INTRODUCTION TO THE NEUROSCIENCE OF RISKY DECISION MAKING

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The processes by which individuals make decisions under uncertainty has important implications for real-world outcomes in law, medicine, economics, clinical psychology, and public policy, to name a few. Despite the explosion of research on risky decision making over the past four decades, many questions remain: What are the neurobiological, psychological, and sociocultural factors that influence risky decision making either in isolation or in combination? How do the effects of these processes on decision making differ across development? And, what are their implications for problematic behaviors and health? The primary goal of this book is to address these questions, thereby advancing basic understanding and scientific theory about the brain mechanisms underlying risky decision making across the life span.

Understanding the mechanisms—from brain to behavior—of risky decision making is essential in paving the way for translation of basic science into policy and practice. A second goal of this book is to encourage intellectual integration of existing diverse approaches. To date, the factors that influence
risky decision making have been studied from a number of perspectives that span the spectrum of neuroscience, psychology, and behavioral economics. These approaches address the same general topic. However, each focuses on a different level of analysis (neural, individual, and societal, respectively), different units of analysis (behaviors, cognitions, affective states, neural patterns of activation), different domains (e.g., problematic behaviors, financial decision making, medical and health-related decisions), and different types of questions (e.g., normative processes to individual differences to developmental changes). Despite significant scientific advances, researchers in each area have remained relatively isolated from one another.

The speed of scientific advances, especially in neuroscience, calls for integrating findings from various levels of analysis to provide a more comprehensive view of the process underlying risky decision making as they operate over the lifespan. This intellectual integration is another goal of the book. Building on the recent surge of research on the neuroscience underlying risky decision making, the book brings together scholars with expertise that blends approaches from multiple disciplines to promote the development of a comprehensive and contextually sensitive model of risky decision making across the life span.

In the chapters that follow, leading neuroeconomists, neuroscientists, and social scientists discuss the latest findings and theoretical perspectives on risky decision making, reviewing such topics as the demanding impact of rewards and punishments at different ages (from early childhood through old age); the role of emotional regulation and self-control abilities as well as individual differences in personality in contributing to chronic difficulties in risky decision making; and the social, cognitive, biological, and developmental factors that shape risky behavior.

The book is organized into three sections that reflect active areas of research on the neural underpinnings of risky decision making: neuroeconomics, neurodevelopment, and neuropsychology. Neuroeconomics is the study of the brain making economic judgments and decisions. We lead off the book with interdisciplinary approaches to neuroeconomics because of the foundational role that economics has played in defining the basic phenomenon of risky decision making. Hence, from the outset, we compare tenets of psychology and economics that have provided the context for neuroscience research on risky decision making over the past decade.

The second section on neurodevelopment describes a special focus on research on risky decision making, namely, how risky decision making changes dramatically from childhood to adolescence to adulthood to old age as a function of maturational and experienced-based changes in the brain. The third section presents influential research in neuropsychology and individual differences, including the famous paradigms known as the "marshmallow test" (that incorporates the economic notion of temporal or delayed discounting) and the Iowa Gambling Task. Both tasks call on overlapping neural systems and elicit behavior that predicts risk taking in the real world. Throughout the book, many of the authors weave elements of neuroeconomics, neurodevelopment, and neuropsychology together.

Specifically, in Part I on neuroeconomics, fundamental economic phenomena such as risk preferences and framing effects (i.e., shifting from risk-seeking to risk-avoiding when options are equivalent but worded differently as gains versus losses) are discussed. In Chapter 1, Reyna and Huettel describe the implications of risky decision making for law, medicine, and public health and contrast the definitions of risky decision making in economics versus psychology. They explain that economists focus on risk in the sense of variance in outcomes (hence, by this definition, risk takers are people who tolerate uncertainty in outcomes), whereas psychologists focus on risk in the sense of the particular case in which uncertain outcomes are bad and detrimental to well-being (e.g., financially, legally, or medically) and highlight the effects of emotion and immaturity. Reyna and Huettel then summarize neuroscientific evidence ranging from ventral striatal reward circuitry to involvement of the default network in impulsivity. Grounded in this evidence, they introduce a preliminary integrative theoretical framework encompassing neural substrates of emotional salience, memory representations of options, and decision conflicts as people experience internal clashes between competing strategies for making risky decisions.

In Chapter 2, Levin, McElroy, Gaeth, Hedgcock, and Denburg summarize research on framing effects, which challenge axiomatic principles of economic theories of risk preference. Levin et al. present a process-oriented perspective that explains why people take risks and why their risk preferences shift in different circumstances. Summarizing and integrating research using behavioral and biological/neurological measures, such as neuroimaging, eye-tracking, circadian rhythms, and life span developmental techniques, they characterize the cognitive and emotional underpinnings of risky decisions across tasks and individuals.

In Part II on neurodevelopment, the authors address how developmental differences in brain functioning—from childhood to old age—are associated with risky decision making. In Chapter 3, Braams, van Leijenhorst, and Crane review the conditions under which developmental differences in risky behaviors are found among children, adolescents, and adults and how neuroscience elucidates the neural underpinnings of these differences. They also describe important neurodevelopmental frameworks of risk and reward processing, including the dual-processing network, the imbalance model, and the social information processing network approaches. They explore such issues as why the striatum is sometimes overactivated and other times
underactivated in adolescents; the role of hormones and individual differences; and the role of social factors, such as peer relations and peer pressure. They conclude with a new working model that explains how the striatum is influenced by environmental context and how it connects to other regions in the brain, which ultimately influence risk-taking behavior. This model is informative for policymakers and educational practitioners because it identifies what can be expected of people depending on their age.

