The Economics of Attention

George Loewenstein and Zachary Wojtowicz*

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

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1. *Introduction*

At the dawn of an industrial revolution in which 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, generations of economists have elaborated on this perspective by emphasizing additional intangible factors—most notably technology, human capital, and information—that have come to play an increasingly prominent role in successive 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 constrains both production and consumption in many aspects of the modern economy.
2. Accounting for attention resolves many outstanding puzzles in economic theory, especially those iden-

* Loewenstein: Department of Social and Decision Sciences, Carnegie Mellon University (e-mail: gl20@andrew.cmu.edu). Wojtowicz: Department of Economics and Department of Negotiations, Organizations, & Markets, Harvard University (e-mail: zwojtowicz@fas.harvard.edu). Acknowledgements: 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 Duckworth, Peter Landry, David Romer, and four anonymous reviewers for their insightful comments and suggestions. We also thank the Alfred P. Sloan Foundation, NOMIS Foundation, and New York University, for sponsoring the Attentional and Perceptual Foundations of Economic Behavior meetings, and its organizers for inviting us to participate.

[1] See Festré and Garrouste (2015), for a historical review of attention in economics, and Gabaix (2019), Caplin (2016), and Maćkowiak, Matějka and Wiederholt (2023) for recent surveys.

tified by behavioral economists.

3. The economics of attention help to clarify the implications of artificial intelligence and other novel digital technologies, many of which function to augment, absorb, redirect, or replace human attention.

Incorporating attention into economics 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.

One goal of this review is to distill what psychologists have learned about attention over the past 150 years into a form that clarifies its relevance for economics. We organize this effort around the following definition, which highlights both the similarities and differences between attention and traditional economic factors of production.

DEFINITION: *An* ***attentional resource*** *is characterized by the following four criteria:*

1. ***Scarce****: The resource is in limited supply (if fixed) or costly to supply (if variable).*

2. ***Rivalrous****: If committed to one activity, the resource is not available for alternative activities.*

3. ***Cognitive****: The resource directly acquires information, processes information, or controls information-processing operations.*

4. ***Volitional****: An agent has the potential to directly influence the resource's allocation.*

The first two criteria (*scarce* and *rivalrous*) establish attention's kinship with other key resources—such as land, labor, and capital—that have long been studied in economic analysis.

Scarcity implies that our capacity to acquire and process information is fundamentally limited. *Rivalry* implies that attending to one task or source of information necessarily excludes other potential foci.

The third and fourth criteria (*cognitive* and *volitional*), by contrast, identify the specific features that distinguish attention from other resources typically studied in economics.

Cognitive specifies that attentional resources directly acquire information, process information, or are used to control information-processing operations. The word "directly" is essential to distinguish the resources which ultimately perform attentional functions from precursor resources that merely serve as inputs. For example, gasoline is critical to many forms of transportation, but does not itself provide transportation services. Analogously, oxygenated blood glucose is critical to many attentional resources, but is not itself a form of attention. We will discuss this distinction in more detail and give further examples in Section 2.

Volitional specifies that an individual has the potential to exercise direct control over an attentional resource. The distinction between volitional and nonvolitional processes arises across a variety of psychological domains. For example, heartbeat is not volitional because one cannot directly choose when to beat one's heart. Blinking, on the other hand, is volitional because one can directly choose when to blink one's eyes. Note, however, that virtually all instances of blinking happen automatically and unconsciously—what's important is that an individual has the *potential* to intervene and exercise control over the process if they so chose.

Similarly, people need not—and in fact usually do not—exercise such control over attentional resources. For example, although people can consciously decide where to look at any given moment, by default most often our gaze is automatically drawn to salient features of the visual environment by non-volitional, "bottom-up" processes. In combination with scarcity and rivalry, the volitional character of attention implies that people must often make consequential decisions about what they should in fact pay attention to. We review the various determinants of attention and how they interact in Section 2.4.

The selective allocation of attention focuses 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, makes them feel good, and fits with their existing beliefs (Berger and Milkman, 2012; Vosoughi, Roy and Aral, 2018; 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; Maćkowiak, Matějka and Wiederholt, 2023), our treatment places a particular emphasis on translating the vast literature on attention spread across the behavioral sciences into the language of economics. Accordingly, we discuss existing economic theories at a more conceptual level than in prior reviews, with the principle goal of identifying promising avenues for further development.

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) primarily consumes attentional 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 "fracked"[4] or "stolen" (Wu, 2018; McFedries, 2014; Hari, 2023).

While many new technologies *draw* on attention and seek to attract it, others 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*). Large language models and other highly capable artificial intelligence systems, in particular, are rapidly changing the attentional demands of modern work (Noy and Zhang, 2023). 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 concrete research level, treating attention as a core economic resource promises substantial opportunities for intellectual "gains from trade" between economics and other disciplines. 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).[5]

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). Attentional limitations not only influence what information we store in memory, but also what we later recall (Chun and Turk-Browne, 2007).

Lastly, establishing attention as a scarce mental resource and clarifying its properties relative to other productive factors naturally suggests an 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.

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

[3] `https://pewrsr.ch/2Y5pwdX`

[4] `www.nytimes.com/2023/11/24/opinion/attention-economy-education.html`

[5] 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.

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. 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 discusses the implications that limited attention has 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. Section 9 concludes.

2. The Psychology of Attention

Early in the history of psychology, 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).

Although many intuitively agree with James' insight that attention reflects 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 limitations on attention, as we have defined the term.

Fortunately for economists, psychologists and neuroscientists have spent the last century investigating attention through 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, attention limits the number of separate input streams being parsed rather than the total rate of information processing.

