

The History and Future of Human Prospec-tion

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Abstract

In psychology, neuroscience, artificial intelligence, and philosophy, “prediction” is widely recognized as central to cognition. *Mental time travel* into the future is the form of cognitive prediction (“prospec-tion”) most intimately connected to adaptive human functioning. It underpins explicit goal-setting, collaborative planning, and the pursuit of creative innovation. Theories focusing on prediction have a long intellectual history. Broadly construed, they offer perhaps the best opportunity yet for a global picture of neural and cognitive functioning. Exploiting this opportunity requires building bridges between prediction—as instantiated in perception or reinforcement learning—and full-fledged mental time travel into the future. The surge of recent work on these topics indicates consensus about the promise of prospec-tion for understanding diverse aspects of cognition, but subfields still lack theoretical synthesis.

Keywords: prospec-tion, foresight, prediction, mental time travel, evolution, imagination, culture, innovation, creativity, the self, free will, consciousness

BOOKS UNDER REVIEW

Seligman, Martin E. P., Peter Railton, Roy F. Baumeister, and Chandra Sripada, eds. 2016. *Homo Prospec-tus*. Oxford: Oxford University Press. xiv, 400 pages. Hardcover \$36.95.

Michaelian, Kourken, Stanley B. Klein, and Karl K. Szpunar, eds. 2016. *Seeing the Future: Theoretical Perspectives on Future-Oriented Mental Time Travel*. Oxford: Oxford University Press. viii, 464 pages. Hardcover \$90.

INTRODUCTION: ARTIFACTS OF PREDICTION

In the year 1900, a group of Greek sponge divers pulled an enigmatic artifact from the Aegean Sea: a lump of wood and metal that would only many decades later be identified as the world’s first-known analogue computer (Freeth et al. 2006). The device, approximately 2,000 years old and called the *Antikythera mechanism*, is of astonishing technological complexity (Marchant 2006). Analyses of the object in recent decades have revealed that it functioned as a *predictive machine*, used to represent the future of the heavens: the movement

of the planets, position of the sun, and the phases of the moon. Once predicted, this celestial information was enlisted in the service of *preparation*, probably for timing agricultural and religious activities. Modern computer simulations suggest the device would have successfully predicted even recent eclipses, including the one whose shadow crossed the United States on August 21, 2017 (Wolfram 2017). The Antikythera mechanism tells us that for thousands of years humans have invested enormous effort in an attempt to predict and prepare, and, by extension, to engage in *prospec-tion*—cognition that represents the future.

Ancient material evidence suggests that the history of human future thinking has a far more extensive lineage still. Consider a recently reported set of ground-edged hatchets from northern Australia (Clarkson et al. 2017). At approximately 65,000 years old, they are the world’s oldest-known. The tools were long-lived, and creating their highly polished edges required extensive abrasion with other rocks (Dickson 1980). They were also continually

maintained, reshaped, and reworked, with worn or damaged edges repaired so they could be used again when needed in the future (Hiscock et al. 2016). Further back into pre-history, perhaps some of the earliest evidence for prospective cognition in any *Homo* species comes in the form of bifacial hand axes (Hallos 2005), the oldest of which may be more than 1.76 million years old (Lepre et al. 2011). The complex production process of bifaces required more advanced planning than earlier tools (Wynn and Coolidge 2016). Moreover, they appear often to have been built in one location and then transported elsewhere for repeated use (Ambrose 2010).

An ancient stone tool like the biface might seem to have little in common with the Antikythera mechanism, other than that both are the functional end products of human ingenuity and the spread of ideas. But both objects can also be thought of as extensions of a mind fundamentally geared towards the future. Only with behaviors enacted in the present moment (including the creation of powerful tools) can future successes be ensured and disasters averted, the crops kept alive, and the predators warded off. The same logic applies to a great many of the artifacts of humanity fashioned over the eons to predict, prepare for, and confront possible futures: walls to stop potential invaders, writing to remember the debtor, seed banks in case our planet begins to expire. These artifacts reflect a more general underlying fact: many of the mechanisms of human cognition are fundamentally future-oriented. The rise and growth of this prospective cognition has been a critical driver of our evolutionary success (Suddendorf and Corballis 2007). On this point, at least, most modern thinking about the science of human prospection converges.

