Emotion and Decision Making:
Online Supplement

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Table of Contents

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S-I. BRIEF PRIMER ON EMOTION

Overview. The field of emotion research is still in its infancy. In terms of Thomas Kuhn's (1962) approach to scientific revolutions, it has yet to become a "normal science" with established paradigms. It instead features sparring theories, each trying to best represent the true nature of emotion. Even the question posed in the title of William James' (1884) essay "What is an Emotion?" still sparks debate today (see Keltner & Lerner 2010, Russell & Barrett 1999). It is not surprising, then, that within the JDM literature, specifically, researchers have labeled a wide variety of mental states as "emotional": from fleeting, momentary reactions (e.g., Todorov et al 2007) to protracted, durable moods that last a lifetime (e.g., Lerner & Keltner 2001); from states characterized solely by subjective feelings to those characterized by complex coordination of physiological, hormonal, and expressive activity (e.g., Bechara et al 1997, Chapman et al 2009, Kassam et al 2009); and from evaluations that involve simple positive and negative associations to those that involve more complex affective relationships (for review, see Loewenstein & Lerner 2003). Although a full understanding of these relationships is not needed to study the impact of emotion on JDM, it is nonetheless useful to mention two theoretical questions that can contextualize this review within the current state of emotion research: 1) How are emotion and cognition related? 2) What is the consensual model for the universe of emotions (discrete versus dimensional)?

How are emotion and cognition related? The interplay of emotion and cognition has been debated for centuries (Descartes 1649, Descartes 1989). Notable scholars have long contributed to it. For example, in *The Expression of Emotion in Man and Animals*, Charles Darwin described an attempt to determine whether his cognitive awareness that a piece of glass prevented a snake from striking could override the emotional response of fear:

> I put my face close to the thick glass-plate in front of a puff-adder in the Zoological Gardens, with the determination of not starting back if the snake struck at me; but, as soon as the blow was struck, my resolution went for nothing, and I jumped a yard or two backwards with astonishing rapidity. My will and reason were powerless against the imagination of a danger which had never been experienced (1872/1998, p. 38).

Darwin captures two crucial elements of the relationship between cognition and emotion with which researchers have been concerned: the separability of cognition and emotion and the notion of "affective primacy." Though largely ignored through the eras of behaviorism and the cognitive revolution (see Simon 1967, for a notable exception), these issues were thrust to the forefront of psychology in the 1980s due in large part to Robert Zajonc (1980, 1984). He proposed that emotions operate independently, and in advance of, cognitive operations, an idea that has since accumulated empirical support (Bargh 1984, Clore 1992, Kuhnen & Knutson 2005, LeDoux 1996, Murphy & Zajonc 1993). Some emotion processes, at least in primitive form at the stage of elicitation, can precede and even diverge from cognitive assessments; emotions need not depend on cognitions. For example, recent neuroscience studies have shown that certain emotional circuits in the brain send faster (sub-cortical) signals than do circuits that involve the cortex (for review, see Phelps et al in press). Such evidence, along with related lines of work, have contributed to the conclusion that emotion is not epiphenomenal and can influence cognition and behavior in powerful ways (for reviews, see Damasio 1994, Loewenstein 1996, Loewenstein et al 2001, Phelps 2006, Rozin et al 2008).

At the same time, cognitive processes can also shape emotion (e.g., Folkman et al 1986, Roseman 2001, Scherer et al 2001, Smith & Ellsworth 1985), and the past few decades of neuroscience research have revealed a complex interplay between the two processes (Kassam et al 2013, Phelps 2006). Few would now dispute that emotion and cognition are intertwined, and many theories model them as such (Bechara et al 1999, Beer et al 2006, Izard 1992, Phelps et al in press, Schachter 1964). Contrary to the view that a "limbic system" serves as the set of pathways for emotion, it is now believed that emotion and cognition are not separate systems, *per se*; they interact continuously even if an emotion-based signal arrives milliseconds sooner.