In the remainder of this section, we selectively review research on attention with a particular focus on its implications for economics. (Section 2.9 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, as is often done in economic applications.

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 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. 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; Christiansen and Chater, 2016), 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 generally necessitates a process of *selection*: some information gets through, but much—and, in fact, typically most—is irrevocably lost.

Second, the bottleneck metaphor suggests both that the information is homogeneous and that it passes through the bottleneck in an indiscriminate order. The fact that we can direct our attention, by contrast, enables us to *prioritize* which information makes it through a particular stage of processing. Attention, therefore, invites 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 select the target—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 conceptualization has the advantage that it naturally maps onto the resource-based approach of economics.

Supporting this perspective, 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 resource is a composite of many qualitatively distinct sub-resources (Posner and Petersen, 1990). 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" (pg. 74). The authors conclude that "we 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" (pg. 74).

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. 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 attentional resource.

Biological factors not only limit our ability to gather information from the external environment (sensory attention), but also our capacity to process information that we already possess (internal attention). Indeed, one of the central—and indeed defining—insights of cognitive psychology has been that higher-order mental processes (*e.g.*, 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. In what follows, we provide a brief overview of sensory and internal attentional resources.

Sensory Attention

The human visual system includes a variety of well-studied and instructive examples of sensory attention (and indeed motivates the "spotlight" and "zoom lens" metaphors discussed above).

Foveal visual attention: Vision begins when light strikes photoreceptors. Even at this first point of contact with the sensory environment, however, concentrated pits of cone cells in the middle of each retina known as the *fovea centralis* give rise to an attentional resource: foveal visual attention.

Although 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 encumbers us with the need to continually direct and redirect our gaze. Thus, foveal visual attention satisfies our definitional criteria:

1. Scarce: Fovea cover only about 2° of our visual field.
2. Rivalrous: Looking in one direction precludes looking in others.
3. Cognitive: Foveal vision gathers information from light.
4. Volitional: We can choose where to look.

When stimulated, photoreceptors trigger a cascade that passes electrical signals through several intermediate cell types to the optic nerve and, ultimately, the visual cortex of the brain. A variety of re-coding operations are applied during this process—however, because all such transformations happen automatically with no possibility of volitional intervention, they are not attentional per our definition.

Iconic memory: Upon reaching the brain, visual information is transferred to a temporary buffer known as iconic memory, where it persists in a nearly complete form for about 150ms (Sperling, 1960). During this brief window, one can select a subset of the visual scene for further processing, 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 (Coltheart, 1980). As the experiments of Sperling (1960) demonstrate, iconic memory constitutes yet another attentional resource per our definition:

1. Scarce: We can only select about 3-4 items from iconic memory.
2. Rivalrous: Items not selected from the buffer are irrevocably lost.

3. Cognitive: Selection permits semantic tagging and further processing.
4. Volitional: Items can be selected based on their location.

Covert visual attention: We can also, at least temporarily, modulate how intensively information is processed in the visual cortex and, consequently, increase acuity at various points in the visual field outside our fovea. As Carrasco (2011) documents, this capacity, known as covert visual attention, satisfies our definitional criteria:

1. Scarce: Increased neural activity depletes metabolic resources.
2. Rivalrous: Biophysical factors limit how completely the visual field can be processed on a sustained basis.
3. Cognitive: Covert attention enhances acuity in the visual field.
4. Volitional: We can voluntarily select where to deploy covert attention.

Hearing, touch, *etc.*: Similar attentional resources exist for 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, nonhuman 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). Accordingly, running one's fingertips over a surface to get a better sense of its texture represents an act of selective attention in as much as it precludes our ability to simultaneously touch—and therefore gather tactile information about—other objects. As in the case of vision, sensory buffers exist for both touch ("haptic memory"; Bliss et al., 1966) and hearing ("echoic memory"; Darwin, Turvey and Crowder, 1972) that are analogous to iconic memory.

Internal Attention

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 (*e.g.*, letters, tones, or colors). 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 "redrum" as the word "murder" spelled backwards 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

[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 indicates that at least some baseline monitoring and categorization occurs for unattended—in this case auditory—stimuli.

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 depends 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).

The basic fact that our working memory can only represent and manipulate a limited store of information at any given time forms the basis of an attentional resource that satisfies our four definitional criteria:

1. Scarce: Working memory span is fixed by physical factors.
2. Rivalrous: Each slot can hold one informational "chunk" at a time.
3. Cognitive: Working memory temporarily represents information.
4. Volitional: We can choose to maintain information in working memory.

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—generally 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 learn to "see" advantageous board positions by encoding past experience into their perceptual faculty (Chase and Simon, 1973), which enables them to intuitively avoid bad moves and concentrate their working memory on explicitly simulating only the most promising lines of play.

Cognitive control: Another key attentional resource is 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). Like working memory, cognitive control is a flexible capacity that supports nearly all processes of deliberative thought.

The exercise of cognitive control is required, for example, to resolve conflicting behavioral responses in the "Stroop task" (Stroop, 1935), in which 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 suggests 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 to complete the task successfully (Botvinick et al., 2001). Limited cognitive control explains both why participants react more slowly on trials 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; Botvinick et al., 2001).[7]

As Shenhav et al. (2017) detail, cognitive control satisfies our definitional criteria:

1. Scarce: Metabolic, structural, or representational constraints make exercising control costly.[8]
2. Rivalrous: Each of these fundamental constraints is rivalrous.
3. Cognitive: Cognitive control modulates information processing.
4. Volitional: We choose whether and how to exert cognitive control.