The two books under review here repeatedly propound the centrality of prospection to adaptive human functioning. Together, the books represent a cross section of much of the relevant contemporary work, and readers will

find much creative and fascinating research and theory in both. They are good companion pieces, together providing an exciting primer to the topic and a helpful resource on the array of emerging subfields. After surveying the history of research on prospection, I shall review these major subfields and discuss the major questions raised in the books: How do the mechanisms of “low-level” prediction relate to mental time travel (MTT)? What are the ultimate evolutionary origins of prospection? What are the applications to questions about metacognition, the self, free will, and consciousness? How does prospection as a capacity bear on creativity, innovation, and cultural change? Is it fair to conceptualize prospection as a *paradigm shift* in our approach to the cognitive sciences (Kuhn 1962)?

THE CENTRALITY OF PROSPECTION: A HISTORICAL PERSPECTIVE

The contributors to *Homo Prospectus* herald the science of prospection as a revelatory new approach for psychology. Seligman and colleagues tell us that psychologists, who have been long attached to the notion that the past and present determine human actions—as seen in behaviorism, psychoanalysis, and “most of cognitive psychology” (10)—have ignored the draw of the future. The authors assert that their reconception, which places the future center stage, is so radical in its implications that it calls for renaming our species “*Homo prospectus*.” The authors ask us to “take this name seriously” and underscore their request by making it the title of their book (10). I agree that the subject should be taken seriously, but the name would probably best be regarded as a rhetorical device. After all, “*Homo prospectus*” joins a long list of other proposed names for our species, from “*Homo grammaticus*” to “*Homo technologicus*” (https://en.wikipedia.org/wiki/Names_for_the_human_species), all of which have gone unadopted since Linnaeus called us *Homo sapiens* (1758). These names

typically emphasize some particular aspect of human cognition or behavior that the author considers most imperative. “Prospecion” has great promise as a research program but also risks becoming a buzzword.

In being “drawn into the future” Seligman and colleagues—with an unintentional but appropriate irony—gloss over the intellectual history that scaffolds the contemporary science (Fukukura, Helzer, and Ferguson 2013). Prospecion has been seriously discussed by thinkers ranging from the ancient Roman philosopher Seneca (65 AD) to the modern German philosopher Schopenhauer (1918). The seventeenth-century political philosopher Thomas Hobbes declared that “the opinions men have of the rewards and punishments which are to follow their actions are the causes that make and govern the will to those actions” (1640, 103).

In the opening pages of their introduction, Railton suggests an amendment to a famous statement by William James: “My thinking is first, and last, and always for my doing.” To which Railton would add, “and all of my doing extends forward in time, not backward.” However, a more complete reading of James reveals his already extensive emphasis on the future. In *Principles of Psychology I* (1890), for instance, he argues that the fundamental function of the cerebral hemispheres of an animal is to simulate “remote objects” and “distant ends” that are not currently available to its senses. “[In] the cerebrum itself the same general distinction obtains, between considerations of the more immediate and considerations of the more remote. In all ages the man whose determinations are swayed by reference to the most distant ends has been held to possess the highest intelligence” (1980, 20).

In *Principles of Psychology II*, in a chapter dedicated to “the will,” James deals at length with deliberation, anticipation, and voluntary action. Thus, as is often the case in psychology, James preempted or founded much

of our current discussion, and it would be difficult to identify any significant hiatus in the interim. Other notable early thinkers on the topic include Helmholtz, Bergson, Kohler, Tolman, and Craik. Aside from his well-known work on “cognitive maps” and latent learning (Tolman 1948), Tolman wrote at length, earlier, about “purpose” as it related to psychological processing. He defined human “thought” as “an internal presentation to the organism (on the basis of memory and association) of stimuli not actually present *but which would be present, if some hypothesized action were carried out*” (my emphasis) (Tolman 1920, 230). In his remarkably prescient “The Nature of Explanation” (1943), English philosopher Kenneth Craik paralleled this idea, introducing the concept of “mental models” and discussing their potential function as tools for organizing behavior in the face of upcoming dangers and opportunities.

In the United States, the concept of “mental models” arose at around the same time as “cybernetics,” a field that brought together control systems theory, information theory, neuroscience, anthropology, and psychology to study control and communication in the animal and the machine—the subtitle of a seminal book by Norbert Wiener (1948). Cyberneticists examined systems that act as if they have *goals*. (The word “cybernetic” is derived from the Greek κυβερνάω [kubernáō], meaning “steersman, governor, pilot, or rudder.”) In the 1940s and 1950s, cyberneticists placed a strong emphasis on prediction and feedback in the context of adaptive functioning. Those concepts eventually found a home in artificial intelligence research (Wiener 1948). A highly fruitful bidirectional relationship between the cognitive sciences and artificial intelligence followed, with search problems, planning, and goal-direction being productive areas of joint interest (reviewed in Russel and Norvig 2009).