How should emotion be modeled? Much debate remains about the processes generating emotion and the implications these processes have for appropriate models. Researchers generally fall into one of two camps (for reviews, see Barrett 2006, Barrett et al 2007b, Ekman 1992, Ekman & Davidson 1994, Izard 2007, Lindquist 2013, Panksepp 2007b). Basic emotion theorists suggest that specific emotion programs are given to us by nature—that disgust, for example, is a coordinated set of responses shaped over millennia by natural selection. They find evidence in the universality of emotional responses across cultures (Darwin 1998, Ekman 1993) and in analogous or homologous responses in non-human primates and other mammals (Panksepp 2007a). Constructionists, on the other hand, argue that language, culture, and conceptual knowledge shape our emotional responses—that simple components of emotion such as valence (i.e., simple positivity or negativity) may represent hardwired reactions, but more complex aspects of emotional response are learned, involve non-emotional processes, and are heavily dependent on the contextual factors. They point to shortcomings in the research on universality and analogy, the sometimes absent correlation between various aspects of emotional response in published studies (e.g., subjective feelings and physiological response), and research suggesting culture and language shape emotional response (Barrett 2006, Barrett et al 2007a, Lindquist & Gendron 2013). In many respects, this is a nature-versus-nurture debate. No one doubts that we have evolved some capacity for emotional response or that learning or cognitive schema can serve to shape that response. Instead, the question is whether culture, learning, and language play a relatively minor role in complex emotional responses (basic emotion theory) or a substantial one (constructionist theory).

Each emotion-generation theory has been linked to a corresponding model. Such models suggest a relationship between the components of emotional response—subjective feeling states; facial, vocal, and bodily expressions; hormonal and physiological responses; cognitive processing changes; and *action tendencies* (for more detail, see below). Basic emotion theories favor a discrete emotion model (e.g., Ekman 1992) characterizing states as clusters of responses in these channels. Constructionist theories favor dimensional models, where states are characterized predominantly by values along continuums such as valence (negative to positive) and arousal (lethargic to energized). According to such models, feelings of negativity/positivity or lethargy/energy are more closely tied to expression, bodily response, and cognitive-processing changes. More complex emotional states (such as anger) stem from a combination of valence and arousal together with non-emotional processes (e.g., conceptual knowledge about the situation at hand; Lindquist 2013).

Beyond theoretical debates, we emphasize that both discrete and dimensional frameworks are merely *models*, offering different descriptions of the same underlying phenomena while emphasizing different aspects. Neither model is expected to be perfectly represented in the underlying emotion-generation process: There is little evidence that the brain contains circuits dedicated solely to the generation of discrete emotional states such as anger (Kassam et al 2013, Lindquist et al 2012), and it is similarly unlikely that valence and arousal are the only bottom-up influences responsible for differences in emotional response (Panksepp 2007a).

Of importance for models of JDM, discrete and dimensional models of emotion differ in terms of their number of parameters. Dimensional models typically require two parameters: valence and arousal. Discrete models require values for each discrete emotion, but generally agree that six dimensions best define the patterns of cognitive appraisal underlying discrete emotions: certainty, pleasantness, attentional activity, control, anticipated effort, and self-other responsibility (for review, see Smith & Ellsworth 1985). At the same time, some cognitive-appraisal theorists have argued that each emotion is best defined by one or two dimensions that characterize its core meaning or theme (Lazarus 1991, Smith & Ellsworth 1985). For example, certainty, control, and responsibility are the central dimensions that distinguish anger from other negative emotions. Anger arises from appraisals of (a) other-responsibility for negative events, (b) individual control, and (c) a sense of certainty about what happened (Averill 1983, Betancourt & Blair 1992, Smith & Ellsworth 1985, Weiner et al 1982). Notably, as mentioned above, emotions may arise in other ways, including relatively non-cognitive methods, such as bodily feedback or unconscious priming (for review, see Keltner & Lerner 2010). In these cases, appraisals do not play a causal role in generating the emotion; nonetheless, the corresponding appraisals will ultimately be experienced as influencing subsequent choices and judgments. Thus, fully experiencing a discrete emotion may also mean experiencing the cognitive appraisals that comprise that emotional state (Clore 1994, Frijda 1994, Lazarus 1994).

