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Sources of Variation within the Individual

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Abstract

This chapter reviews sources of variation in decision making and choice that arise within the individual, and discusses the possible significance of such variation for the development of an evolutionarily plausible account of decision making. Different sources of within-individual variation are reviewed, including noise, general cognitive ability and life span changes, mood, and personality.

The approaches taken by economics, cognitive psychology, and the psychology of personality and individual differences are compared to and contrasted with ecological and evolutionary approaches. It is argued that sampling models may provide a unified cognitive approach to within- and between-individual variation in human judgment and decision making, albeit one that has yet to be linked sufficiently to ecological and evolutionary approaches.

Introduction

Our focus in this chapter is on sources of variation *within* the individual and on the possible significance of such variation for an evolutionarily plausible account of decision making. We therefore enumerate different sources of within-individual variation, focusing mainly on the human literature, in each case noting adaptive approaches where available. Our discussion contrasts with much work on human personality and individual differences, and in some parts of economics, which have focused on (assumed stable) *between*-individual sources of behavioral variation.

First we map out the different approaches to within-individual behavioral variation, and its relation to between-individual variation, which have developed largely independently in literatures that have concerned themselves with (a) the psychology of human personality and individual differences, (b) the cognitive psychology of judgment and decision making, (c) neoclassical economics, and

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(d) evolutionary and ecological approaches in nonhuman animals. Much of the research is described in more detail under separate headings below.

The study of human personality has focused for half a century on identifying stable characteristics of individuals that capture systematic differences in people's "average" behavior (e.g., whether they are extraverted, conscientious, etc.) across different social situations. Thus the focus has generally been on between-individual rather than within-individual variation, with the long-standing person-situation debate concerning whether behavior is better predicted by personality or by the environment (Epstein 1979; Funder and Ozer 1983; Mischel 1968). Only relatively recently has research into human personality begun to examine within-individual variation in behavioral reactivity (Fleeson 2001, 2004; Sheldon et al. 1997).

Evolutionary and ecological approaches to studying human personality have differed greatly to how psychology has treated the subject. Integration of the across-individual human and animal literature is therefore difficult, although a start is being made (e.g., Nettle and Penke 2010). The concept of personality as applied to nonhuman animals is relatively recent (Dall et al. 2004; Nettle and Penke 2010) and more grounded in behavior (for a review, see Dingemanse and Wolf, this volume). In contrast to the human personality literature, ecological approaches have moved rapidly toward developing adaptive accounts of between-individual variation in behavior (e.g., Dingemanse and Wolf 2010a; McNamara et al. 2009). Moreover, evolutionary approaches have begun to emphasize the importance of providing an integrated and adaptive account of both within- and between-individual behavioral variation ("personality and plasticity"), emphasizing the fact that the two sources of variation can be considered as complementary aspects of a phenotype (Dingemanse et al. 2010b; Nussey et al. 2007) and demonstrating that behavioral patterns evolve in population environments in which natural selection favors them (e.g., Dingemanse et al. 2007).

Until relatively recently, economics and cognitive psychology have taken different approaches to variation in decision making. Within one tradition of neoclassical microeconomics, normative models of decision making—and many of the descriptive accounts derived from them—focus typically on between-individual differences in risk aversion, temporal discounting, etc. Such characteristics and preferences have traditionally been assumed to be stable, although subject to noise. Normative accounts, however, do allow for within-individual variation over time and as a function both of the environment and in response to the strategic choices—and unpredictability—of other players. Furthermore, much of behavioral economics and consumer psychology has focused on the construction of preferences (e.g., Lichtenstein and Slovic 2006; Plott 1996; Prelec et al. 1997; Simonson 2008), while experimental economists have extensively examined variation that arises from interactive decision making and its development over time (e.g., Duffy and Nagel 1997; Selten and Stoecker 1986).

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Cognitive psychological models of judgment and decision making have, in contrast, taken a central explanandum to be the effects of context on decision making; they have asked, for example, how the introduction of additional options to a choice set can influence the option that is preferred or chosen, and how apparent anomalies and inconsistencies arise. Thus a key focus in psychology has been the effects of situational (and hence within-individual) variation, rather than across-individual variation or variation arising from strategic interactions, on decision making. Many similar issues, especially concerning preference reversals, are addressed by behavioral economics.

