347–359.

Dertwinkel-Kalt, Markus, and Mats Köster. 2020. "Salience and skewness preferences." *Journal of the European Economic Association*, 18(5): 2057–2107.

Dertwinkel-Kalt, Markus, Holger Gerhardt, Gerhard Riener, Frederik Schwerter, and Louis Strang. 2022. "Concentration bias in intertemporal choice." *The Review of Economic Studies*, 89(3): 1314–1334.

Devetag, Giovanna, Sibilla Di Guida, and Luca Polonio. 2016. "An eye-tracking study of feature-based choice in one-shot games." *Experimental Economics*, 19(1): 177–201.

Devetag, Maria G, Paolo Legrenzi, and Massimo Warglien. 1999. "Focusing Strategies in Reasoning About Games." *Deductive Reasoning and Strategies*, 233.

Dong, Yi, and Chenkai Ni. 2014. "Does Limited Attention Constrain Investors' Acquisition of Firm-specific Information?" *Journal of Business Finance & Accounting*, 41(9-10): 1361–1392.

Duckworth, Angela L, Katherine L Milkman, and David Laibson. 2018. "Beyond willpower: Strategies for reducing failures of self-control." *Psychological Science in the Public Interest*, 19(3): 102–129.

Durgin, Frank H, Srimant P Tripathy, and Dennis M Levi. 1995. "On the filling in of the visual blind spot: Some rules of thumb." *Perception*, 24(7): 827–840.

Eil, David, and Justin M Rao. 2011. "The good news-bad news effect: asymmetric processing of objective information about yourself." *American Economic Journal: Microeconomics*, 3(2): 114–38.

Eisenberger, Naomi I, Matthew D Lieberman, and Kipling D Williams. 2003. "Does rejection hurt? An fMRI study of social exclusion." *Science*, 302(5643): 290–292.

Engelberg, Joseph E, and Christopher A Parsons. 2011. "The causal impact of media in financial markets." *the Journal of Finance*, 66(1): 67–97.

Engel, Christoph. 2011. "Dictator games: A meta study." *Experimental economics*, 14(4): 583–610.

Enke, Benjamin. 2020. "What you see is all there is." *The Quarterly Journal of Economics*, 135(3): 1363–1398.

Enke, Benjamin, and Florian Zimmermann. 2019. "Correlation neglect in belief formation." *The Review of Economic Studies*, 86(1): 313–332.

Enke, Benjamin, Frederik Schwerter, and Florian Zimmermann. 2020. "Associative memory and belief formation." National Bureau of Economic Research.

Enke, Benjamin, Uri Gneezy, Brian Hall, David Martin, Vadim Nelidov, Theo Offerman, and Jeroen Van De Ven. 2021. "Cognitive biases: Mistakes or missing stakes?" *The Review of Economics and Statistics*, 1–45.

Eriksen, Charles W, and James D St James. 1986. "Visual attention within and around the field of focal attention: A zoom lens model." *Perception & psychophysics*, 40(4): 225–240.

Evans, David S. 2020. "The economics of attention markets." *Available at SSRN 3044858*.

Fairbanks, Grant, Newman Guttman, and Murray S Miron. 1957. "Auditory comprehension in relation to listening rate and selective verbal redundancy." *Journal of Speech and Hearing Disorders*, 22(1): 23–32.

Farhi, Emmanuel, and Xavier Gabaix. 2020. "Optimal taxation with behavioral agents." *American Economic Review*, 110(1): 298–336.

Festré, Agnès, and Pierre Garrouste. 2015. "The 'economics of attention': A history of economic thought perspective." *Œconomia. History, Methodology, Philosophy*, , (5-1): 3–36.

Fiedler, Susann, and Andreas Glöckner. 2015. "Attention and moral behavior." *Current Opinion in Psychology*, 6: 139–144.

Finkelstein, Amy. 2009. "E-ztax: Tax salience and tax rates." *The Quarterly Journal of Economics*, 124(3): 969–1010.

Firestone, Chaz, and Brian J Scholl. 2016. "Cognition does not affect perception: Evaluating the evidence for "top-down" effects." *Behavioral and brain sciences*, 39: e229.

First, Michael B. 2013. *DSM-5 handbook of differential diagnosis.* American Psychiatric Pub.

Fishbane, Alissa, Aurelie Ouss, and Anuj K Shah. 2020. "Behavioral nudges reduce failure to appear for court." *Science*, 370(6517): eabb6591.

Fisher, Cynthia D. 1993. "Boredom at work: A neglected concept." *Human Relations*, 46(3): 395–417.

Flosi, Stephanie, Gian Fulgoni, and Andrea Vollman. 2013. "If an advertisement runs online and no one sees it, is it still an ad?: Empirical generalizations in digital advertising." *Journal of Advertising Research*, 53(2): 192–199.

Forcato, Cecilia, Rodrigo S Fernandez, and María E Pedreira. 2014. "Strengthening a consolidated memory: the key role of the reconsolidation process." *Journal of Physiology-Paris*, 108(4-6): 323–333.

Fox, Craig R, and Amos Tversky. 1995. "Ambiguity aversion and comparative ignorance." *The quarterly journal of economics*, 110(3): 585–603.

Frederick, Shane. 2005. "Cognitive reflection and decision making." *Journal of Economic perspectives*, 19(4): 25–42.