Plans and the Structure of Behaviour, published in 1960 by George Miller and colleagues, applied cybernetics to psychology and

became a founding text of the cognitive revolution (Miller, Galanter, and Pribram 1960). Miller et al. argued that complex stepwise planning might emerge through the operation and manipulation of internal mental models. Arguably, then, one of the hallmarks of the cognitive revolution in psychology was the introduction of “prospection” as expressed in the goal-directed control of behavior. Around the same time, social psychologist Walter Mischel had begun to investigate the capacity of young children to postpone their immediate gratification in pursuit of delayed rewards (Mischel 1961), though one should note that the concept of delayed gratification has parallel roots in sociology and economics (Strotz 1955; Straus 1962). In the 1970s, the study of “intertemporal choices”—of which Mischel’s iconic marshmallow test can be considered one variant—was extended to pigeons (Ainslie 1974), and later to many other nonhuman animals (for reviews, see Stevens 2010; Redshaw and Bulley 2018).

Prospection, forecasting and goal-directedness were central to much of Kahneman and Tversky’s Nobel Prize-winning research during the 1970s (e.g., Kahneman and Tversky 1977). At the same time, developmental psychologists were using linguistic analyses of young children’s vocabulary to track “past” and “future” understanding (Harner 1975), and cognitive psychologists were beginning to study the mechanisms of prospective memory and delayed intention-setting (Meacham and Singer 1977). Learning theory was also being placed on a solid foundation of “expectation” (Rescorla and Wagner 1972), and neuroscientists had started to consider the role of the frontal lobes in executive functions and planning (Nauta 1971). Endel Tulving’s framework for memory (1972) was particularly foundational at this time, and would soon be extended to encompass “future thinking” (Tulving 1985). In the 1980s and 1990s, philosophers offered detailed treatments of “intention” and “planning” (e.g., Bratman 1987). Meanwhile, economists

continued to investigate the way prospective emotions guide decision-making (Frank 1988), and clinical psychologists investigated their influence on affective disorders (Beck, Emery, and Greenberg 1985; MacLeod et al. 1997). Studies of patients with frontal lobe damage came to corroborate hypotheses about how the frontal lobe functions in adaptive goal-directed cognition (Ingvar 1985; Damasio 1994).

In 1997, Suddendorf and Corballis presented their seminal treatment of MTT, describing in detail its possible subcomponent processes. They also fleshed out the link between memory and foresight systems and discussed the evolutionary origins of MTT. Working in parallel, other scientists were investigating “low-level” sensory and behavioral neuroscience and artificial intelligence, developing arguments supporting the brain-basis of learning by prediction error. Those arguments led to theoretical models that identified prediction as a key aspect of sensory processing and deep learning (e.g., Dayan et al. 1995). Models like these, grounded in artificial intelligence research, found substantive empirical support in emerging neuroscientific investigations, including those delineating a key role for dopamine in reward prediction (Berridge and Robinson 1998; Schultz, Dayan, and Montague 1997). By the 2000s, the invention of neuroimaging led to a series of studies that served to corroborate the notion that memory and prospection should be thought of as two sides of the same coin (e.g., Okuda et al. 2003).

Since the turn of the millennium, a thriving research industry has emerged on the back of this rich history, much of which I cover in more detail below. Some major reviews have recently been published (Szpunar and Radvansky 2015; Schacter, Benoit, and Szpunar 2017), as have a number of books and edited volumes, including the two under direct consideration here (Bar 2011; Suddendorf 2013b; Clark 2015; Michaelian 2016b; Macleod 2017; Oettingen, Sevincer, and Gollwitzer 2018). This brief

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historical sketch should suffice to indicate that the significance of prospecion has long been recognized. Accordingly, claims that the current surge of research amounts to a radical paradigm shift in psychology need to be taken with a grain of salt. Even so, it is undoubtedly true that we are witnessing a rapid growth in cross-disciplinary work on such questions. The two books under review here are testament to that growth.

Prospecion is a term sometimes reserved for “higher-order” cognition with a predictive component involving “thinking about the future” via explicit planning, foresight and imagination. These topics will be the focus of this review. However, the broader definition that includes all “predictive” processing in the brain and cognition touches a vast array of topics in the cognitive sciences. Some authors have suggested that there is a harmony at play here: that “prospecion,” broadly construed, might offer us an organizing principle for the brain and behavioral sciences (e.g., Clark 2015). The multiple fields of inquiry reviewed in the preceding historical sketch constitute different “levels” of analysis. Building conceptual linkages among those levels remains a major challenge.