Below we review sources of within-individual variation, consider the implications of such variation for adaptive accounts, and suggest that sampling-based accounts may have the potential to offer a more ecologically plausible account of individual variation and decision making across contexts than current models.

Sources of Within-Individual Variation: Importance to Evolutionary Approaches

Why is within-individual variation interesting for an evolutionary plausible model of decision making? Any such account must explain the systematic ways in which choices and decisions are determined by the context of choice options available. A notable weakness of narrow neoclassical accounts, which assume that individual preferences are (within limits) stable and consistent across different times and contexts, is their inability to account for such apparent inconsistencies. We argue below that sampling-based accounts, based on very simple processing principles, may offer better models. It is at least plausible that an evolutionary foundation may be provided for such accounts, although this remains a neglected area.

There are, however, more general considerations. Following the development of evolutionary game theory (Maynard Smith and Price 1973; Maynard Smith 1982), it has been clear that, due to frequency-dependent selection, an evolutionarily stable strategy (ESS) may involve the simultaneous presence of different decision-making personalities within a population. Recent work has examined how the existence of variation in decision making might foster the evolution of cooperation within social networks (e.g., Lotem et al. 1999; McNamara et al. 2004). However, the coexistence of different decision-making styles or personalities at a given time could involve a mixed strategy (e.g., an individual could behave in an extraverted fashion for 65% of the time, perhaps to facilitate exploration and development of social relationships, and behave in a non-extraverted fashion the remaining 35% of the time, to reduce risk), such that stable individual differences did not exist. Alternatively, the ESS could involve 65% consistent extraverts and 35% consistent non-extraverts. Consistency can be selected for when reputation matters and personality is publicly observable (Nowak and Sigmund 1998). Thus, at a global level, it

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may be better to be consistently rather than inconsistently aggressive, effectively because of reputational considerations: individuals who are consistently hawkish in their behavior may avoid conflicts if their "personality" is publicly known. A different tradition of research within experimental economics, as noted above, focuses on how players of strategic games learn how to defect or cooperate in different contexts (i.e., to respond strategically to produce best responses).

Stability could arise for other reasons. Lukaszewski and Roney (2011) suggest that extraverted behavioral strategies are more likely to be successful when associated with physical strength and attractiveness. Consistent with their expectations, they found that physical strength and attractiveness accounted for much of the variance in extraversion. Such considerations, therefore, lead to an expectation of within-individual stability in general decision-making style. Nonetheless, as will be shown below, within-individual variation in both personality and decision making can arise from a number of sources, and such variation remains a key target of models.

Sources of Within-Individual Variation

We now turn to a review of within-individual variation that arises as a result of noise, general cognitive ability and life span changes, mood, and personality. We then argue that sampling models may provide a unified cognitive approach, albeit one that has yet to be linked sufficiently to the ecological and evolutionary approaches noted above. To make the review manageable, we confine ourselves predominantly to internal sources of variability. Of course, variability may also result from noisy environments and in response to the behavior and payoffs of other agents, but we largely pass over these exogenous sources of variability.

Within-Individual Variation Due to Noise

Let us first consider noise and inconsistency in risky choice. An individual may choose option *A* over option *B* at time 1, yet choose *B* over *A* at time 2 because of the noise within the decision-making system (Hey and Orme 1994). Choice reversals may occur on around 25% of choices, depending on context. Insofar as higher general cognitive ability is associated with greater consistency in risky choice and discounting (Burks et al. 2009), it seems unlikely that this particular type of within-individual noise-related inconsistency serves a direct adaptive function. Other types of noise and probabalistic strategy may well, however, be adaptive, as reviewed below.