Frederick, Shane, George Loewenstein, and Ted O'donoghue. 2002. "Time discounting and time preference: A critical review." *Journal of economic literature*, 40(2): 351–401.

Frydman, Cary, and Baolian Wang. 2020. "The impact of salience on investor behavior: Evidence from a natural experiment." *The Journal of Finance*, 75(1): 229–276.

Gabaix, Xavier. 2012. "Game theory with sparsity-based bounded rationality." Citeseer.

Gabaix, Xavier. 2014. "A sparsity-based model of bounded rationality." *The Quarterly Journal of Economics*, 129(4): 1661–1710.

Gabaix, Xavier. 2016. "Behavioral macroeconomics via sparse dynamic programming." National Bureau of Economic Research.

Gabaix, Xavier. 2019. "Behavioral inattention." In *Handbook of Behavioral Economics: Applications and Foundations 1.* Vol. 2, 261–343. Elsevier.

Gabaix, Xavier, and David Laibson. 2006. "Shrouded attributes, consumer myopia, and information suppression in competitive markets." *The Quarterly Journal of Economics*, 121(2): 505–540.

Gagnon-Bartsch, Tristan, Matthew Rabin, and Joshua Schwartzstein. 2018. *Channeled attention and stable errors.* Harvard Business School Boston.

Gallup, Andrew C, Joseph J Hale, David JT Sumpter, Simon Garnier, Alex Kacelnik, John R Krebs, and Iain D Couzin. 2012. "Visual attention and the acquisition of information in human crowds." *Proceedings of the National Academy of Sciences*, 109(19): 7245–7250.

Gathergood, John, David Hirshleifer, David Leake, Hiroaki Sakaguchi, and Neil Stewart. 2023. "Naive buying diversification and narrow framing by individual investors." *The Journal of Finance*, 78(3): 1705–1741.

Geanakoplos, John, David Pearce, and Ennio Stacchetti. 1989. "Psychological games and sequential rationality." *Games and economic Behavior*, 1(1): 60–79.

Gilbert, Charles D, and Mariano Sigman. 2007. "Brain states: top-down influences in sensory processing." *Neuron*, 54(5): 677–696.

Gilovich, Thomas, Victoria Husted Medvec, and Kenneth Savitsky. 2000. "The spotlight effect in social judgment: an egocentric bias in estimates of the salience of one's own actions and appearance." *Journal of personality and social psychology*, 78(2): 211.

Glickman, Moshe, Konstantinos Tsetsos, and Marius Usher. 2018. "Attentional selection mediates framing and risk-bias effects." *Psychological science*, 29(12): 2010–2019.

Gobet, Fernand, Peter CR Lane, Steve Croker, Peter CH Cheng, Gary Jones, Iain Oliver, and Julian M Pine. 2001. "Chunking mechanisms in human learning." *Trends in cognitive sciences*, 5(6): 236–243.

Goldstein, Avram. 2001. *Addiction: From biology to drug policy.* Oxford University Press.

Goldwater, Bram C. 1972. "Psychological significance of pupillary movements." *Psychological bulletin*, 77(5): 340.

Golman, Russell, and George Loewenstein. 2018. "Information gaps: A theory of preferences regarding the presence and absence of information." *Decision*, 5(3): 143.

Golman, Russell, David Hagmann, and George Loewenstein. 2017. "Information avoidance." *Journal of Economic Literature*, 55(1): 96–135.

Golman, Russell, George Loewenstein, Andras Molnar, and Silvia Saccardo. 2022. "The demand for, and avoidance of, information." *Management Science*, 68(9): 6454–6476.

Golman, Russell, Nikolos Gurney, and George Loewenstein. 2020. "Information gaps for risk and ambiguity." *Psychological Review.*

Golman, Russell, Nikolos Gurney, and George Loewenstein. 2021. "Information gaps for risk and ambiguity." *Psychological Review*, 128(1): 86.

Graeber, Thomas. 2023. "Inattentive inference." *Journal of the European Economic Association*, 21(2): 560–592.

Graeber, Thomas, Florian Zimmermann, and Christopher Roth. 2022. "Stories, statistics, and memory."

Greenberg, Jeff, Tom Pyszczynski, and Sheldon Solomon. 1986. "The causes and consequences of a need for self-esteem: A terror management theory." In *Public self and private self.* 189–212. Springer.

Griffiths, Thomas L, Falk Lieder, and Noah D Goodman. 2015. "Rational use of cognitive resources: Levels of analysis between the computational and the algorithmic." *Topics in cognitive science*, 7(2): 217–229.

Grossman, Philip J, and Catherine C Eckel. 2015. "Loving the long shot: Risk taking with skewed lotteries." *Journal of Risk and Uncertainty*, 51: 195–217.

Haier, Richard J, Benjamin V Siegel Jr, Andrew MacLachlan, Eric Soderling, Stephen Lottenberg, and Monte S Buchsbaum. 1992. "Regional glucose metabolic changes after learning a complex visuospatial/motor task: a positron emission tomographic study." *Brain research*, 570(1-2): 134–143.

Handel, Benjamin, and Joshua Schwartzstein. 2018. "Frictions or mental gaps: what's behind the information we (don't) use and when do we care?" *Journal of Economic Perspectives*, 32(1): 155–78.

Hanna, Rema, Sendhil Mullainathan, and Joshua Schwartzstein. 2014. "Learning through noticing: Theory and evidence from a field experiment." *The Quarterly Journal of Economics*, 129(3): 1311–1353.