TRAVERSING THE LEVELS: FROM PREDICTION-ERRORS TO MTT

“Low-Level” Prediction

In the opening chapters of *Seeing the Future* (STF), before they scale upwards, Railton and Shripada make a compelling and neurobiologically informed case for the operation and mechanisms of low-level prospecion. Their account dovetails with a recent surge of interest related to “predictive processing” (Clark 2013, 2015; Pezzulo 2016). Predictive processing and Bayesian approaches to brain function conceptualize neural processing as an ongoing comparison between new sensory input and existing internal probabilistic models of the causes of those sensory signals. In vision, for

example, the brain is thought to strive toward a minimization of the prediction error that occurs as the eyes gather information from the outside world and **compare** that information **is compared** with existing mental models. The interacting component parts of the visual system use this prediction error to update internal probabilistic models and thereby create increasingly useful cognitive representations (Dayan et al. 1995; Friston 2009; Pezzulo, Rigoli, and Friston 2015). In STF, Pezzulo (2016) surveys the relevant findings and current theoretical positions (see also Bubić, von Cramon, and Schubotz 2010). In the predictive processing account, the confluence of top-down predictions with bottom-up sensory input operates at the neural core of perception and action.

“High-Level” Prediction

Episodic foresight is the capacity to simulate future events, embed them in larger narratives, and then adjust present decision-making and behavior accordingly (Suddendorf and Moore 2011). Episodic foresight is not a unitary cognitive module; it requires a suite of interacting component capacities and operations. Neuroimaging while participants simulate the future has revealed a wealth of details about the possible **neural** mechanisms of episodic foresight, **including its neural basis**. Generally, imagining the future is associated with activation in the “default mode network,” so named because it is the activity also observed during task-unrelated rest. The involved brain regions include the medial temporal lobes, midline prefrontal cortex, and cingulate cortex (Raichle et al. 2001; Buckner, Andrews-Hanna, and Schacter 2008; Smallwood et al. 2013; Bubić and Abraham 2014). Such findings suggest that people may often resort to imagining future possibilities when external task demands are low (Burgess, Dumontheil, and Gilbert 2007; Spreng and Grady 2010; Corballis 2013a; Smallwood and Schooler 2015).

Building Bridges

How much commonality is there between the “prediction” taking place at different levels of analysis in the cognitive sciences? Clark (2015) makes a rallying call for the utility of the predictive processing account:

Predictive processing offers an attractive “cognitive package deal” in which perception, understanding, dreaming, memory, and imagination all emerge as variant expressions of the same underlying mechanistic ploy—the ploy that meets incoming sensory data with matching top-down prediction. At the heart of the package lies the ability to use downwards connections to self-generate perception-like states. The very same “perceptual” machinery, driven from the top-down but insulated from entrainment by the driving sensory signal, then accounts for imagery and dreaming, and may pave the way for “mental time travel” as we assemble cues and contexts able to reconstruct the past and preconstruct the future. (107)

This is a notion that receives support elsewhere (Pezzulo 2008). In an informative and wide-ranging chapter of *STF*, Pezzulo (2016) expresses his broad interpretation of the promise of predictive processing. Pezzulo’s chapter includes an important discussion of findings of rodent hippocampus place cell activity that “replays” and “pre-plays” physical movement even when the animal is not moving. Interpreting these findings has proven contentious (Gupta et al. 2010; Corballis 2013b; Suddendorf 2013a; see also Pezzulo, Kemere, and Van Der Meer 2017). As Clark (2015) and Pezzulo (2016) acknowledge, achieving a global synthesis of prediction in the brain presents several problems. One is that “future-oriented” processing is highly multidimensional at every scale, especially the most “higher-order.” Note, however, that there have been recent attempts to address even “high-level” concepts like “optimistic beliefs” (Sharot and Garrett 2016), and

explicit “intertemporal choice” at the “low-level” of reinforcement learning (Lefebvre et al. 2017; Solway, Lohrenz, and Montague 2017). This problem extends to using different terminology for (perhaps?) the same things—such as the myriad names for episodic foresight/episodic future thinking/future-oriented MTT/future simulations, and so forth. Another problem is that theoretical and mathematical models of neural and cognitive mechanisms will only get us so far; we need to have an understanding that is not only neurobiologically plausible but also anchored in specific neural activity while simultaneously linking that activity to specific behavior. And a third problem: we should have a sense of how these mechanisms evolved, and on account of which selective pressures—notoriously difficult questions for complex cognitive processes (Tinbergen 1963). Given problems of this magnitude, one can understand the caution expressed in the final lines of the introduction to *STF*: “While parsimony is a laudable goal in theory construction, it may nevertheless turn out to be the case that the search for a common mechanism underlying the various forms of FMTT is futile” (14).