The operation of a stochastic component has been examined extensively within models of economic choice between risky prospects (e.g., Blavatskyy and Pogrebna 2010; Blavatskyy 2011; Loomes 2005; Loomes and Sugden

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1995). Models that are derived from an economic framework can incorporate a stochastic element in a number of ways. One possibility is that the utility of the two choice outcomes is calculated according to a standard framework, and that noise is then added to the resulting utilities (or perhaps to the difference between them). Such noise can result in violations of normative axioms. An alternative idea is that noise is added to model parameters (e.g., the curvature of the utility function) on each occasion that utility is calculated. In this case, the calculated utilities (and hence choices) may differ from one occasion to the next, but violation of axioms will not result. The choice of stochastic decision rule is important: Blavatskyy and Pogrebna (2010) distinguish seven different possible probabilistic accounts and, by combining these with various decision-making models, find that the rank ordering of model architectures in terms of their fit to the data can change as a result. Thus models of decision making cannot be evaluated independently of the account of noise they assume.

Sampling models of decision making provides another approach to within-individual variation in judgment and decision making more generally. For example, Vul and Pashler (2008) find that successive estimates of a quantity may have uncorrelated errors, such that the average of the two estimates is more accurate than either of them individually (the "crowd within"). Such effects fit naturally with an account in which a new mental sample is drawn from a remembered distribution on each occasion that an estimate is made, with successive estimates differing because they are made on the basis of different mental samples on each occasion (see also Stewart et al. 2006).

To what extent is the existence of noise in decision making relevant to the development of evolutionary-based models of decision making? We have already noted that variability may play a role in the evolution of systems, including cooperation. Some mathematical models of evolution accord a role to randomness as a part of development of successful strategies. Thus, in the prisoner's dilemma and other games, probabilistic versions of *win–stay, lose–shift* strategies can outperform other versions by taking advantage of unconditional cooperators (Nowak and Highfield 2011). More generally, unpredictability is crucial to the successful play of many predator-prey models. Noise is central to the concept of *trembling hand equilibrium* (Selten 1975) and noisy behavior (e.g., based on small-sample judgments), with the consequence that others may occasionally behave irrationally; this can provide an essential underpinning to the development of rational strategies (Aumann and Sorin 1989). Kareev (this volume) ably reviews a number of relevant strands of evidence, which will not be repeated here.

Within-Individual Variation Due to General Cognitive Ability and Life Span Changes

Overall cognitive capacity (as indexed, e.g., by measures of working memory capacity or general intelligence) has a substantial impact on individual

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decision making. To the extent that cognitive capacity changes within an individual, either because of distraction (divided attention), lack of energy (e.g., due to sleep deprivation or hunger), or during cognitive development, we would expect consequent within-individual variation in decision making. Such variation is indeed observed empirically in all these cases. For example, changing glucose levels lead to changes in human decision making—higher glucose levels lead to reduced temporal discounting (Wang and Dvorak 2010)—and mental fatigue has been linked to a "jumping to conclusions" style of reasoning (Webster et al. 1996).

Research on the effects on decision making of within-individual variation in general cognitive ability relies on the much larger body of between-individual variation, so we note the latter first. Across individuals, higher levels of general intelligence are associated with reduced use of heuristic strategies in reasoning (Stanovich and West 2000). In terms of specific decision making, Burks et al. (2009) find higher cognitive ability to be associated with reduced temporal discounting, higher social awareness, better prediction of others' first choices in a prisoner's dilemma game, superior planning, and greater risk seeking for gambles where the expected gain is positive. Reduced working memory capacity is associated with specific types of reasoning. For example, within the economics literature, memory limitations have been invoked to explain why agents might rationally select apparently dominated strategies (Bernheim and Thomadsen 2005), to understand the effects of price competition (Chen et al. 2010), the forgetting of past costs (Smith 2009), and the optimal way for rational agents to release information (Sarafidis 2007). Stevens et al. (2011) shows how imperfect memory for other players' actions can lead to biased strategy selection in repeated games, and Kareev (1995a and this volume) reviews evidence for adaptive roles of cognitive limitations.

The importance of working memory and sampling in judgment and decision making is addressed by various models (Fiedler and Juslin 2005). Judgments of likelihood have been explained within the framework of the MINERVA-DM memory model (Dougherty et al. 1999), and working memory capacity limitations have been linked to biased probability judgments (Dougherty and Sprenger 2006) and hypothesis testing (Sprenger and Dougherty 2006).