Hari, Johann. 2023. *Stolen Focus: Why You Can't Pay Attention–and how to Think Deeply Again.* Crown.

Hartzmark, Samuel M, Samuel D Hirshman, and Alex Imas. 2021. "Ownership, learning, and beliefs." *The Quarterly journal of economics*, 136(3): 1665–1717.

Hausman, Jerry A. 1979. "Individual discount rates and the purchase and utilization of energy-using durables." *The Bell Journal of Economics*, 33–54.

Hermalin, Benjamin E, Avery W Katz, and Richard Craswell. 2007. "Contract law." *Handbook of law and economics*, 1: 3–138.

Hess, Eckhard H. 1965. "Attitude and pupil size." *Scientific american*, 212(4): 46–55.

Hess, Eckhard H, and James M Polt. 1964. "Pupil size in relation to mental activity during simple problem-solving." *Science*, 143(3611): 1190–1192.

Hills, Thomas T, Michael N Jones, and Peter M Todd. 2012. "Optimal foraging in semantic memory." *Psychological review*, 119(2): 431.

Hills, Thomas T, Peter M Todd, and Michael N Jones. 2015. "Foraging in semantic fields: How we search through memory." *Topics in cognitive science*, 7(3): 513–534.

Hirshleifer, David. 2015. "Behavioral finance." *Annual Review of Financial Economics*, 7: 133–159.

Hirshleifer, David, Sonya Seongyeon Lim, and Siew Hong Teoh. 2009. "Driven to distraction: Extraneous events and underreaction to earnings news." *The Journal of Finance*, 64(5): 2289–2325.

Hirshleifer, David, Sonya S Lim, and Siew Hong Teoh. 2011. "Limited investor attention and stock market misreactions to accounting information." *The Review of Asset Pricing Studies*, 1(1): 35–73.

Horn, Samantha, and George Loewenstein. 2021. "Underestimating Learning by Doing." *Available at SSRN 3941441*.

Hsee, Chrisopher K, George F Loewenstein, Sally Blount, and Max H Bazerman. 1999. "Preference reversals between joint and separate evaluations of options: a review and theoretical analysis." *Psychological bulletin*, 125(5): 576.

Hsee, Christopher K, and Howard C Kunreuther. 2000. "The affection effect in insurance decisions." *Journal of Risk and Uncertainty*, 20(2): 141–159.

James, William. 1890. *The Principles of Psychology.* Vol. 1, New York:Henry Holt.

Jensen, Carlos, Colin Potts, and Christian Jensen. 2005. "Privacy practices of Internet users: Self-reports versus observed behavior." *International Journal of Human-Computer Studies*, 63(1-2): 203–227.

Jensen, Michael C, and Kevin J Murphy. 1990. "Performance pay and top-management incentives." *Journal of political economy*, 98(2): 225–264.

Jin, Ginger Zhe, Michael Luca, and Daniel Martin. 2022. "Complex disclosure." *Management Science*, 68(5): 3236–3261.

Johnson, Eric J, Colin Camerer, Sankar Sen, and Talia Rymon. 2002. "Detecting failures of backward induction: Monitoring information search in sequential bargaining." *Journal of economic theory*, 104(1): 16–47.

Johnson, Eric J, John W Payne, James R Bettman, and David A Schkade. 1989. "Monitoring information processing and decisions: The mouselab system." DUKE UNIV DURHAM NC CENTER FOR DECISION STUDIES.

Johnson, Kenneth O, and John R Phillips. 1981. "Tactile spatial resolution. I. Two-point discrimination, gap detection, grating resolution, and letter recognition." *Journal of neurophysiology*, 46(6): 1177–1192.

Jones, Barry T, Ben C Jones, Helena Smith, and Nicola Copley. 2003. "A flicker paradigm for inducing change blindness reveals alcohol and cannabis information processing biases in social users." *Addiction*, 98(2): 235–244.

Judd, Tilke, Krista Ehinger, Frédo Durand, and Antonio Torralba. 2009. "Learning to predict where humans look." 2106–2113, IEEE.

Jung, Junehyuk, Jeong Ho Kim, Filip Matějka, and Christopher A Sims. 2019. "Discrete actions in information-constrained decision problems." *The Review of Economic Studies*, 86(6): 2643–2667.

Kacperczyk, Marcin, Stijn Van Nieuwerburgh, and Laura Veldkamp. 2016. "A rational theory of mutual funds' attention allocation." *Econometrica*, 84(2): 571–626.

Kahneman, Daniel. 1970. "Remarks on attention control." *Acta Psychologica*, 33: 118–131.

Kahneman, Daniel. 1973. *Attention and effort.* Vol. 1063, Citeseer.

Kahneman, Daniel. 2011. *Thinking, fast and slow.* Macmillan.

Kahneman, Daniel, and Amos Tversky. 1979. "Prospect Theory: An Analysis of Decision under Risk." *Econometrica*, 47(2): 263–292.

Kahneman, Daniel, Stewart Paul Slovic, Paul Slovic, and Amos Tversky. 1982. *Judgment under uncertainty: Heuristics and biases.* Cambridge university press.

Kamaradova, Dana, Klara Latalova, Jan Prasko, Radim Kubinek, Kristyna Vrbova, Barbora Mainerova, Andrea Cinculova, Marie Ociskova, Michaela Holubova, Jarmila Smoldasova, et al. 2016. "Connection between self-stigma, adherence to treatment, and discontinuation of medication." *Patient preference and adherence*, 10: 1289.