The Relationship between Memory and Prosppection

Several authors have converged on the idea that memory is in essence forward-facing. This idea builds on early ideas of James (1890) about the source of “remote” sensations and also on concepts from cybernetics—for example, that in thinking systems “the prediction of the future of a message is done by some sort of operator on its past” (Wiener 1948). Memory, in this view, is a system that empowers an organism to imagine, predict, or prepare for the future (Suddendorf and Corballis 1997; Suddendorf 2010; Szpunar and Tulving 2011; Klein 2013; Suddendorf and Henry 2013). Information accrued and stored through lived experience forms the building blocks for prosppection. The ability to generate novel expectations about

future events, especially in the form of narratives, relies in part on the recursive nesting of that information (Suddendorf and Corballis 1997; Schacter, Addis, and Buckner 2007; Hassabis and Maguire 2009).

MTT and semantic knowledge are deeply intertwined (Szpunar 2010; Irish 2016). As a “time-invariant repository of conceptual knowledge” semantic information provides a crucial “ingredient” in the construction of mental scenarios and may also guide the construction of diverse forms of future-oriented cognition (Irish, Piguët, and Hodges 2012; Irish et al. 2016). Indeed, researchers have suggested that semantic memory underpins episodic processing in both memory and prospection (Tulving 1985; Binder and Desai 2011; Irish and Piguët 2013) and that semantic knowledge is integrated into imagined possibilities during the “scenario building” process (Cheng et al., 2016). Szpunar, Spreng, and Schacter (2016) suggest that episodic and semantic formats of cognition are best thought of as lying on a gradient along which different “formats” of future thinking are expressed. One should recognize that there are also important differences between episodic foresight and episodic memory (Suddendorf 2010). For instance, they may differ in their reliance on “recombination” (Weiler et al. 2011) and also in brain activity (Bubić and Abraham 2014; Schacter, Benoit, and Szpunar 2017). See also the ongoing debates in philosophy about “continuism” versus “discontinuism” as reviewed in *STF* (Michaelian 2016a; Perrin 2016).

THE UTILITY OF PROSPECTION (AND ITS EMERGENCE)

In seeking a comprehensive account of prospection, one may usefully invoke Tinbergen’s four questions: about mechanisms, development, phylogeny, and function (Tinbergen 1963; Scott-Phillips, Dickins, and West 2011). Several contributors to *STF* have made good headway on these questions. The development of prospective capacities has been discussed at length

(Gopnik et al. 2004; Suddendorf and Redshaw 2013; Martin-Ordas, Atance, and Caza 2014; Atance and Mahy 2016; Suddendorf 2017). An emerging consensus affirms that the capacities come on line piecemeal, with most available in rudimentary form by around age four. Comparing research on children’s episodic future thinking to the research conducted with healthy adults, Atance and Mahy (2016) argue that many assumptions we make about how adults imagine the future do not necessarily apply to nonverbal children. We cannot assume, for instance, that nonverbal children even imagine the future at all.

Many of the difficulties presented by studying prospection in nonverbal infants appear also in studying prospection in nonhuman animals. Comparative psychologists have had a long preoccupation with MTT, and “human uniqueness” has remained a major point of contention since MTT was originally articulated (Suddendorf and Corballis 1997; Tulving 2002). Emerging evidence suggests that animals are capable of considerably more sophisticated future-oriented behavior than was once thought possible (Osvath and Martin-Ordas 2014; Martin-Ordas 2016; Thom and Clayton 2016; Redshaw and Bulley 2018). Explanations for these behaviors remain controversial, but in some cases the most parsimonious explanations attribute ~~to animals’~~ mental representations of an anticipated future. ^{to non-human animals} (But see Thom and Clayton in *STF* for an insightful critique of the principle of parsimony and “Morgan’s Canon.”)

Taking account of the way prospection enters into decision-making, most researchers agree that it has adaptive functionality (Gilbert and Wilson 2007). Its adaptive functionality is especially clear in its relationship with emotion. The emotional significance of a particular stimulus or event is an indicator of its biological value. Consequently, emotional reactions can serve as a common appraisal metric for environmental occurrences (Panksepp 1998). Value, in this biological sense, relates directly to survival and reproduction. Episodic foresight

enables the ascription of such value signals to imagined future events as well as to events that are directly perceived (Suddendorf and Busby 2005; Damasio 2009; Lin et al. 2015). People can thereby “evaluate” a future possibility long in advance by the way it makes them feel when they imagine it—a process known as “affective forecasting” (Wilson and Gilbert 2005).