In Chapter 4, Luna, Padmanabhan, and Geier focus on sensation seeking in adolescence, which is known to increase during the pubertal period across different societies and different species and often results in risk-taking behaviors that undermine survival. Despite being a period of peak physical health, adolescence is a time of increased mortality rates due in great part to risky behaviors such as substance abuse, unprotected sex, and extreme sports. To account for the paradox of heightened fitness and increased mortality during adolescence, Luna et al. propose that increased sensation seeking in adolescence is an adaptive mechanism. Sensation seeking affords the ability to explore the environment and expose the individual to information, thereby modeling the maturing brain. Sensation seeking may also underlie motivation for seeking independence, which supports an adolescent's transition to adult levels of maturity and responsibility.

Drawing on evidence from animal models and human studies, Luna et al. propose that developmental changes in neurotransmitter availability (along with pubertal changes) are a possible mechanism underlying the heightened propensity for sensation seeking in adolescence. Like Braam et al., they explore discrepancies in neuroimaging studies of engagement of reward-related brain systems in adolescence, drawing on developmental differences during stages of reward processing and age-related differences in value assessment. Luna et al.'s model of increased sensation seeking in adolescence has implications for juvenile law and education. Concluding the section on neurodevelopment, in Chapter 5, Samanez-Larkin and Knutson discuss emerging research on risky decision making in the aging brain. Despite the aging of the world population and the importance of decision competence in old age (e.g., retirement and end-of-life decisions), remarkably little research has focused on how aging might influence risk and reward processing. Samanez-Larkin and Knutson review studies that examine how age influences psychological and neurological responses to financial incentives and risks. Early findings from this literature suggest that aging may influence the structure and function of neural circuits implicated in incentive processing and risky decision making (e.g., the ventral striatum, the anterior insula, the prefrontal cortex) and that the consequences of these changes for choice apply to both laboratory and real-world settings. In addition to informing theory about the impact of affect and cognition on choice, these novel findings imply that understanding how the aging brain processes incentives may eventually inform the design of more targeted and effective decision aids for individuals of all ages.

In Part III on neuropsychology, Zayas, Mischel, and Pandey provide a compelling review of 40 years of research on delay of gratification. By age 4, children differ in the ability to delay gratification, and such individual differences predict risky decision and problematic behaviors across development, such as higher social competence, higher academic achievement (SAT scores), and lower substance abuse and body mass index (BMI). Recent findings provide empirical evidence that the remarkable long-term continuity in delay of gratification is rooted in individual differences in prefrontal cortical activity as well as affect-related brain circuits—a proposition consistent with a growing body of neuropsychological work on risky decision making.

Specifically, differences in preschool delay of gratification ability were observed most clearly in adulthood in tasks that involve inhibiting responses to rewarding stimuli (e.g., smiling face indicating approval) but not to neutral stimuli. Moreover, in imaging work, the preschool delay predicted greater activation of the inferior frontal gyrus, a structure in the prefrontal cortex (PFC) recruited when resolving conflict between representations and motor responses, on trials that required inhibiting a response. Preschool delay ability also predicted less activation of the ventral striatum in response to the rewarding stimulus. These authors conclude by arguing that a key benefit of enacting effortful self-control is that it lessens the tempting aspects of the cues to be inhibited and thus makes the very act of delaying gratification easier, essentially lessening the need to exert effortful self-control.

In the final chapter on neuropsychology, Wood and Bechara weigh in on the debate about "single system" versus "dual system" models for valuing in risky decision making. Using clinical evidence, they argue that not only are the traditional two processes supported by the clinical facts, but, in addition, the evidence points to a third process, thus calling for the notion of "triple process" models. This third system, involving the insula, translates homeostatic, bodily signals into feelings of craving.

That is, Wood and Bechara present evidence that many clinical conditions associated with poor impulse control and poor decision making are the product of an imbalance between two separate but interacting neural systems: (a) an impulsive, amygdala and striatum-dependent, neural system that promotes automatic and habitual behaviors and (b) a reflective, PFC-dependent, neural system for decision making. These neural systems map onto the psychological systems named "System 1" and "System 2," respectively. System 1 is defined as quick, automatic, and associative in its response, while System 2 is slow, effortful, reflective, and "rational." The reflective system controls the impulsive system via several mechanisms. However, this control is not
absolute; hyperactivity within the impulsive system can override the reflective system. The impulsive system is reminiscent of the described properties of System 1, which require a long time to build associations, but once those associations are made, they are rapid and difficult to override.

However, critically, going beyond standard dual-process models, Wood and Bechara suggest that the insula plays a key role in modulating the dynamics of these two systems. While most prior research has focused on the impulsive versus reflective or System 1 versus System 2, they suggest that the insula plays a key role in modulating the dynamics of these two systems. More specifically, the insula or "craving" system potentiates the activity of the impulsive system, weakens the goal-driven cognitive resources that are needed for the normal operation of the reflective system, or does both. Thus, when physiological states that involve deprivation, withdrawal, stress, anxiety, or any condition associated with homeostatic perturbation are considered, a third process (the insula) comes to the fore with direct impact on the functionality of the traditional dual systems.

As a whole, the book provides a comprehensive and up-to-date overview of major approaches to the neuroscience of risky decision making. The authors summarize cutting-edge research on the neuroeconomic, neurodevelopmental, and neuropsychological factors that explain and predict risky decision making. Diverse findings from structural and functional neuroimaging, as well as behavioral and neurophysiological studies, on populations ranging from young children to old age, are integrated to provide a scientific framework for understanding causal mechanisms underlying risky decision making across the life span. This work has important implications not only for reconceptualizing and reforming the next phase of research on the neuroscience of risky decision making but also for informing practice and policy in law, medicine, and public health.