Kanwisher, Nancy, and Galit Yovel. 2006. "The fusiform face area: a cortical region specialized for the perception of faces." *Philosophical Transactions of the Royal Society B: Biological Sciences*, 361(1476): 2109–2128.

Karlan, Dean, Margaret McConnell, Sendhil Mullainathan, and Jonathan Zinman. 2016. "Getting to the top of mind: How reminders increase saving." *Management Science*, 62(12): 3393–3411.

Kaur, Supreet, Sendhil Mullainathan, Suanna Oh, and Frank Schilbach. 2021. "Do Financial Concerns Make Workers Less Productive?" National Bureau of Economic Research.

Khaw, Mel Win, Ziang Li, and Michael Woodford. 2021. "Cognitive imprecision and small-stakes risk aversion." *The review of economic studies*, 88(4): 1979–2013.

Klein, Benjamin. 1980. "Transaction cost determinants of" unfair" contractual arrangements." *The American economic review*, 70(2): 356–362.

Knoepfle, Daniel T, Joseph Taoyi Wang, and Colin F Camerer. 2009. "Studying learning in games using eye-tracking." *Journal of the European Economic Association*, 7(2-3): 388–398.

Koriat, Asher, Limor Sheffer, and Hilit Ma'ayan. 2002. "Comparing objective and subjective learning curves: Judgments of learning exhibit increased underconfidence with practice." *Journal of Experimental Psychology: General*, 131(2): 147.

Kőszegi, Botond. 2003. "Health anxiety and patient behavior." *Journal of health economics*, 22(6): 1073–1084.

Kőszegi, Botond, and Adam Szeidl. 2013. "A model of focusing in economic choice." *The Quarterly journal of economics*, 128(1): 53–104.

Kőszegi, Botond, George Loewenstein, and Takeshi Murooka. 2022. "Fragile self-esteem." *The Review of Economic Studies*, 89(4): 2026–2060.

Krajbich, Ian, Carrie Armel, and Antonio Rangel. 2010. "Visual fixations and the computation and comparison of value in simple choice." *Nature neuroscience*, 13(10): 1292–1298.

Lacetera, Nicola, Devin G Pope, and Justin R Sydnor. 2012. "Heuristic thinking and limited attention in the car market." *American Economic Review*, 102(5): 2206–36.

Lacko, James M, and Janis K Pappalardo. 2010. "The failure and promise of mandated consumer mortgage disclosures: Evidence from qualitative interviews and a controlled experiment with mortgage borrowers." *American Economic Review*, 100(2): 516–521.

Laibson, David. 1997. "Golden eggs and hyperbolic discounting." *The Quarterly Journal of Economics*, 112(2): 443–478.

Laibson, David. 2001. "A cue-theory of consumption." *The Quarterly Journal of Economics*, 116(1): 81–119.

Landry, Peter. 2021. "A behavioral economic theory of cue-induced attention-and task-switching with implications for neurodiversity." *Journal of Economic Psychology*, 86: 102423.

Landry, Reginald, and Susan E Bryson. 2004. "Impaired disengagement of attention in young children with autism." *Journal of Child Psychology and Psychiatry*, 45(6): 1115–1122.

Lavie, Nilli. 2005. "Distracted and confused?: Selective attention under load." *Trends in cognitive sciences*, 9(2): 75–82.

Leitner, Yael. 2014. "The co-occurrence of autism and attention deficit hyperactivity disorder in children–what do we know?" *Frontiers in human neuroscience*, 8: 268.

Leland, Jonathan W. 1994. "Generalized similarity judgments: An alternative explanation for choice anomalies." *Journal of Risk and Uncertainty*, 9: 151–172.

Levinthal, Daniel A, and James G March. 1993. "The myopia of learning." *Strategic management journal*, 14(S2): 95–112.

Lieder, Falk, and Thomas L Griffiths. 2020. "Resource-rational analysis: Understanding human cognition as the optimal use of limited computational resources." *Behavioral and brain sciences*, 43.

Lindström, Björn, Martin Bellander, David T Schultner, Allen Chang, Philippe N Tobler, and David M Amodio. 2021. "A computational reward learning account of social media engagement." *Nature communications*, 12(1): 1311.

Li, Shengwu. 2017. "Obviously strategy-proof mechanisms." *American Economic Review*, 107(11): 3257–87.

Liss, Miriam, Celine Saulnier, Deborah Fein, and Marcel Kinsbourne. 2006. "Sensory and attention abnormalities in autistic spectrum disorders." *Autism*, 10(2): 155–172.

Li, Xiaomin, and Colin F Camerer. 2022. "Predictable effects of visual salience in experimental decisions and games." *The Quarterly Journal of Economics*, 137(3): 1849–1900.

Locke, John. 2015. *The second treatise of civil government.* Broadview Press.

Loewenstein, George. 1987. "Anticipation and the valuation of delayed consumption." *The Economic Journal*, 97(387): 666–684.

Loewenstein, George. 1994. "The psychology of curiosity: A review and reinterpretation." *Psychological bulletin*, 116(1): 75.

Loewenstein, George. 1996. "Out of control: Visceral influences on behavior." *Organizational behavior and human decision processes*, 65(3): 272–292.