Anticipated emotional reactions are commonly evoked in decision-making, but the role of foresight may be especially important in decisions with outcomes that play out only over time. Such decisions include intertemporal choices in which present and future consequences are in conflict (Peters and Büchel 2010; Benoit, Gilbert, and Burgess 2011; Bulley, Henry, and Suddendorf 2016; Jenkins and Hsu 2017). Boyer (2008) suggests that imagining future benefits may act as a motivational “brake” on the kind of impulsive decision-making that sacrifices long-term and cooperative effort to individual and immediate gratification. The brake works by providing some of the motivational salience of a future reward before it arises (Pezzulo and Rigoli 2011; Kurth-Nelson, Bickel, and Redish 2012; Hoerl and McCormack 2016; Viganò 2017). In line with this perspective, researchers increasingly see impaired foresight as a risk factor for addiction and a barrier to recovery (Bickel et al. 2017; Noël, Jaafari, and Bechara 2017; Terrett et al. 2017). (For an interesting discussion about the relative role of the semantic and episodic systems in modifying intertemporal choices, see Hoerl and McCormack in *STF* [2016], Kwan et al. [2015], and Palombo, Keane, and Verfaellie [2016]. The latter two sources also discuss the role of the medial temporal lobes among participants with amnesia.)

Evidence suggests that foresight is closely associated with the organization of personal goals and might thus be a particularly powerful tool in decision-making (e.g., Lehner and D’Argembeau 2016). Pursuit of these personal goals often involves “shaping one’s future

self” through *deliberate practice* (Suddendorf, Brinums, and Imuta 2016). In *STF*, Suddendorf et al. argue that people can deliberately pursue specialization only by identifying a future skill set (and the path towards its acquirement), and that this deliberate pursuit goes some way toward explaining the powerful diversity of expertise that characterizes humanity. Metacognition underpins such adaptive foresight in humans: one can only overcome one’s cognitive limits by recognizing those limits—recognizing, for instance that one *lacks a certain skill*, or that one’s predictions *could be wrong* (Redshaw 2014; Redshaw and Bulley 2018).

Impairments and Costs

Life had overshot its target and blown itself apart. A species had been too heavily armed—its genius made it not only all-powerful in the external world, but equally dangerous to its own well-being. (Zapffe 1933)

Human MTT has been described as “costly” because it probably requires a big, densely wired brain, which is slow to develop and metabolically “expensive.” The empirical evidence about the “metabolic” costs of prospection is wanting, but these arguments can be regarded as extensions of the common idea that more “flexible” cognitive processes are harder to build than fixed action patterns of behavior designed to activate upon particular stimulus cues in the environment (see Dennett 1984). There is another potential cost to any highly complicated mechanism with many moving parts: it can break down in various ways. Research is now accumulating on changes in prospection in clinical subgroups, including patients suffering from dementia, epilepsy, multiple sclerosis, schizophrenia, and normal aging (see Henry et al. 2016 for a special issue on the topic). It is difficult to ascertain precisely which situations are best viewed as “malfunctions” of the mechanisms, and which are better

conceived of as either (1) by-products of other interacting capacities or (2) extreme manifestations of normal individual-difference variance (Nesse and Williams 1994; Zietsch, de Candia, and Keller 2015)

Evolutionary costs and benefits to an organism are not the same as the costs and benefits to its subjective well-being. Peter Zapffe (1933) observes that the “genius” of human beings is a source also of great suffering. This may be true about the “genius” of prospecion, which provides us not only with extraordinary powers of control, but also gives us the best seats in the house to mentally access futures we would perhaps rather not foresee: those that include ruin, suffering, and the death of loved ones or of ourselves. Varki (2009) suggests that for mechanisms allowing this mental access to have evolved at all, simultaneous systems for self-deception would have been required to offset the negative consequences such existential dread would engender for adaptive behavior (see also von Hippel and Trivers 2011). Whether or not this is true, the suffering brought about by prospecion is most obvious in the context of depression and anxiety, where negatively valenced future simulations are common. Of depression, Seligman and Roepke declare in *STF* that “dysfunctional prospecion creates depression” (see also Roepke and Seligman, 2015), but this is perhaps a premature conclusion given the correlational nature of the majority of the research (reviewed in Miloyan, Pachana, and Suddendorf 2014). A long-running research program by MacLeod and colleagues has suggested a more complex relationship between prospecion, well-being, and mental health (MacLeod et al. 1997; MacLeod 2016). Being able to “auto-cue” future threat events and narratives without any immediate sensory threat cues is a powerful adaptive tool for managing potential dangers (Miloyan, Bulley, and Suddendorf 2018), but it is also a central feature of clinical anxiety (Miloyan, Pachana, and Suddendorf 2014; Bulley, Henry,

and Suddendorf 2017). As with depression, it is still unclear what causal role negative prospecion may play in anxiety.