Cognitive control is distinct among attentional resources in that it enables an individual to coordinate other resources—and thereby redirect other forms of attention—when pursuing intentional goals.

In particular, 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). 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).

[7] These effects provide the foundation for the "implicit association test" used to measure implicit bias (Greenwald and Banaji, 1995)

[8] Identifying the precise biophysical constraints that limit our capacity for cognitive control is an area of active research. Shenhav et al. (2017) review existing evidence supporting each of the three hypothesis above.

2.3. One Resource or Many?

As the foregoing makes clear, attention is not a single, homogeneous resource. Indeed, the human central nervous system consists of a variety of functionally (and often physiologically) distinct information-processing capacities. For example, when someone says "pay attention," they might mean either "look at me" (sensory 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 type 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 the preceding subsection, cognitive control is necessary to maintain and manipulate information in working memory, such that cognitive control and working memory can be jointly modeled as a single system for many purposes (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 subsection, we review three broad categories of attentional determinants: "bottom-up" (stimulus-driven), "top-down" (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 the first two categories (top-down and bottom-up) 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. 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). All of these dichotomies 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 allocation.

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 (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 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; Judd et al., 2009) and locations that feature distinctive "low-level" qualities (*e.g.*, brightness, orientation, color, or motion; see the highly influential theory of 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 and Berkowitz, 1969), and, as noted earlier, reliably overhear their own name mentioned in a neighboring conversation at a party (Arons, 1992).

Attention is also automatically drawn toward certain categories of stimuli that are related to emotions (*e.g.*, words associated with sadness) or threats (*e.g.*, a picture of a spider; Vuilleumier, 2005). Many such effects are themselves enhanced, moreover, by state or trait anxiety and depression (see Yiend, 2010; Todd et al., 2012, for recent reviews). Recent experimental work by Dohmen, Quercia and Willrodt (2023) documents that dispositional pessimism or optimism influences which risky outcomes an individual focuses on, which in turn influences choice. More broadly, a variety of affective states (*e.g.*, pain and hunger) directly draw attention to specific goals (*e.g.*, avoiding further tissue damage or consuming nutrients). Indeed, Simon (1967) argued that the core function of all emotions is to "interrupt" narrowly focused decision makers—dislodging attention from existing goals when more pressing needs arise.

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 mechanisms operate by modifying or in some cases overriding the operation of bottom-up mechanisms. For example, knowledge of a specific threat (*e.g.*, a tiger) will enhance the salience of goal-congruent perceptual features such as motion, color, and luminance (*e.g.*, orange colors and striped patterns; Hopfinger, Buonocore and Mangun, 2000).

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, in part 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, Stigler (1961) 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 one of the foremost underlying constraints generating such costs, recent work has sought to explicitly model these psychological microfoundations. In "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). In contrast with many bottom-up determinants, which tend to bias attention toward threats and other negative stimuli, people often use top-down determinants to steer their attention toward stimuli that make them feel good, an idea that we develop more fully in Section 3.

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 identify 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 incentivize 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 resources. Along with bottom-up processes, motivational states act as an attentional auto-pilot to ensure that we default to a reasonably efficient mental resource allocation even when we invest little, if any, deliberative thought into the allocation problem itself.

Motivational attention-directing 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 (although one can, of course, strategically engage in behaviors to activate or avoid activating them).[9] Second, like other feeling states such as hunger, states of attentional motivation 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 thought into presents) and external cues (*e.g.*, a conspicuously large package).

Although motivational attention-directing states 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 increasing the hedonic benefit of doing so. Curiosity likewise motivates us by making specific foci hedonically

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

appealing (Wojtowicz and Loewenstein, 2020; Chater and Loewenstein, 2016). Finally, Shenhav et al. (2017) review an extensive body of evidence supporting the hypothesis that the subjective feeling of mental effort arises from limitations on the attentional resource of cognitive control, and either reflect opportunity costs (Kurzban et al., 2013) or underlying biological constraints.

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. Non-Volitional Cousins of Attention

Attentional resources are a subset of a more general category that we call *mental resources*, which are scarce, rivalrous, and cognitive, but not necessarily volitional. For example, the sensory cortex is scarce (it occupies a limited volume in the brain), rivalrous (a cortical column dedicated to processing one type of information does not process another) and cognitive, but its allocation is not volitional. When people are born without, or (to a lesser extent) lose, vision, their brain automatically adapts their visual cortex to process other types of sensory information (Théoret, Merabet and Pascual-Leone, 2004), but this transformation proceeds automatically. In the cognitive domain, when people are faced with a novel task (*e.g.*, the game Tetris in one study Haier et al., 1992), the brain initially recruits diverse mental resources in a "scattershot," inefficient, fashion; but, with practice, unconscious, non-volitional, processes enlist mental resources to execute the task more efficiently over time.

The processes by which non-volitional mental resources are allocated have important implications for economic behavior and interact with attention in consequential ways. For example, the "efficient coding hypothesis" (Barlow et al., 1961; Attneave, 1954) posits that early stages of perceptual processing encode sensory stimuli into distributed patterns of neural activation that are maximally informative, subject to biological constraints. One such constraint arises from the inherent stochasticity of neural activity, which introduces noise into the resulting representations ("neural noise"). Any given stimuli can be represented more precisely by encoding it with greater redundancy (Linsker, 1988); however, doing so reduces the capacity of the same population of neurons to precisely represent other stimuli. Representational precision therefore constitutes a mental resource that satisfies the three criteria above.

1. Scarce: The total representational capacity of a given population of neurons is fixed.
2. Rivalrous: Representational capacity allocated to one stimuli cannot be allocated to another.
3. Cognitive: Representational capacity determines the precision of sensory encoding.