Loewenstein, George. 1999. "A visceral account of addiction." *Getting Hooked: Rationality and Addiction*, , ed. J. Elster and O.J. Skog, 235–264. Sage Publications, Inc.

Loewenstein, George, and Andras Molnar. 2018. "The renaissance of belief-based utility in economics." *Nature Human Behaviour*, 2(3): 166–167.

Loewenstein, George, and Ted O'Donoghue. 2006. "" We can do this the easy way or the hard way": Negative emotions, self-regulation, and the law." *The University of Chicago Law Review*, 73(1): 183–206.

Loewenstein, George, Cass R Sunstein, and Russell Golman. 2014. "Disclosure: Psychology changes everything." *Annu. Rev. Econ.*, 6(1): 391–419.

Loewenstein, George, Don A Moore, and Roberto A Weber. 2006. "Misperceiving the value of information in predicting the performance of others." *Experimental Economics*, 9(3): 281–295.

Loewenstein, George, Ted O'Donoghue, and Sudeep Bhatia. 2015. "Modeling the interplay between affect and deliberation." *Decision*, 2(2): 55.

Luo, Yulei, and Eric R Young. 2010. "Risk-sensitive consumption and savings under rational inattention." *American Economic Journal: Macroeconomics*, 2(4): 281–325.

Mackowiak, Bartosz, and Mirko Wiederholt. 2009. "Optimal sticky prices under rational inattention." *American Economic Review*, 99(3): 769–803.

Maćkowiak, Bartosz, and Mirko Wiederholt. 2015. "Business cycle dynamics under rational inattention." *The Review of Economic Studies*, 82(4): 1502–1532.

Maćkowiak, Bartosz, Filip Matějka, and Mirko Wiederholt. 2021. "Rational inattention: A review."

Madipakkam, Apoorva Rajiv, Marcus Rothkirch, Isabel Dziobek, and Philipp Sterzer. 2017. "Unconscious avoidance of eye contact in autism spectrum disorder." *Scientific reports*, 7(1): 13378.

Mann, Traci, and Andrew Ward. 2007. "Attention, self-control, and health behaviors." *Current Directions in Psychological Science*, 16(5): 280–283.

Markey, Amanda, and George Loewenstein. 2014. "Curiosity." *International handbook of emotions in education*, 238–255.

Marschak, Jacob, and Roy Radner. 1972. *Economic Theory of Teams.*

Marshall, George. 2015. *Don't even think about it: Why our brains are wired to ignore climate change.* Bloomsbury Publishing USA.

Massey, Cade, and Richard H Thaler. 2013. "The loser's curse: Decision making and market efficiency in the National Football League draft." *Management Science*, 59(7): 1479–1495.

Masters, Richard SW. 1992. "Knowledge, knerves and know-how: The role of explicit versus implicit knowledge in the breakdown of a complex motor skill under pressure." *British journal of psychology*, 83(3): 343–358.

Matějka, Filip. 2016. "Rationally inattentive seller: Sales and discrete pricing." *The Review of Economic Studies*, 83(3): 1125–1155.

Matějka, Filip, and Alisdair McKay. 2015. "Rational inattention to discrete choices: A new foundation for the multinomial logit model." *American Economic Review*, 105(1): 272–98.

McFedries, Paul. 2014. "Stop, attention thief![Technically Speaking]." *IEEE Spectrum*, 6(51): 28.

Mesagno, Christopher, and Juergen Beckmann. 2017. "Choking under pressure: Theoretical models and interventions." *Current opinion in psychology*, 16: 170–175.

Mesagno, Christopher, Jack T Harvey, and Christopher M Janelle. 2012. "Choking under pressure: The role of fear of negative evaluation." *Psychology of Sport and Exercise*, 13(1): 60–68.

Meshi, Dar, Carmen Morawetz, and Hauke R Heekeren. 2013. "Nucleus accumbens response to gains in reputation for the self relative to gains for others predicts social media use." *Frontiers in human neuroscience*, 439.

Milgram, Stanley, Leonard Bickman, and Lawrence Berkowitz. 1969. "Note on the drawing power of crowds of different size." *Journal of personality and social psychology*, 13(2): 79.

Miller, George A. 1956. "The magical number seven, plus or minus two: Some limits on our capacity for processing information." *Psychological review*, 63(2): 81.

Möbius, Markus M, Muriel Niederle, Paul Niehaus, and Tanya S Rosenblat. 2014. "Managing self-confidence."

Morrison, William, and Dmitry Taubinsky. 2021. "Rules of thumb and attention elasticities: Evidence from under-and overreaction to taxes." *Review of Economics and Statistics*, 1–45.

Motter, Brad C. 1994. "Neural correlates of attentive selection for color or luminance in extrastriate area V4." *Journal of Neuroscience*, 14(4): 2178–2189.

Müller, Hermann J, and Patrick M Rabbitt. 1989. "Reflexive and voluntary orienting of visual attention: time course of activation and resistance to interruption." *Journal of Experimental psychology: Human perception and performance*, 15(2): 315.

Narhi-Martinez, William, Blaire Dube, and Julie D Golomb. 2022. "Attention as a multi-level system of weights and balances." *Wiley Interdisciplinary Reviews: Cognitive Science*, e1633.

Navalpakkam, Vidhya, and Laurent Itti. 2007. "Search goal tunes visual features optimally." *Neuron*, 53(4): 605–617.