With additional degrees of freedom, discrete models are able to account for more patterns of response than dimensional models can. For example, research has found that discrete emotional states characterized by similar valence and arousal levels have divergent effects on risk perception (Lerner & Keltner 2001) and a variety of other outcomes, reviewed in Section V of this paper. More generally, the ideal emotion model will depend on the domain of inquiry. Studies of facial expression have traditionally employed discrete models (Ekman 1993), whereas physiological responses to emotional stimuli have more typically employed dimensional models (Larsen et al 2008). The best model for decision-making domains will likewise depend on the particular decision-making context.

S-II. BRIEF PRIMER ON JUDGMENT AND DECISION MAKING

Overview. The study of JDM has a long, multi-disciplinary history. This primer focuses on individual judgments and decisions (for more on interpersonal contexts, see Camerer 2003).

JDM research is generally characterized by efforts to compare how people actually make judgments and decisions with normative standards from probability and decision theory of how people ideally should make judgments and decisions. Much as vision scientists study optical illusions to understand the visual system, this approach focuses on systematic deviations—that is, where judgments and decisions are inaccurate, inconsistent, or otherwise suboptimal. These deviations provide insight into underlying processes, leading to more accurate descriptive models. Indeed, the field can be summed up as an attempt to develop models that blend descriptive reality and normative precision. Here, we present three topics in which this paradigm has devoted considerable attention and in which emotion effects are now actively investigated.

Topic: judgment processes. Systematic study of human judgment is exemplified in the influential heuristics-and-biases program of research pioneered by Tversky and Kahneman (for review, see Gilovich et al 2002). Biases, or systematic deviations from normative standards, are used to identify the heuristics—simple rules-of-thumb or shortcuts—underlying JDM. Initial work focused on probability judgments. For example, in the "Linda problem" (Tversky & Kahneman 1983), participants read a description of Linda, including that "she was deeply concerned with issues of discrimination and social justice" as a college student. Thereafter, participants judged Linda as more likely to be "a bank teller and active feminist" than simply "a bank teller." Yet, a compound probability (A and B) cannot be more probable than a simple probability (A). This error identifies the *representativeness* heuristic, whereby people use similarity to judge probability rather than integrating information normatively (using Bayesian standards). The availability, representativeness, and anchoring heuristics (Tversky & Kahneman 1974) launched a paradigm that has since spread far beyond probability judgments (for review, see Gigerenzer et al 1999, Shah & Oppenheimer 2008).

One potential consequence of using heuristics is that they tend to produce *overconfident* judgments. For example, when Alpert and Raiffa (1982) asked people to generate 98% confidence intervals for quantities such as the length of the Amazon River, the intervals only included the true value 60% of the time. One explanation is that people anchor on what they believe to be the true value and adjust the endpoints of the interval insufficiently. More generally, although heuristics are generally thought to make a tradeoff between effort and accuracy (Payne et al 1993, Shah & Oppenheimer 2008), using heuristics can produce efficient yet accurate judgments depending on the structure of the environment (Gigerenzer & Gaissmaier 2011).

Topic: decision making under risk. Most JDM research on decision making focuses on deviations from expected utility (EU) theory, a normative model of decision making under risk and uncertainty (Savage 1954, Von Neumann & Morgenstern 1947), a number of deviations soon surfaced (e.g., Allais 1953, Edwards 1954, Ellsberg 1961). Psychologists Kahneman and

Tversky (1979) famously summarized these issues and proposed an alternative descriptive model of risky decision making: "prospect theory." The article is the most cited in all of economics.