Importantly, however, the sensory system adapts its coding strategy to efficiently allocate representational capacity autonomously (Simoncelli and Olshausen, 2001), without any possibility for volitional intervention (and is therefore not attentional per our definition). Wei and Stocker (2015) show that efficient coding, combined with Bayesian decoding, can account for observed patterns of bias in judgements of features such as visual orientation and spatial frequency.

A spate of recent papers in economics has explored the possibility that representational biases introduced by efficient coding may also account for non-classical choice phenomenon (see Woodford, 2020, for a recent review). Rayo and Becker (2007), for example, argue that efficient coding of utility values gives rise to reference-dependent preferences, and Woodford (2012) proposes that efficient coding of gambles generates small-stakes risk aversion. Subsequent experiments by Khaw, Li and Woodford (2021) and Frydman and Jin (2022) demonstrate that lottery preferences are sensitive to the underlying distribution of payoff values to which subjects have adapted, verifying a key prediction of the efficient coding account.

Owing to the combined effects of limited representational capacity and other mental resource constraints, the sensory information we collect is inherently noisy and incomplete, meaning our brain must continually fill in blanks, resolve ambiguities, and regularize improbable observations to construct a coherent picture of the world. Our perceptions 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" in the world, formed by synthesizing incoming sensory information with expectations generated by our current understanding and expectations, an insight that has spawned a variety of related hypothesis, such as "predictive coding," the "Bayesian brain," and "active inference" (Knill and Pouget, 2004; Rao and Ballard, 1999; De Lange, Heilbron and Kok, 2018; Clark, 2013; Yuille and Kersten, 2006; Friston et al., 2017). The general idea that perception is a best-guess model of the world—rather than a direct read-out of sensory data—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) and can only see perceptually multi-stable optical illusions, such as the Necker cube, one way at a time (Brascamp et al., 2018).

Mental resource limitations are also closely related to a variety of other perceptual failures, such as inattentional blindness (*e.g.*, failing to notice a gorilla walking through a basketball game while counting passes; Mack, 2003), change blindness (*e.g.*, failing to notice that a person's shirt suddenly changed color between two successive photos—see Section 4; Simons and Rensink, 2005), and the "attentional blink" (*e.g.*, failure to accurately report the second of two letters presented within 500ms of one another; Shapiro, Raymond and Arnell, 1997). Such perceptual processes typically operate outside of conscious awareness—to such a degree that people tend to be unaware of the biases they introduce and consequently overlook the need to enact counter-measures.

2.6. Attention & 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 activates 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 attention plays a key role in limiting 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.*, Baddeley, 1992). Lastly, attending to ("recalling") recently stored explicit memories alters the process of consolidation and can therefore strengthen, change, or damage them (Forcato, Fernandez and Pedreira, 2014).

The link between attentional selection and certain acts of memory retrieval (*e.g.*, object recognition) is so close that some theories argue they should be viewed as two perspectives on the same underlying cognitive process, *i.e.*, that memory is effectively "attention turned inward" (Logan et al., 2021). Recent research on explicit memory 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 show 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, 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 or negative moods trigger thoughts and memories that reinforce those states, creating the potential for alternative self-esteem equilibria. 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 who are in a positive self-esteem equilibrium take to avoid slipping into a negative one.

2.7. *Attention & Coordination*

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 expose the direction of our gaze to others (Tomasello et al., 2007). Freely (and, indeed, unavoidably) sharing information about our focus of foveal attentional 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 give rise to a variety of downstream challenges (Dawson et al., 2004). Finally, joint attention (*e.g.*, looking at the same thing at the same time) has been argued to play a crucial role in helping groups establishing states of common knowledge (Clark and Marshall, 1981; Chwe, 2013), which are, in turn, important for strategic interaction (see Geanakoplos, 1992, for a detailed review).

2.8. Attentional Disorders

The adverse consequences of attentional disorders shed light on the central role that attention plays in normal 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" (American Psychiatric Association, American Psychiatric Association et al., 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), especially to social cues (*see, for example,* 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 propensity to underestimate the cost of redirecting attention, and the latter arises from the reverse tendency.

2.9. Summary: Features of Attention

Having introduced the reader to some of the details of how attention operates, we summarize the foregoing in five 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 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 2. Attention is flexible and can be applied to a wide range of different uses at each point in time.

Attention can be used, for example, to read a book or drive a car through a chaotic environment. However, given the fact that attention is constrained (Property 1), one cannot both read a book and drive a car simultaneously. Given that each attentional resource 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 to direct our attention.

Property 3. 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. 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.[10] To a first approximation, therefore, the flow of attention can be treated as effectively constant.

Property 4. 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 factors can both miss features of, or interactions between, these different forms of attentional control.

Property 5. 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.

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 (Loewenstein, 1987; Geanakoplos, Pearce and Stacchetti, 1989; Caplin and Leahy, 2001; Brunnermeier and Parker, 2005).

This insight, frequently referred to as *belief-based utility*, 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 persistence of biased beliefs (*e.g.*, Eil and Rao, 2011; Möbius et al., 2014).

[10] 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 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).

What people believe powerfully affects their utility, but what people pay attention to (externally through the senses or internally through rumination) can have an even more powerful hedonic impact than the portfolio of beliefs they in some sense "hold" but do not call 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 phenomenon known as "terror management"; Greenberg, Pyszczynski and Solomon, 1986).