Noar, Seth M, Diane B Francis, Christy Bridges, Jennah M Sontag, Noel T Brewer, and Kurt M Ribisl. 2017. "Effects of strengthening cigarette pack warnings on attention and message processing: A systematic review." *Journalism & Mass Communication Quarterly*, 94(2): 416–442.

Norman, Donald A, and Tim Shallice. 1986. "Attention to action." In *Consciousness and self-regulation.* 1–18. Springer.

Ocasio, William. 1997. "Towards an attention-based view of the firm." *Strategic management journal*, 18(S1): 187–206.

Ocasio, William. 2011. "Attention to attention." *Organization science*, 22(5): 1286–1296.

O'Donoghue, Ted, and Matthew Rabin. 1999. "Doing it now or later." *American economic review*, 89(1): 103–124.

Olenski, Andrew R, André Zimerman, Stephen Coussens, and Anupam B Jena. 2020. "Behavioral heuristics in coronary-artery bypass graft surgery." *New England Journal of Medicine*, 382(8): 778–779.

Oprea, Ryan. 2022. "Simplicity equivalents." *Working Paper.*

Oster, Emily, Ira Shoulson, and E Dorsey. 2013. "Optimal expectations and limited medical testing: evidence from Huntington disease." *American Economic Review*, 103(2): 804–30.

Pachur, Thorsten, Michael Schulte-Mecklenbeck, Ryan O Murphy, and Ralph Hertwig. 2018. "Prospect theory reflects selective allocation of attention." *Journal of experimental psychology: general*, 147(2): 147.

Paciello, Luigi, and Mirko Wiederholt. 2014. "Exogenous information, endogenous information, and optimal monetary policy." *Review of Economic Studies*, 81(1): 356–388.

Parco, James E, Amnon Rapoport, and William E Stein. 2002. "Effects of financial incentives on the breakdown of mutual trust." *Psychological Science*, 13(3): 292–297.

Payne, John W. 1976. "Task complexity and contingent processing in decision making: An information search and protocol analysis." *Organizational behavior and human performance*, 16(2): 366–387.

Peng, Lin, and Wei Xiong. 2006. "Investor attention, overconfidence and category learning." *Journal of Financial Economics*, 80(3): 563–602.

Pinto, Yair, Andries R van der Leij, Ilja G Sligte, Victor AF Lamme, and H Steven Scholte. 2013. "Bottom-up and top-down attention are independent." *Journal of vision*, 13(3): 16–16.

Posner, MI. 1975. "Attention and cognitive control." 55–85, Lawrence Erlbaum Associates.

Posner, Michael I. 1980. "Orienting of attention." *Quarterly journal of experimental psychology*, 32(1): 3–25.

Posner, Michael I, and Steven E Petersen. 1990. "The attention system of the human brain." *Annual review of neuroscience*, 13(1): 25–42.

Quispe-Torreblanca, Edika, John Gathergood, George Loewenstein, and Neil Stewart. 2020. "Attention utility: Evidence from individual investors." *Available at SSRN 3527082.*

Rabin, Matthew. 2000. "Risk Aversion and Expected-utility Theory: A Calibration Theorem." *Econometrica*, 68(5): 1281–1292.

Rabin, Matthew, and Georg Weizsäcker. 2009. "Narrow bracketing and dominated choices." *American Economic Review*, 99(4): 1508–43.

Read, Daniel, George Loewenstein, Matthew Rabin, Gideon Keren, and David Laibson. 1999. "Choice bracketing." In *Elicitation of preferences*. 171–202. Springer.

Rensink, Ronald A, J Kevin O'regan, and James J Clark. 1997. "To see or not to see: The need for attention to perceive changes in scenes." *Psychological science*, 8(5): 368–373.

Reyes, Germán. 2023. "Cognitive Endurance, Talent Selection, and the Labor Market Returns to Human Capital." Working Paper.

Rick, Scott, and George Loewenstein. 2008. "Intangibility in intertemporal choice." *Philosophical transactions of the royal Society B: Biological Sciences*, 363(1511): 3813–3824.

Robinson, Terry E, and Kent C Berridge. 1993. "The neural basis of drug craving: an incentive-sensitization theory of addiction." *Brain research reviews*, 18(3): 247–291.

Rubinstein, Ariel. 1988. "Similarity and decision-making under risk (Is there a utility theory resolution to the Allais paradox?)." *Journal of economic theory*, 46(1): 145–153.

Russo, J Edward, and Larry D Rosen. 1975. "An eye fixation analysis of multialternative choice." *Memory & Cognition*, 3(3): 267–276.

Savitsky, Kenneth, Nicholas Epley, and Thomas Gilovich. 2001. "Do others judge us as harshly as we think? Overestimating the impact of our failures, shortcomings, and mishaps." *Journal of Personality and Social Psychology*, 81(1): 44.

Schelling, Thomas C. 1968. "The life you save may be your own." *Problems in public expenditure*, 127–162.

Schelling, Thomas C. 1980. *The Strategy of Conflict: with a new Preface by the Author.* Harvard university press.

Schneider, Walter, and Richard M Shiffrin. 1977. "Controlled and automatic human information processing: I. Detection, search, and attention." *Psychological review*, 84(1): 1.

Schüll, Natasha Dow. 2012. "Addiction by design." In *Addiction by Design*. Princeton University Press.