Prospect theory is comprised of two parts: a value function and a probability weighting function. The value function describes how objective values (e.g., money) are subjectively perceived and identifies three deviations from EU. First, EU assumes that utility is defined over final wealth states (e.g., a $100 coin flip for someone with $1,000 of wealth is evaluated as 50% chance at $1,100 and 50% chance at $900). Instead, prospect theory's value function exhibits *reference dependence*—utility is defined as changes in wealth relative to a *reference point*. Second, whereas in EU, the positive utility from a gain (e.g., $100) is weighed the same as the negative utility from a loss of the same amount, prospect theory's value function allows for *loss aversion*—a tendency to weigh losses more heavily than gains. Finally, whereas EU generally assumes that people are either risk-averse or risk-seeking, prospect theory allows for both: people are risk-averse in gains and risk-seeking in losses.

Prospect theory's probability weighting function describes how probabilities are distorted relative to objective levels: people overweigh small probabilities, underweigh large probabilities, and are relatively insensitive to differences in moderate probabilities. For example, the difference between 0% and 1% or 99% and 100% seems large in comparison to the difference between 33% and 34%. Combining these two functions, prospect theory explains a "fourfold pattern of risk attitudes," including anomalies such as why people pay a premium to gamble on long shots (i.e., risk-seeking for low-probability gains) yet pay a premium for insurance (i.e., risk-averse for low-probability losses).

One implication of prospect theory is possible inconsistencies arising from framing effects. For example, in the "Asian disease problem" (Tversky & Kahneman 1981), people evaluated treatment programs for a disease expected to kill 600 people. People mostly prefer a program that saves 200 lives for sure over one with a "one-thirds probability that 600 people will be saved and a two-thirds probability that no people will be saved." They also prefer a program that has a "one-third probability that nobody will die and a two-thirds probability that 600 people will die" over one where 400 people will die for sure. Although these two choices are objectively identical, people in the "die" frame are more likely to reason in terms of losses than people in the "lives saved" frame. Framing outcomes as gains versus losses may also explain the *endowment effect* (Kahneman et al 1991), whereby sellers value objects more than buyers do, perhaps because sellers think of the sale as a loss of ownership. Similarly, whether someone paid for basketball tickets or received them as a gift should not affect whether she attends the game during a snowstorm, yet it does, perhaps because paying for tickets is framed as a loss. As this example shows, people exhibit the *sunk cost* effect, becoming more likely to continue with an action after making an investment of money, time, or effort (Arkes & Blumer 1985).

Topic: intertemporal choice. Just as EU became the de facto economic model of risky choice, the discounted-utility (DU; Samuelson 1937) model dominated early economic thinking on intertemporal choice—decisions involving alternatives whose costs and benefits occur at different times. JDM researchers have similarly documented a number of descriptive shortcomings for DU and its axioms. For example, discount rates—how much less future utility is worth relative to today—are inconsistent across time. DU requires a delay of 1 month to discount the utility of an outcome by the same degree whether that 1 month is a delay from today to next month or from 12 to 13 months, and for the total discounting over one year to be equivalent to the degree of discounting over 1 month compounded 12 times. To demonstrate inconsistent discount rates, Thaler (1981) asked participants how much they would require in 1 month, 1 year, and 10 years to make them indifferent to receiving $15 today. The median responses of $20, $50, and $100 suggest discount rates of 345%, 120%, and 19%, respectively. A number of descriptive models have been proposed to account for this phenomenon of high discount rates for short delays and lower discount rates for longer delays, commonly referred to as present bias or hyperbolic discounting (e.g., Ainslie 1975, Laibson 1997, O'Donoghue & Rabin 1999). Other systematic anomalies such as the magnitude (less discounting for larger amounts), sign (less discounting for losses than gains), and direction (less discounting to decrease than to increase delays) effects required further relaxations of DU's assumptions (Frederick et al 2002, Loewenstein & Prelec 1992).

Summary. More than half a century of JDM research has catalogued numerous empirical "anomalies" in judgments and decisions. Identifying these deviations from normative models has led to the development of more descriptively accurate models. By clarifying JDM processes, the field—often paradoxically referred to as behavioral economics despite the fact that many of its founders (e.g., Kahneman, Tversky, Edwards, Dawes) were psychologists—has built a foundation for more effective research and application in a wide array of fields, including political science, finance, law, and medicine.