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 latter; however, the reverse is not true, and "raw" time, absent the concerted application of attentional resources, is insufficient on its own for many consumptive or productive processes.[11] Indeed, 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. 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 an exogenous shock to one's attentional allocation—*e.g.*, a sudden economic downturn that unavoidably and repeatedly draws attention to the possibility of being laid off—can have such a widespread and sizable impact on life satisfaction. Such attention-absorbing events simultaneously crowd out many forms of consumptive attention, making it difficult to derive pleasure from other aspects of life. In such circumstances, individuals may turn to "distracting" activities—television, movies, drugs, alcohol, gambling, and extreme sports, to name but a few—to absorb excess attention and thereby crowd out negative thoughts (Wilson et al., 2014; Schüll, 2012).

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

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

on weekends, when the market is closed and there is no new information to be gained from logging in, which seems to suggest that people may be motivated to log in by the pleasure they derive from re-focusing their attention on the good news.

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 execute this selective login strategy if they already knew how the stock was performing, consistent with attention-based utility. They also present three experiments showing that investors who own individual stocks are more likely to answer questions about an investment in exchange for pay if the investment has performed well. Using financial panel data, Olafsson and Pagel (2017) show that income arrivals are more likely to spur people to log in when their cash holdings and liquidity are high, consumer debt is low, and when their balance changes from negative to positive. 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.[12]

Although the insights and research findings motivated by the two hypotheses overlap significantly, attention-based utility has one enormous advantage over belief-based utility: attentional resources, unlike beliefs, are finite or costly to supply. Hence, as we have been arguing from the outset of this review, it can be analyzed 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).

Attention-based utility has important implications for information-disclosure policies, especially those, such as mandatory calorie labels at fast food restaurants and 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. To whatever degree informationally redundant disclosures 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, software such as "mouselab" achieves the same effect by covering each piece of information with an opaque box that

[12] 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.

becomes translucent once participants hover their cursor over it (Johnson et al., 1989).

A variety of "eye-tracking" methods enable researchers to dynamically measure 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).[13] 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 technique 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 made to 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. Identifying which changes people notice can be used as a technique to measure visual salience.[14] For example, if the clothing of an individual is varied, people have trouble detecting the difference; but if the individual's race or gender was changed, they would likely notice.

Another line of research has applied attention-measurement techniques 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).

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). Open-ended questions have also been prominently used to assess what is "top of mind" and therefore a likely attentional priority for people (see Haaland et al., 2024, for a comprehensive review).

5. *Attention in Economic Theory*

Over the last two decades, economists have developed a variety of theoretical frameworks for studying the implications

[13] 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 it is unimportant, or that its importance is so evident that the decision maker can instantly assimilate it into the decision.

[14] 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 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.

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 the 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 remain open for exploration.

5.1. Attention & 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 determinants dominate; or (2) 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—*i.e.*, both sensory and internal attention—together in a single reduced-form cost function.[15]

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 limitations in play. Insurance purchasers might make suboptimal 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 has yet to be modeled explicitly in terms of a constrained

[15]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.

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.

Rational Inattention

Sims (2003) introduced the "rational inattention" framework, which has become the dominant approach to studying the effects of limited attention in economics (see Maćkowiak, Matějka and Wiederholt, 2021, for a recent review). The rational inattention framework has been so widely applied, in part, because it abstracts away from the psychological question of identifying the *causes* of limited attention by directly modeling the *effects* of limited attention, and it can therefore be used to capture the conjoint influence of various sensory, perceptual, and cognitive limitations in a single reduced-form representation.

Specifically, rational inattention models assume that, in order to gather and process information, agents pay an attentional cost that is proportional to how much these activities reduce their uncertainty about the true state of the world. This reduction of uncertainty is formalized using an information-theoretic measure known as "mutual information"(see Cover and Thomas, 1999, for a comprehensive introduction to information theory). If, as many applications of rational inattention assume, the allocation of attention (*i.e.*, mutual information) could be the outcome of an explicit decision, then it satisfies our definitional criteria for an attentional resource.

1. Scarce: Attention is fixed or acquired at a per-unit cost.
2. Rivalrous: Attention used to reduce uncertainty about one variable cannot be reused for another.
3. Cognitive: Attention reduces statistical uncertainty (*i.e.*, entropy).
4. Volitional: Agents select an optimal allocation of attention.

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 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). Constraints on attention (and hence, mutual information) 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).

One strong claim that the rational inattention framework does make, however, is that attentional costs are always positive, an assumption that may not hold when a particular focus of attention is pleasant. 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, such as attention-based utility or motivational determinants, play an important role in the allocation of attention.

Sparse Maximization

Gabaix (2014) presents another framework for studying the impact of attention on consumer choice and equilibrium theory. In the framework, decision-relevant variables (*e.g.*, prices and qualities) are subject to random shocks, modeled as normally distributed random variables. The decision maker can choose how much to update their beliefs about each individual shock, but doing so requires the allocation of scarce attention. If they place no importance on a particular variable, they will not allocate attention to resolving its uncertainty, and will subsequently act as if the variable equals its expected value; conversely, if they place sufficient importance on a variable, however, they will allocate attention to resolve its uncertainty.

Similar to mutual information in models of rational inattention, Gabaix assumes an attentional cost function that captures the impact of attentional limitations in a tractable, reduced form. Introducing it into a variety of "textbook" economic models frequently taught in first-year graduate courses yields a variety of novel implications, such as 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. *Attention & 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 effects of limited attention on learning 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 find the former, and laboratory experiments the latter. Using a Mouselab intervention (see Section 4), they experimentally demonstrate that increasing attentional costs amplifies these effects.

6. *Economic Consequences of Attention: Foundational Topics*

In this section, we discuss attention's implications for a variety of foundational topics in economics: (6.1) Consumption and Choice; (6.2) Risk; (6.3) Time; (6.4) Social Preferences; (6.5) Strategic Interactions; (6.6) Information and Learning; (6.7) Human Capital Development; and (6.8) Incentives and Performance.