Schwartzstein, Joshua. 2014. "Selective attention and learning." *Journal of the European Economic Association*, 12(6): 1423–1452.

Seasholes, Mark S, and Guojun Wu. 2007. "Predictable behavior, profits, and attention." *Journal of Empirical Finance*, 14(5): 590–610.

Shenhav, Amitai, Sebastian Musslick, Falk Lieder, Wouter Kool, Thomas L Griffiths, Jonathan D Cohen, and Matthew M Botvinick. 2017. "Toward a rational and mechanistic account of mental effort." *Annual review of neuroscience*, 40: 99–124.

Sicherman, Nachum, George Loewenstein, Duane J Seppi, and Stephen P Utkus. 2016. "Financial attention." *The Review of Financial Studies*, 29(4): 863–897.

Simon, Herbert A. 1944. "Decision-making and administrative organization." *Public Administration Review*, 4(1): 16–30.

Simon, Herbert A. 1947. *Administrative behavior.* Simon and Schuster.

Simon, Herbert A. 1967. "Motivational and emotional controls of cognition." *Psychological review*, 74(1): 29.

Simon, Herbert A. 1971. "Designing organizations for an information-rich world."

Simon, Herbert A. 1974. "How Big Is a Chunk? By combining data from several experiments, a basic human memory unit can be identified and measured." *Science*, 183(4124): 482–488.

Simon, Herbert Alexander. 1965. *The shape of automation for men and management.* Vol. 13, Harper & Row New York.

Simons, Daniel J, and Daniel T Levin. 1997. "Change blindness." *Trends in cognitive sciences*, 1(7): 261–267.

Simons, Daniel J, and Ronald A Rensink. 2005. "Change blindness: Past, present, and future." *Trends in cognitive sciences*, 9(1): 16–20.

Simonsohn, Uri, Niklas Karlsson, George Loewenstein, and Dan Ariely. 2008. "The tree of experience in the forest of information: Overweighing experienced relative to observed information." *Games and Economic Behavior*, 62(1): 263–286.

Sims, Christopher A. 2003. "Implications of rational inattention." *Journal of monetary Economics*, 50(3): 665–690.

Slovic, Paul, and Elke U Weber. 2013. "Perception of risk posed by extreme events." *Regulation of Toxic Substances and Hazardous Waste (2nd edition)(Applegate, Gabba, Laitos, and Sachs, Editors), Foundation Press, Forthcoming.*

Small, Deborah A, and George Loewenstein. 2003. "Helping a victim or helping the victim: Altruism and identifiability." *Journal of Risk and uncertainty*, 26(1): 5–16.

Smythe-Leistico, Kenneth, and Lindsay C Page. 2018. "Connect-text: Leveraging text-message communication to mitigate chronic absenteeism and improve parental engagement in the earliest years of schooling." *Journal of Education for Students Placed at Risk (JESPAR)*, 23(1-2): 139–152.

Sperling, George. 1960. "The information available in brief visual presentations." *Psychological monographs: General and applied*, 74(11): 1.

Stango, Victor, and Jonathan Zinman. 2014. "Limited and varying consumer attention: Evidence from shocks to the salience of bank overdraft fees." *The Review of Financial Studies*, 27(4): 990–1030.

Steele, Claude M, and Robert A Josephs. 1990. "Alcohol myopia: Its prized and dangerous effects." *American psychologist*, 45(8): 921.

Steiner, Jakub, Colin Stewart, and Filip Matějka. 2017. "Rational inattention dynamics: Inertia and delay in decision-making." *Econometrica*, 85(2): 521–553.

Stephenson, Lisa J, S Gareth Edwards, and Andrew P Bayliss.

2021. “From gaze perception to social cognition: The shared-attention system.” *Perspectives on Psychological Science*, 16(3): 553–576.

Stigler, George J. 1961. “The economics of information.” *Journal of political economy*, 69(3): 213–225.

Strayer, David L, and William A Johnston. 2001. “Driven to distraction: Dual-task studies of simulated driving and conversing on a cellular telephone.” *Psychological science*, 12(6): 462–466.

Stroop, J Ridley. 1935. “Studies of interference in serial verbal reactions.” *Journal of experimental psychology*, 18(6): 643.

Stutts, Jane, John Feaganes, Donald Reinfurt, Eric Rodgman, Charles Hamlett, Kenneth Gish, and Loren Staplin. 2005. “Driver’s exposure to distractions in their natural driving environment.” *Accident Analysis & Prevention*, 37(6): 1093–1101.

Sugaya, Takuo, and Alexander Wolitzky. 2023. “Moral Hazard and Repeated Games with Many Agents.”

Sunstein, Cass. 2018. “# Republic.” In *# Republic*. Princeton university press.

Sunstein, Cass R. 2019. “Ruining popcorn? The welfare effects of information.” *Journal of Risk and Uncertainty*, 58(2): 121–142.

Taubinsky, Dmitry, and Alex Rees-Jones. 2018. “Attention variation and welfare: theory and evidence from a tax salience experiment.” *The Review of Economic Studies*, 85(4): 2462–2496.

Thakkar, Jay, Rahul Kurup, Tracey-Lea Laba, Karla Santo, Aravinda Thiagalingam, Anthony Rodgers, Mark Woodward, Julie Redfern, and Clara K Chow. 2016. “Mobile telephone text messaging for medication adherence in chronic disease: a meta-analysis.” *JAMA internal medicine*, 176(3): 340–349.