S-III. HISTORY OF RESEARCH ON EMOTION AND DECISION MAKING

Across disciplines ranging from philosophy (Solomon 1993) to neuroscience (e.g., Phelps et al in press), a vigorous quest to identify the effects of emotion on judgment and decision making (JDM) is in progress. In some disciplines, this quest dates to ancient times. Aristotle first described the tendency for anger to influence behavior in a global, undiscerning way (*Nicomachean Ethics*). In other fields, research in emotion and JDM has a much shorter history.

Economics, the historically dominant academic discipline for research on decision theory, offers an interesting case. Two hundred and fifty years ago, Adam Smith (1759) highlighted the power of emotion to bias decisions (see Bentham 1879, Jevons 1871 for other early treatments of emotion in economic theories), much of modern economics overlooked this aspect of Smith's writing, with a few notable exceptions (e.g., Elster 1998, Loewenstein 1996, Loewenstein 2000). But its wisdom has resurfaced in light of several developments, including (a) breakthroughs in the methodology for studying emotion (for review, see Keltner & Lerner 2010, Phelps et al in press); (b) solid evidence that emotion drives economic behavior (for review, see Rick & Loewenstein 2008); and (c) the failure of rational choice models to predict or explain the worldwide economic crisis that began in 2008. In the wake of the crisis, Paul Krugman, 2008 Nobel Laureate in economics, argued that neoclassical economic theory and its elegant mathematical models had experienced a devastating failure (Krugman 2009, September 2).

Indeed, Alan Greenspan, chairman of the U.S. Federal Reserve from 1987 to 2006, admitted that he was in a state of "*shocked* disbelief" because "the whole intellectual edifice" had "collapsed" (Andrews 2008, October 24). It should be noted, however, that at least one leading macroeconomist was not shocked. Nobel Laureate Robert Shiller predicted the housing market crash and that it would do so because of "irrational exuberance"—an emotional phenomenon (Shiller 2005).

In psychology, a causal role for emotion in decision making also hardly ever appeared, and this, too, held for most of the 20th century. Even the behavioral decision researchers' early critiques of rational decision models in economics primarily focused on identifying cognitive processes. Moreover, for most of the 20th century, research examining emotion in *all* fields of psychology was scant (for a review, see Gilovich & Griffin 2010). As far as the psychology literature went, one almost needed to go back to Freud to find theoretical bases for emotion in decision making.

Undoubtedly, many factors contributed to this dearth of research on emotion and decision making. One factor was the dominance of behaviorism in psychology from approximately 1940 to 1975. B. F. Skinner, behaviorism's greatest champion, actively discouraged research on emotion: "The 'emotions' are excellent examples of the fictional causes to which we commonly attribute behavior (1953, p. 160)." Therefore, "The safest practice is to hold the adjectival form…by describing behavior as fearful, affectionate, timid, and so on, we are not led to look for *things* called emotions" (pp. 162-3). Skinner treated emotions as merely unscientific, shorthand ways of characterizing behavior; observable behavior was all that mattered for scientific theory, not mental states (Cunningham 2000). When Skinner retired in 1974, peer-reviewed journals contained essentially no studies of emotion and cognition.

Perhaps as equally important as the behaviorist era in delaying the dawn of modern emotion research was the subsequent counter-revolution to behaviorism, termed the "cognitive revolution." Cognitive science emerged in the 1970s, systematically inserting the concept of *cognition* between behaviorism's famous stimulus-response pairing. As much as early years of the cognitive revolution illuminated the role of cognition (see Miller 2003, Simon et al 2008), it obscured the role of emotion.

But "when the 'cognitive revolution' ebbed, there was a rapid and pronounced return to the study of emotion" (Gilovich & Griffin 2010, p. 559). Since approximately 1980, research in decision making has begun to increasingly incorporate affective factors. Figure 1 in the main paper (repeated below for convenience) displays the results of Google Scholar searches for scholarly publications using the exact terms "[emotion(s)/affect/mood] and decision making," from 1970 to the present. The data reveal that the field is young and growing tremendously; yearly works on emotion and decision making doubled from 2004 to 2007 and again from 2007 to 2011, and increased by an order of magnitude as a percentage of all scholarly publications on "decision making" (already a quickly growing field) from 2001 to 2013.