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*, or the general tendency for economic agents to make choices in isolation when their utility, in fact, depends on a broader set of considerations (see, for example, Camara, 2022; 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. For example, Slovic and Weber (2013) argue that salience leads people to overweight low-probability risks that are viscerally imaginable, such as shark attacks, and underweight other, less dramatic threats, such as heart disease. In a similar vein, Barber, Odean and Zheng (2005) argue that investors decisions are more sensitive to salient "in-your-face" fees like commissions than they are to less salient ones, like operating expenses.

6.1. Consumption and Choice

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. Accordingly, most extant work in economics 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. The fact that these effects persist when (in many of the studies documenting such reversals) individuals are exposed to both alternatives, but do not explicitly compare one to the other, supports the idea that these effects are largely the consequence of attentional focus, and not differences in information across the two situations.

Eye-tracking methods have been especially helpful in uncovering the relationship between attention and choice (Orquin and Loose, 2013). For example, the *drift diffusion model*, views decision making as a noisy process of information accumulation that halts when the net evidence in favor of one option reaches a threshold (see Ratcliff and McKoon, 2008, for a review). An extension known as the *attentional drift diffusion model* explicitly posits that the average rate of evidence accumulation depends on where the decision maker directs visual attention at each point in time (Krajbich, Armel and Rangel, 2010). In the context of a "take or leave it" purchasing decision, Krajbich et al. (2012) showed that the attentional drift diffusion model also captures the relationship between choice and patterns of fixation to either the object itself or its price.

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. As Camara (2022) shows, narrow bracketing is an optimal strategy when making choices subject to limited or costly information-processing resources, such as those outlined in Section 2.2. 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. Attention may therefore play a role in leading people to overlook correlations that tie the performance of assets together (*e.g.*, as in the experiment of 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 that Benjamin, Rabin and Raymond, 2016, have labeled the "nonbelief in the law of 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). Supporting this perspective, Glickman, Tsetsos and Usher (2018) argue that the effects of limited 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.

Taking (or not taking) risks can have a substantial impact on what people pay attention to and the attention-based utility they experience. 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 (*see, e.g.,*, 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.

Recent work has raised the possibility that small-stakes risk preferences may not reflect preferences *per se*, but rather the impact of people's limited ability to perform the calculations required to evaluate lottery valuations accurately. For example, Oprea (2022) shows that the fourfold pattern of risk preferences implied by prospect theory is reproduced by the errors people make in deterministic decisions that require the same calculations as binary lotteries. In a related vein, Enke and Shubatt (2023) construct proxies for how difficult lotteries are to compare, and show that these indices predict violations of expected value maximization. Enke and Graeber (2023) introduce a general model in which cognitive uncertainty (arising, *e.g.*, from the computational difficulty of making a decision) predictably biases decision making in ways consistent with prospect theory through a process of Bayesian regularization. Although the cognitive mechanism driving these effects is still an active research question, the limitations imposed by internal attention provide one potential explanation.

6.3. Time

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."

To the degree that explicitly weighing the consequences of one's actions requires attending to those consequences, someone who is fully absorbed "in the now" may appear to be relatively insensitive to the future. 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 often leads to short-sighted behavior.

Even when we are not intoxicated or in a hot state, concerns in the immediate present can demand so much attention that they eclipse those in the future, meaning that limitations on attention may be one—and possibly a primary—culprit of "present bias" (Laibson, 1997; O'Donoghue and Rabin, 1999). Disproportionate attention to the present may also explain high rates of time discounting when immediate outcomes are concentrated and delayed outcomes are dispersed (Rick and Loewenstein, 2008; Kőszegi and Szeidl, 2013; Dertwinkel-Kalt et al., 2022). On the other hand, some highly salient future events—such as the prospect of winning a kiss from one's favorite movie star—can draw a significant amount of attention and generate attention-based utility in the form of anticipation, meaning that people sometimes want to accelerate negative events and delay positive ones (Loewenstein, 1987; Berns et al., 2006; Tasoff and Madarasz, 2009).

Many problems of self-control involve the inhibition of prepotent behaviors in favor of other actions one wishes to implement (Loewenstein, 1996; Loewenstein, O'Donoghue and Bhatia, 2015). 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.

6.4. Social Preferences

Attention has a significant impact on the activation and expression of social preferences. First, note that narrow bracketing plays a similar 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. 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—may receive far less 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).

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) 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.

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. A similar attentional asymmetry may explain why Hartzmark, Hirshman and Imas (2021) find 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). Past experiences encoded in memory, moreover, can draw people's attention to particular features of their current situations, which has downstream consequences for judgement and decision making (Bordalo, Gennaioli and Shleifer, 2020). For example, Link et al. (2024) use panel survey data to show that individuals who have suffered from inflation in the past are more attentive to subsequent spikes in inflation.

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 biased or selective information (Jin, Luca and Martin, 2022; Enke, 2020; Gurney and Loewenstein, 2020), such as only hearing one side of an argument (Brenner, Koehler and Tversky, 1996) or 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, in general, be "unseen" (Ross, Lepper and Hubbard, 1975). Given that directing internal attention to 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: 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 learning a new language or musical instrument, 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).