We would expect, therefore, that within-individual variation in general cognitive capacity would result in changes in decision making. Such variation is indeed seen as a result of cognitive aging and the concomitant reduction in cognitive ability. Thus aging is generally associated with increased risk aversion (cf. Deakin et al. 2004; Sanfey and Hastie 1999) and larger offers in dictator games (Bosch-Domenech et al. 2010). Temporal discounting is reduced in older adults (Read and Read 2004; Reimers et al. 2009), whereas loss aversion is increased (Johnson et al. 2006). As yet there is relatively little research on how reduction of cognitive capacity by distraction or fatigue influences such parameters as risk aversion, although this is a growing area (e.g., Hockey et al. 2000).

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In summary: There is clear evidence of within-individual variation in decision making over the life span, and there is well-documented within-individual change in memory capacity and general intelligence, both of which impact on decision making. Mata et al. (2007) found that older adults used simpler decision-making strategies with reduced cognitive requirements, but argued that aging did not reduce the adaptiveness of decision making. However, there is little conclusive research on evolutionary accounts of this source of within-individual variation.

Within-Individual Variation Due to Mood

In contrast to general cognitive ability, and in partial contrast to personality (discussed below), strong within-individual variations in mood are part of common experience. Here, we confine ourselves to the human literature, while noting behavioral research on nonhuman animals that adopt a similar perspective. For example, behavior consistent with a "pessimistic cognitive bias" appears even in invertebrates: stimulus categorization by honeybees appears more pessimistic (i.e., an ambiguous stimulus is more likely to be perceived as predicting punishment) when the bees are, literally, agitated (Bateson et al. 2011).

Are within-individual mood variations related to variations in decision making, and can such variations inform evolutionary models of decision making? As Hermalin and Isen (2008) note, effects of mood have not yet generally been incorporated into economic models of human decision making, and there is a need to do so. There are strong effects of mood on decision making (Werner et al. 2009). For example, a considerable body of research conducted by Isen and colleagues has examined the effect of positive mood on reasoning and decision-making style. Positive affect generally enhances decision making (Isen 2001; Isen and Means 1983; Isen and Patrick 1983), perhaps because increased dopamine levels enhance cognitive flexibility (Ashby et al. 1999). In evaluations of gambles, positive affect has been associated with a shift in attention toward outcomes rather than probabilities (Nygren et al. 1996), and with increased confirmation bias in a selection task (Oaksford et al. 1996).

There has been little in the way of evolutionary models of mood shifts within human individuals, although Nettle (2009) develops a model according to which low mood states can lead to either risk seeking or risk avoidance according to the severity of the situation, such that mood states may adaptively adjust risk-taking propensity in response to environmental circumstances (for nonhuman animals, see Dingemanse et al. 2010b).

Given that mood appears to show substantial within-individual variation, with consequences for decision-making style, we identify a need for more research to develop theoretical accounts of the adaptive significance of mood shifts.

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Within-Individual Variation Due to Personality

To what extent does within-individual variation in personality exist, and are the data of relevance to evolutionary models of decision making? We begin with research on between-individual variation. The idea that a small number of basic traits characterize individuals and their decision making has a long history, going back at least to Galen (129–200 AD) and the description of humans as phlegmatic, choleric, etc. Modern theories of human personality have made use of statistical advances to go beyond intuitive classification, converging on the "Big 5" personality factors (extraversion, neuroticism, agreeableness, openness, and conscientiousness), each with their own subcomponents (facets) as a stable, culturally generalizable, and reliable descriptive characterization of human personality (e.g., Goldberg 1993; McCrae and Costa 1987). The Big 5 has recently begun to be used as behavioral predictors and linked to specific components of decision making. Thus, Roberts et al. (2007) argue that individual differences in human personality predict important life outcomes (e.g., mortality, divorce, and career success) as well as or better than do socioeconomic and cognitive variables.