PHILOSOPHICAL IMPLICATIONS

The Self and the Future

Cognitive scientists and philosophers have begun to address the difficult problem of how the current “self” relates to the future or possible “selves” into which it may transition (Markus and Nurius 1986; Hershfield et al. 2011; Manning 2016). Empirical advances in the form of “thought-sampling” and studies of selfhood in amnesic patients have begun to trace out what a science of “the self” integrated with prospecion would look like. In *STF*, D’Argembeau (2016) argues that much of our MTT is organized around “self-defining experiences” in memory and “self-defining future projections” in foresight. Research on personal semantic memory (Renoult et al. 2012) and semantic conceptions of the self suggest that multiple interacting systems are at play in its construction (Klein and Gangi 2010; Conway, Loveday, and Cole 2016).

Predictive processing accounts of the self are often tied up with notions of embodiment and action. “Active” and “interoceptive” inference paint a picture of reciprocal feedback between internal predictive models and stimuli in the environment or the body (e.g., from the viscera), respectively (Clark 2008). Because the organism continually engages the world via motor planning and behavior to select the stimuli that will connect with its sensors, it can perform actions that reduce prediction errors by bringing sensory states in line with expectations (Friston 2009; Pezzulo 2012; Seth 2014). Newly accrued evidence can thereby update the initial models and thus change future learning and action (Friston et al. 2017). This process of “active inference” inexorably links the organism and the environment. Related “enactivist”

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or “embodiment” perspectives raise interesting questions about where the boundaries of the self would best be drawn. Again, this idea traces its lineage to cybernetics:

Consider a tree and a man and an axe. We observe that the axe flies through the air and makes certain sorts of gashes in a pre-existing cut in the side of the tree. If now we want to explain this set of phenomena, we shall be concerned with differences in the cut of the face of the tree, differences in the retina of the man, differences in his central nervous system, differences in his efferent neural messages, differences in the behaviour of his muscles, differences in how the axe flies, to the differences which the axe then makes in the face of the tree. Our explanation (for certain purposes) will go round and round that circuit. In principle, if you want to explain or understand anything in human behaviour, you are always dealing with total circuits, completed circuits. This is the elementary cybernetic thought. (Bateson 1972, 465)

Prospection and Free Will

In *STF*, Seligman and colleagues underscore the importance of having an “option set” for free will. Recent experiments have shown it may be possible to increase the cognitive “option set” and change the perceived emotionality and plausibility of those options (Jing, Madore, and Schacter 2017). However, Seligman and colleagues disavow any intention of engaging the metaphysical debate about free will. The reader is then left to wonder why “free will” as a philosophical question enters the discussion at all. As the authors acknowledge, nothing about “prospection” necessarily hints at reframing the free will debate in metaphysical terms. (Prospective cognition all takes place “in the present,” as a result of whatever processes in the universe happen to engender them.) Metaphysics aside, the prospection approach is clearly useful in the psychology of volition—

for instance in understanding the psychological determinants of choices when options are pitted against one another and people must choose between them (Berns, Laibson, and Loewenstein 2007; Haggard 2008).

The King of the Questions in the Cognitive Sciences

Questions about consciousness have long been central to the study of prospection. The famous distinction made by Endel Tulving between episodic and semantic forms of declarative memory placed a special kind of conscious awareness center stage. Episodic memory is defined by “autonoetic” (“self-knowing”) consciousness that involves the first-person subjective experience of previously lived events. Semantic memory represents “noetic” (knowing) consciousness that does not require any explicit mental simulation (see also Szpunar and Tulving 2011). The subjectivity of autonoesis has produced much hand-wringing, especially in preverbal developmental and comparative psychology, where self-report is impossible, but the scientific opacity of autonoesis has not stopped some interesting speculations about the mechanistic underpinnings of conscious prospection. In *STF*, Sripada (2016) invokes conscious broadcasting to explain the way episodic memory states disseminate to neocortical “deep learning mechanisms,” which use them for foresight. This explanation is not wholly satisfying. There is no compelling reason memory states would need to be distributed via conscious means. Baumeister (2016a) suggests that the conscious experience of feelings might serve a role in affective “evaluations” that are useful in learning and prospection rather than in immediate action. This is an interesting idea, but it too is speculative.