Extensive practice and training—especially of physical skills—tends to gradually reduce the amount of cognitive control (and, hence, internal attention) required to execute a task over time (Schneider and Shiffrin, 1977). This enables experts to perform at a high level of skill even when their focus is split between multiple tasks, *e.g.*, reading sheet music while playing the piano and singing at the same time. Perhaps because people lack introspective access to the cognitive changes that drive such learning, they tend to underestimate both the speed and extent of automation, a misprediction that can lead to underinvestment in certain forms of human capital (Koriat, Sheffer and Ma'ayan, 2002; Billeter, Kalra and Loewenstein, 2011; Horn and Loewenstein, 2021).

6.8. Performance & Incentives

Classical economic theory assumes that people perform better when they are adequately incentivized to do so, a premise reflected in the design of criminal justice sanctions, executive compensation schemes, and many other real-world institutions. This assumption is especially significant 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 devote sufficient attentional resources to a task. (For counter-evidence see Massey and Thaler, 2013; Camerer and Hogarth, 1999; but, for evidence supportive of such a pattern, see Parco, Rapoport and Stein, 2002).

Although performance typically is positively related to the magnitude of incentives, 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), document the opposite pattern under certain circumstances. In specific situations, and on certain types of tasks, people systematically "choke" under pressure—*i.e.*, perform worse when incentives are increased.

Many prominent theories explain choking as a result of mismanaged attention. For example, "distraction theories" postulate that choking occurs because high stakes direct attention away from performance-determining aspects of a task toward thoughts that are either unhelpful or actively deleterious to performance, such as 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 execute cognitive control (a form of internal attention), interrupting well-practiced routines (Masters, 1992).

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

A large body of research in behavioral finance examines the consequences of limited attention for individual investor behavior. As Hirshleifer (2015) explains, "owing to limited attention and processing power, people tend to neglect relevant information signals and strategic features of the decision environment" (page 140). In financial markets, systematic neglect of relevant news due to attentional limitations can result in biased prices, at least in the short run before market participants are able to fully assimilate available information. Hirshleifer continues: "limited attention theories imply positive abnormal returns after neglected good news and negative abnormal returns after neglected bad news" (page 141). As one example of this general pattern, Da, Engelberg and Gao (2011) show that internet search frequencies for individual stocks correlate with other measures of investor attention and predict short-term gains but long-term losses.

A great deal of research in behavioral finance addressing consequences of limited attention examines what features of assets attract disproportionate attention. For example, Peng and Xiong (2006) note that there are too many investment opportunities for any individual to attend to, and argue that this leads people to focus on market and sector-level information instead of tracking individual firms. Bhui and Jiao (2023) test for this behavior in the lab and find that, as predicted, people place more weight on general financial categories when their attentional resources become more constrained. Hartzmark, Hirshman and Imas (2021) show that people have more extreme reactions to information about assets they own as compared with assets they don't own. Using methods involving "change-detection" (see, Section 4), they show that this effect results from what they call "ownership-driven attention" (page 1666). Limitations on attention could also contribute to "home-bias" (*i.e.*, under-investment in international assets; see French and Poterba, 1991), although limits on available information could also play a role.

Connecting to the concept of bottom-up determinants of attention (Section 2.4), as well as to the literature on salience (Section 5.1), 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). Inexperienced investors who trade using mobile applications seem to be especially attracted to attention-grabbing stocks, which exhibit a particularly strong form of the pattern predicted by Hirshleifer (2015): returns are high initially, but ultimately fade after the asset's 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 provided diverse evidence of the causal role of attention, showing, for example, that (1) markets respond more slowly to information when attention is likely to be diffused because, for example, 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 that (5) lack of attention to selling, relative to buying, leads institutional investors to under-perform the market (Akepanidtaworn et al., 2021).

Theoretical models incorporating limited attention have also been used to explain: under-diversification (Van Nieuwerburgh and Veldkamp, 2010); naive diversification (Gathergood et al., 2023); home bias (Van Nieuwerburgh and Veldkamp, 2009); style investing[16] (Peng and Xiong, 2006); and return predictability (Hirshleifer, Lim and Teoh, 2011).

[16] "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.

7.2. Consumer Behavior

Consumers predictably over-weight certain product features and under-weight, or altogether ignore, others. As Gabaix (2019) and others have argued, limited attention can explain a variety of such effects. For example, people are disproportionately sensitive to an appliances' up-front 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 underweight fuel efficiency relative to other cost factors when choosing a car.

Firms, moreover, seem to actively take advantage of consumer's limited attention by strategically obfuscating the price of add-ons, such as the long-run recurring cost of printer ink and ATM overdraft fees. According to the analysis of Gabaix and Laibson (2006), competition fails to eliminate these *shrouded attributes* because honest firms cannot match the "loss leader" prices that deceptive firms offer. Shrouding is, however, responsive to attention-based policy interventions. Stango and Zinman (2014) show, for example, that explicitly drawing attention to overdraft fees by asking overdraft-related questions in a survey substantially reduces the prevalence of over-drafting.

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%. Subsequent experimental studies by Taubinsky and Rees-Jones (2018) and Morrison and Taubinsky (2021) measure over- and under-reaction to consumption taxes and argue that models of limited attention best explain the patterns they find.

Lacetera, Pope and Sydnor (2012) argue that limited attention drives *left-digit bias*, or the tendency for consumers to over-weight the left-hand digits of product information. They show, for example, that used car prices exhibit discontinuous drops at 10,000-mile odometer thresholds, along with smaller drops at 1,000-mile thresholds. 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, despite the absence of clinical guidelines recommending a change in treatment at this age.