However, if the study of within-individual variation in human personality is to inform models of decision making, we need to know how personality characteristics relate to decision-making style. Behavioral economists have recently begun to use the techniques and methods of experimental economics to examine decision making and human personality. Of particular interest is the interaction between personality variables and economic variables (Borghans et al. 2008). Early work within economics focused on questions such as the relationship between personality and economic success as measured, for example, by income (e.g., Bowles et al. 2001). More recently, alongside examinations of the role of general intellectual capacity in economic behavior (Burks et al. 2009), economists have examined the effects of personality traits, particularly agreeableness and conscientiousness, on choices in economic games (such as prisoner's dilemma, ultimatum and dictator games, and cooperation games). It has been found that general intelligence and extraversion together predict attitude to risk (Anderson et al. 2011) and that individuals scoring highly for conscientiousness gain greater additional utility from increases in income (Boyce and Wood 2011). Extraversion and agreeableness influence cooperation in resource dilemmas (Koole et al. 2001), and gratitude prompts prosocial behavior (Tsang 2006).

Overall there is now ample evidence which indicates that between-individual variation in the human personality characteristics studied by psychologists is associated with different decision-making and fitness-related life outcomes. Furthermore, as reviewed below, there are numerous evolutionary accounts of why personality variation within the population might exist, with game-theoretic influences evident since Trivers (1971), although the bulk of this research has been carried out on nonhuman animals (e.g., Dall 2004; Dall et al.

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2004; Gross 1996; Wolf and Weissing 2010). More recently, there have been the beginnings of parallel evolutionary approaches to human personality (Buss 2009; Nettle 2005, 2006; Penke et al. 2007a, b), along with consideration of the extent to which models of human personality generalize across species (e.g., Gosling and John 1999).

What of within-individual variation in personality, and the consequences of such variation for decision making? We consider a personality trait to be a consistent pattern of behaving, thinking, and feeling that can be used to predict behavior. Such definitions appear to exclude the possibility of within-individual variation in decision making. However, personality-related behaviors do vary within individuals over time and across situations, and it is possible at least to speculate on the fitness-relevance of such variation.

Specifically, recent work within personality theory has begun to move beyond the debate about whether situations or stable individual characteristics govern behavior and decision making to a focus on differences within individuals over time and across situations (Fleeson 2001, 2004). The idea is that, even though individuals can be readily identified by their "average" levels of personality, they routinely experience the full range of personality and can also be identified by the extent to which their personalities vary across situations. There are, of course, likely to be limits on such variation.

Changes in an individual psychological profile might be situation-dependent rather than time-dependent; consider, for instance, when people effectively adopt different personalities as they engage with different social worlds (e.g., with parents or with friends) or perhaps state-dependent changes as in the case of mood variation. There is clear evidence that individuals' personalities do indeed vary across the different roles they experience in life, and that there is individual variation in the extent of this differentiation (Sheldon et al. 1997). Thus the same individual may behave in an extraverted manner when they are in the company of their friends but be much more introverted in the presence of their parents, whereas another individual may exhibit much the same personality across each of these roles.

In terms of fitness, is high variation in personality and hence decision making across social roles good or bad? Although we have no direct evidence, higher levels of variation in personality across social roles has been related to lower levels of well-being (Roberts and Donahue 1994). Could we use measures of subjective well-being as a proxy for fitness? Consideration of such an assumption may be worthwhile, because human personality research has tended to look at the relation of personality (including within-individual variation in personality) to subjective measures such as well-being and life satisfaction. For example, it is striking that about 45% of the variance in overall life satisfaction can be predicted from conventional measures of personality—around ten times as much as can be predicted from measures of economic status (Howell and Howell 2008; Wood et al. 2008, 2009).

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It is well established that subjective measures of well-being are reliable and valid in the sense that they are predictable (i.e., not just noise) and correlated with others' ratings, with "objective measures" (e.g., frequency of laughing and smiling), and with nonsubjective economic measures of quality of life (Layard 2005; Oswald and Wu 2010). Such findings, however, do not in themselves legitimate the approach of using well-being measures as a proxy for fitness.