In *STF*, Martin-Ordas (2016) takes aim at the issue of consciousness in nonhuman animals. She argues that while we cannot necessarily prove that nonhuman animals have subjective experiences, we cannot rule out the

possibility, either. Klein (2014) reminds us that we cannot define our way out of this problem: “If our available techniques are unable to capture this core feature of memory [and foresight], then so much worse for our techniques” (23). For the time being, we seem to have reached an impasse on this question. In many projects on which scientists of prospec-tion are engaged, putting consciousness to one side seems to be a useful strategy. Nonetheless, the scientific study of consciousness has seen a herculean surge of research effort over the last three decades (Crick and Koch 1990; Edelman 1992; Chalmers 1995; Dehaene and Naccache 2001; Tononi 2004; Koch and Tsuchiya 2007; Dennett 2017). It remains to be seen what potentially fruitful insights the science of prospec-tion will provide.

PROSPECTION, INVENTION, CULTURE, AND CREATIVITY

Metacognition allows for the invention of particular kinds of tools that allow us to “off-load cognition” into the environment, for instance by writing things down (Risko and Gilbert 2016). The writing paper (or computer) and its symbols can be considered as part of the extended cognitive system—and in some respects as part of the organism’s “extended phenotype” (Dawkins 1982; Clark 2008). The creativity that builds these inventions is fundamentally imaginative and prospective (Dong, Collier-Baker, and Suddendorf 2015; Abraham 2016). Any attempt to generate possible alternatives (e.g., novel “uses” for things) involves some flexible recombinatorial thought. Foresight also means humans can imagine the functionality and aesthetics of potential creations before any physical manufacture begins. Whether a solution to a problem is “figured out” or merely stumbled upon by accident, solutions can be recognized as having future utility (von Hippel and Suddendorf, forthcoming). The new discovery can be spread through social networks, amended, changed, borrowed,

sold, or stolen, all elements in the process of “cultural evolution.”

Corballis and Suddendorf argue that language may have evolved, at least in part, because it enables the sharing of mental time travels into the past and future (Corballis and Suddendorf 2007). Consider the long-recognized connections between imagination, MTT, and story-telling (McBride 2012; Boyer and Parren 2015; Abraham 2016; Mahr and Csibra 2018). With simulations of the future come insights about what it might hold. When pooled, those insights can be improved in accuracy or utility. Humans share, discuss, and create collaborative plans and socially construct concepts about the future, including ideas about what is worth striving for (Baumeister 2016b). When coupled with a powerful desire to “connect our minds together,” the capacity for simulating the future becomes starkly more potent as an evolutionary weapon in the struggle for survival and reproduction (Suddendorf 2013b; von Hippel 2018).

The implications of this perspective for cultural phenomena are intuitively suggestive. Think of the importance of prospec-tion in legal, religious, and financial systems. Nonetheless, the precise role of episodic foresight in cultural evolution remains somewhat opaque (Mesoudi 2007). Cognitive systems for the regulation of collaborative foresight, including those sub-serving morality, may have piggybacked on language-enabled MTT. Recent studies have shown that imagining future prosocial actions can encourage more altruistic behavior (e.g., Gaesser and Schacter 2014): more evidence that foresight might reduce the temporal discounting that would otherwise encourage the pursuit of “selfish” opportunities (see also Boyer 2008; O’Connell, Christakou, and Chakrabarti 2015; Hill et al. 2017). Furthermore, as underscored in *STF*, moral attitudes and judgments may also track prior transgressions and cooperation so that efficient predictions can be made about the likely future cooperativeness of conspecifics (Railton 2016).

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CONCLUSION

The science of prospection, broadly construed, may offer the best opportunity yet devised to find an overarching paradigmatic account of cognition. Over the past 100 years, intense research on the instantiation of prediction, from sensory perception to MTT, has built the foundations for this science. Those foundations have been laid in multiple fields: psychology, neuroscience, artificial intelligence, and philosophy. In coming years, researchers may successfully bridge the levels of analysis in these diverse fields. The surge of recent interest in these questions suggests a growing consensus that prospection, in its many guises, has a central role in neural and cognitive functioning. In its most “higher-order” form, prospection manifests as MTT into the future, mind-wandering, subjective temporality, creativity, and innovation. Whether or not these phenomena can be understood as manifestations of some underlying general mechanism remains to be seen.

Prospection has been billed as offering a framework for big questions about the self, free

will, and consciousness. Such high claims invite skeptical caution. If prospection is to serve as an organizing principle for the cognitive sciences, we will need to recognize its limitations. Despite these caveats, what is emerging is a distinct and valuable conception of the human mind as an embodied predictive system with complex cultural and material scaffolding. Objects like the Antikythera mechanism tell us that humans have obsessed over the future for thousands of years. The evolutionary lineage of this obsession probably runs back into the millions. Ultimately, we will continue using prospection to survey possible futures, to shape ourselves, and to create pathways to bring about the futures we desire.

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