7.3. Productivity

As discussed in our review of the determinants of attention (Section 2.4), maintaining focus can engender motivational states, such as boredom, curiosity, flow, and mental effort. The hedonic impact of attentional motivation forms a significant portion of the overall utility people derive from many productive activities. Thus, the joys and sorrows of work are, in many instances, the pleasures and pains of maintaining attentional 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, 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; 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 to difficult tasks over time. As argued extensively by Shenhav et al. (2017) and summarized in Section 2.2, the limited resource of cognitive control plays a key role in determining why and when maintaining attention to a task is aversive. 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). Individual differences in cognitive endurance predict 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). There is some evidence, however, that cognitive endurance can be improved through practice, with benefits for educational outcomes (Kaur et al., 2021).

7.4. Firm Behavior & Organization

An organization's structure, management, and strategy are shaped by the need to effectively harness a group's attentional resources and align them towards shared objectives. Early in the study of administrative behavior, Simon (1947) 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*.

These perspectives eventually 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."[17] 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 may also play a role in low rates of testing for—and in some cases treatment of—diseases such as cancer and Parkinson's (Caplan, 1995; Kőszegi, 2003; Oster, Shoulson and Dorsey, 2013), and in interventions designed to increase testing (Schweizer and Szech, 2018).

[17]It is worth pointing out, however, that Simon and others writing about the role of attention in firm behavior and organization may have taken a more expansive conception of attention than the definition proposed in this paper.

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 helps to explain a wide range of addiction-related phenomena, such as why people often relapse after long periods of abstinence.

A number of studies have shown that people who are addicted to drugs exhibit attentional biases in favor of drug-related cues in the environment (Robinson and Berridge, 1993). For example, they 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). Those with addictions 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).

Attention may also play a role in some addictive behaviors, such as gambling, because these activities distract attention from things people would prefer to not think about (*e.g.*, unstable employment or a failing marriage). 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.*, one person who describes themselves as being "after nothingness," and another who states that the point of playing slots is to stay in a zone where "nothing else matters" (page 12). Video games, social media platforms, and other digital products also use variable rewards to increase their attentional appeal (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).

Finally, people have strong preferences over the attention of others, in some cases wanting to avoid it (e.g., due to self-consciousness) and in other cases to attract it (e.g., when posting on social media). At an extreme, it appears that people can even 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."[18] In attempting to direct other people's attention, individuals will naturally strategically deploy their understanding of the three determinants of attention focus discussed in Section 2.4. Research in psychology, however, suggests that such efforts

[18] 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`

may be distorted by biases in evaluations of others' attention. For example, research on the "spotlight effect" (Gilovich, Medvec and Savitsky, 2000) suggests that people tend to overestimate how much attention other people are paying to them, a phenomenon which results, 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). Disentangling preferences about how others allocate attention from other preferences (such a desire for social standing), and understanding the strategies that people use to direct others' attention, are important questions for future research.

7.6. Policy and Public Choice

Policy makers have begun to realize that attentional interventions can in some circumstances influence behavior as or more effectively than incentives. For example, simple, targeted, well-timed, attention-directing text messages can positively impact 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). 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 are not necessarily inherently important or even true, 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 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."[19] 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).[20] 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 subject to advertisements and generate data that firms can monetize (Wu, 2017; Zuboff, 2019).

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."

These observations support the idea that, much as taxes on cigarettes and subsidies on corn can impact physical health, policies such as requiring students to lock up their phones during class can, via their impact on collective attentional behaviors, impact mental health and well-being (Haidt, 2024; Bursztyn et al., 2023). China has, in fact, implemented regulations to limit the amount of time children of different ages can spend on video games, livestreams, and smart devices; in the U.S., by comparison, policy stances toward *e.g.*, TikTok, have been largely dictated by national security concerns rather than its consequences for attention allocation and mental health.

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 of display ads in elevators. A recent trade publication focusing on such ads 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

[19] `https://www.nytimes.com/2016/11/03/books/review-attention-merchants-tim-wu.html`

[20] 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.

> and plant the seed of advertising into their brains."[21]

Such ads impose a variety of costs and potential benefits on riders, who may not always be in a position to demand 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.

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 far-reaching implications for production as well as consumption. Many productivity-enhancing technologies operate by relaxing attentional constraints. Consider, for example, the use of multiple screens by financial traders, which reduce the costs of redirecting attention between different sources of information. A variety of other innovations, from whistling kettles to self-driving cars (which enable the driver to redirect attention from the road to, *e.g.*, a book), 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 capabil-

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

ities. To study the impact of *artificial* intelligence, therefore, one must first develop a clear picture of what factors limit *natural* intelligence.

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 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 (Kaur et al., 2021).

Models of human capital formation and skill-development, more generally, could productively incorporate deeper insights about how mental 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 and, with lack of practice, decays.

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 conversation), or high-quality choices (*e.g.*, by engaging in extensive product research) that can be used to generate utility in the future. Recasting Becker's 1965 theory of time production in terms of attention could help clarify the structure of how these applications of attention compete with one another.

A more general theory of attentional budgeting could even help sharpen our understanding of the isolated contexts in which the implications of limited attention are 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 even 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).[22] The reality, as discussed in Section 2.4, is 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 applications, 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, a realistic 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.

Finally, a comprehensive economics of attention would not only describe how attention impacts consumers, producers, retailers, government employees, and other economic agents individually, but would also address the strategic equilibria that arise through their interactions. Such effects will generally depend on the degree to which various agents are aware of their own and other agents' attentional limitations, and adapt their behavior accordingly.

9. Conclusion

Our goal in this review has been to demonstrate that conceptualizing attention as a productive resource can build bridges between economics and other disciplines, make sense of results from behavioral economics, and identify fruitful new avenues for economics research. Separating out physical production from mental production and, ac-

[22] 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).

cordingly, physical resources from mental resources can advance our understanding of the "economics of attention."

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