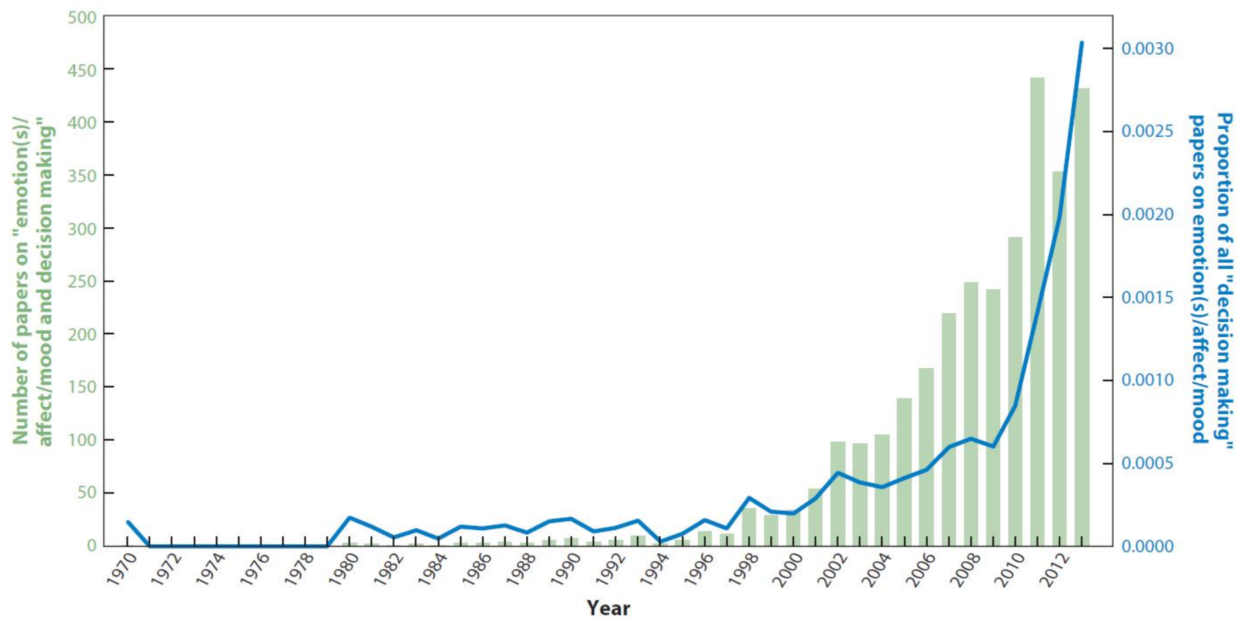

Figure 1

Number of scholarly publications from 1970 to 2013 that refer to "emotion(s)/affect/mood and decision making" (*green bars*) and proportion of all scholarly publications referring to "decision making" that this number represents (*blue line*).

Unsurprisingly, this relatively young subfield is only just beginning to grapple with fundamental questions about emotion and decision making. To provide the reader with a context for interpreting these discoveries, we present two brief primers, one on key concepts in the field of emotion and one on key concepts in the field of judgment and decision making.

S-IV. ADDITIONAL DEFINITIONS LIST

Rationality: accuracy and consistency of expressed beliefs as well as the degree to which choice reflects utility maximization

Heuristic: Mental shortcut that generally allows quick and efficient JDM but can lead to bias under certain situations

Bias: Systematic deviation from rational JDM

Prospect Theory: Risky choice model that allows for reference-dependence, loss aversion, risk-aversion for gains and risk-seeking for losses, and distortions of probability

Frame: Mental representation of a decision; the same decision can be perceived, structured, or interpreted differently, for example, by shifting reference points.

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