Standing in favor of such an approach is the observation that measures of subjective well-being predict a large number of fitness-related outcomes. Subjective well-being is related to factors such as longevity (Diener and Chan 2011), heart disease, and strokes (Sales and House 1971) as well as wound healing, susceptibility to infection, and recovery time (Cohen et al. 2003). There is evidence that happiness leads to marriage as well as the reverse (Stutzer and Frey 2006). The correlation between an individual's income and their life satisfaction that is reliably observed within a country at a given time appears to be due not to the income per se but rather to the ranked position of that income within society (Boyce et al. 2010a). Overall, then, there is some plausibility to the suggestion that subjective well-being might in some circumstances be usable as a proxy for fitness.

However, there are also considerable difficulties with the idea that high subjective well-being is necessarily associated with fitness-maximizing decision-making personalities. The fact that particular personality traits are associated with systematically higher self-rated happiness (DeNeve and Cooper 1998) argues against the idea that different personalities and their associated different decision-making strategies represent different ways to achieve similar fitness outcomes. Furthermore, affective forecasting errors, such that people are wrong about what will make them happy, abound. For example, people think that having children will make them happier but, in fact, the reverse is the case. A plausible ecological account of affective forecasting errors, in general, may be possible—we overestimate how unhappy disablement will make us, or how happy we will be if we win the lottery. Given that we like to be happy, our erroneous forecasts will motivate us to avoid disablement and strive for large amounts of money—reasonably interpretable as fitness-directed motivations. When such states are imposed or attained, however, we adapt, perhaps because there is no longer any evolutionary advantage to feeling happy or unhappy about things that cannot be changed. It is clear, then (and even limited experience of the world surely suffices to confirm), that our happiness is not in itself something that will necessarily be maximized through evolutionary processes. Thus the use of well-being measures as a proxy for fitness seems risky at best.

A final consideration concerns the intuition from biology that, if different decision-making personalities exist and are heritable, there are likely to be both advantages and disadvantages associated with any one of them (Nettle 2006; cf. Sheldon et al. 2007). Such an assumption has been central to approaches within evolutionary biology, but it is only recently that human personality psychologists have begun to examine the downside of personality traits, such as

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conscientiousness, that have generally been viewed as unconditionally positive. Thus, for example, the "Big 5" personality trait of conscientiousness was for a long time seen as entirely positive and associated with higher well-being (DeNeve and Cooper 1998), motivation, and achievement (Judge and Ilies 2002; McGregor and Little 1998). There was hence a view that conscientiousness is always positive for well-being. However, Boyce, Wood, and Brown (2010b) hypothesized that experience of failure might result in greater loss of well-being for highly conscientious individuals. This is indeed what was found: After three years of unemployment, individuals high in conscientiousness (i.e., one standard deviation above the mean) experience a 120% higher decrease in life satisfaction than those at low levels. Similarly, secure attachment might seem an unalloyed good for fitness-related outcomes. However Ein-Dor et al. (2010) suggest that a mixture of social attachment styles may be beneficial in evolutionary terms. Nettle (2006) reviews possible positive and negative aspects of all the "Big 5" personality traits.

Other individual characteristics also appear to have both positive and negative aspects. Thus individuals high on "satisficing" will make better decisions (because they spend more time considering alternatives) but will be less happy with their decisions (due to regret about investigated alternatives). Similarly, high degrees of materialism maybe associated with high motivation to gain social status (i.e., good for fitness) as well as with negative outcomes such as anxiety, depression, and ill health (Kasser 2002). We give less attention to these latter outcomes, as little is known about within-individual variation in them.

Across-Individual and Within-Individual Variation: A Sampling Approach

In this final section we consider how sampling-based approaches to judgment and decision making have offered a perspective on both across- and within-individual variation on decision making. Orthodox approaches derived from economics approach traits, such as risk aversion and temporal discounting in terms of the curvature of stable utility functions. By extension, accounts of within-individual variation need to adopt a similar approach.

However, alternative accounts of the form of utility functions, and of concepts such as risk aversion and loss aversion, have recently been provided by rank-based sampling accounts such as the *decision-by-sampling* (DbS) model (Stewart 2009; Stewart et al. 2006). The DbS model does not assume the existence of utility functions even as a descriptive "as if" convenience, but instead assumes that behavior results from rank-based judgment based on a mental sample. Such an account offers a very different potential account of both between- and within-individual variation in decision making.