Thunström, Linda. 2019. “Welfare effects of nudges: The emotional tax of calorie menu labeling.” *Judgment and Decision making*, 14(1): 11.

Tishby, Naftali, Fernando C Pereira, and William Bialek. 2000. “The information bottleneck method.” *arXiv preprint physics/0004057*.

Tomasello, Michael, and Michael Jeffrey Farrar. 1986. “Joint attention and early language.” *Child development*, 1454–1463.

Tomasello, Michael, Brian Hare, Hagen Lehmann, and Josep Call. 2007. “Reliance on head versus eyes in the gaze following of great apes and human infants: the cooperative eye hypothesis.” *Journal of human evolution*, 52(3): 314–320.

Tomasello, Michael, Malinda Carpenter, Josep Call, Tanya Behne, and Henrike Moll. 2005. “Understanding and sharing intentions: The origins of cultural cognition.” *Behavioral and brain sciences*, 28(5): 675–691.

Toussaert, Séverine. 2018. “Eliciting Temptation and Self-Control Through Menu Choices: A Lab Experiment.” *Econometrica*, 86(3): 859–889.

Townsend, Jeanne, Naomi Singer Harris, and Eric Courchesne. 1996. “Visual attention abnormalities in autism: Delayed orienting to location." *Journal of the International Neuropsychological Society*, 2(6): 541–550.

Treisman, Anne M. 1960. "Contextual cues in selective listening." *Quarterly Journal of Experimental Psychology*, 12(4): 242–248.

Treisman, Anne M, and Garry Gelade. 1980. "A feature-integration theory of attention." *Cognitive psychology*, 12(1): 97–136.

Treue, Stefan, and Julio C Martinez Trujillo. 1999. "Feature-based attention influences motion processing gain in macaque visual cortex." *Nature*, 399(6736): 575–579.

Tufte, Edward R. 1985. "The visual display of quantitative information." *The Journal for Healthcare Quality (JHQ)*, 7(3): 15.

Van Nieuwerburgh, Stijn, and Laura Veldkamp. 2009. "Information immobility and the home bias puzzle." *The Journal of Finance*, 64(3): 1187–1215.

Van Nieuwerburgh, Stijn, and Laura Veldkamp. 2010. "Information acquisition and under-diversification." *The Review of Economic Studies*, 77(2): 779–805.

Vosoughi, Soroush, Deb Roy, and Sinan Aral. 2018. "The spread of true and false news online." *Science*, 359(6380): 1146–1151.

Wang, Joseph Tao-yi, Michael Spezio, and Colin F Camerer. 2010. "Pinocchio's pupil: using eye-tracking and pupil dilation to understand truth telling and deception in sender-receiver games." *American economic review*, 100(3): 984–1007.

Wansink, Brian, and Jeffery Sobal. 2007. "Mindless eating: The 200 daily food decisions we overlook." *Environment and Behavior*, 39(1): 106–123.

Ward, Adrian F, Kristen Duke, Ayelet Gneezy, and Maarten W Bos. 2017. "Brain drain: The mere presence of one's own smartphone reduces available cognitive capacity." *Journal of the Association for Consumer Research*, 2(2): 140–154.

Weinstein, Aviv Malkiel. 2010. "Computer and video game addiction—a comparison between game users and non-game users." *The American journal of drug and alcohol abuse*, 36(5): 268–276.

Wei, Xue-Xin, and Alan A Stocker. 2017. "Lawful relation between perceptual bias and discriminability." *Proceedings of the National Academy of Sciences*, 114(38): 10244–10249.

Wiehler, Antonius, Francesca Branzoli, Isaac Adanyeguh, Fanny Mochel, and Mathias Pessiglione. 2022. "A neuro-metabolic account of why daylong cognitive work alters the control of economic decisions." *Current Biology*, 32(16): 3564–3575.

Wojtowicz, Zachary, and George Loewenstein. 2020. "Curiosity and the Economics of Attention." *Current Opinion in Behavioral Sciences.*

Wojtowicz, Zachary, and George Loewenstein. 2023. "Cognition: A Study In Mental Economy." *Cognitive Science.*

Wojtowicz, Zachary, Nick Chater, and George Loewenstein. 2019. "Boredom and Flow: An Opportunity Cost Theory of Attention-

Directing Motivational States." *Available at SSRN 3339123.*

Wojtowicz, Zachary, Nick Chater, and George Loewenstein. 2022. "The motivational processes of sense-making." *The drive for knowledge: The science of human information seeking*, 3–30.

Wolfe, Jeremy M, George A Alvarez, and Todd S Horowitz. 2000. "Attention is fast but volition is slow." *Nature*, 406(6797): 691–691.

Woodford, Michael. 2012. "Prospect theory as efficient perceptual distortion." *American Economic Review*, 102(3): 41–46.

Wu, Tim. 2017. *The attention merchants: The epic scramble to get inside our heads.* Vintage.

Wu, Tim. 2018. "Blind spot: The attention economy and the law." *Antitrust LJ*, 82: 771.

Zottola, Samantha A, William E Crozier, Deniz Ariturk, and Sarah L Desmarais. 2022. "Court date reminders reduce court nonappearance: A meta-analysis." *Criminology & Public Policy.*

Zuboff, Shoshana. 2015. "Big other: surveillance capitalism and the prospects of an information civilization." *Journal of information technology*, 30(1): 75–89.