DbS was independently motivated by psychophysical research showing that people find it much easier to (and perhaps can only) make binary ordinal

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comparisons of stimuli (e.g., whether one sound is louder than another rather than how much louder it is; whether a light is brighter than another, rather than how much lighter it is). The model specifies the psychological processes involved in judgment formation. It assumes that, when making a judgment, participants sample from their long-term memories (and sometimes also the experimental context) to make a relative judgment based on "cognitively easy" binary ordinal comparisons. For example, when deciding whether a price of £1.20 for a cup of coffee is high, participants might think of half a dozen occasions when they have paid less for a cup of coffee, but only two occasions when they have paid more. The relative rank value of the coffee price of £1.20 would therefore be calculated according to that retrieved sample: (number ranked lower)/(sample size) = .75. It is hypothesized that both social quantities (e.g., health-related behaviors, energy consumption) and economic quantities (e.g., prices, wages, win probabilities) behave like basic psychological quantities (such as weight, brightness, and loudness) in that their subjective magnitudes are given at least partly by their relative ranked position within a comparison set. Considerable evidence supports this suggestion, including studies originally conducted to test the predictions of the earlier *range frequency theory* of judgment (Parducci et al. 1976; Parducci and Perrett 1971). Range frequency theory can be viewed as a descriptive account, in contrast to the process-level model offered by DbS.

Relative rank effects were observed initially in psychophysics (Parducci and Perrett 1971) and subsequently in domains as diverse as sweetness perception (Riskey et al. 1979) and perception of body image (Wedell et al. 2005). More recently, the same principles have been shown to be applicable to economic and social quantities. Thus, rank effects are seen in price perception (Niedrich et al. 2001, 2009). Judgments of "fair" allocations of wage and tax increases follow rank-based principles (Mellers 1982), as do judgments of other economic quantities (Smith et al. 1989) and event-rated death tolls (Olivola and Sagara 2009). Brown et al. (2008) found that wage satisfaction and well-being depended on the ordinal rank of an individual's wage within a comparison group; effects of ranked position of income on satisfaction with income have been found in other large datasets (Clark et al. 2008; Hagerty 2000), while ranked position of income impacts have been found on more general life satisfaction (Boyce et al. 2010a).

The DbS model has been used to show how a number of classic descriptive theories in economic psychology, such as prospect theory (Kahneman and Tversky 1979), can be understood at a deeper level as deriving from sample-based judgments of the type assumed by DbS (Stewart 2009; Stewart et al. 2006). How might it account for both across- and within-individual differences?

Specifically, according to DbS, an individual's attitude to the riskiness of a given event, or the expensiveness of a given price, will be given by the statistics of the retrieved or observed sample of events that provide the context for

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judgment. Thus an individual's beliefs about event distributions will determine their decision making and judgments regarding risks, losses, etc.

The skewness of the retrieved distribution will be particularly important. In an application to individual differences, Olivola and Sagara (2009) demonstrated that the level of risk seeking in mortality-related decisions is lower in countries in which high mortality events are observed relatively more often. Thus an event that carries an associated death toll of 500 will seem subjectively less disastrous in a country where higher event-associated death tolls are relatively more common. According to this account, the attitude toward risk (e.g., how much risk it is worth taking to save 1000 lives rather than 500) is derived not from stable underlying representations of value but from the retrieved distributions of relevant events and the rank-based nature of the evaluation process. Such an approach may, we suggest, hold promise as a more general account of both across- and within-individual variation in decision making and choice.

Further work is also consistent with the suggestion that individual differences in attitudes may be accounted for, at least partly, in terms of beliefs about distributions, with the implication that changes in individuals' beliefs about distributions may change their attitudes; this is consistent with much research on the effects on behavior of providing "social norm" information (Thaler and Sunstein 2008). We illustrate this point with research we recently completed (Wood et al. 2012) to study attitudes toward alcohol consumption. Regression analyses found that students' level of concern about their drinking, and their self-perceived risk of suffering from alcohol-related disease over the next twenty years, is predicted partly by their absolute level of drinking, not at all by the relation of their level of drinking to what they think the average level of drinking is, but strongly by the percentile ranked position that they perceive themselves as occupying within the community. This study supports the suggestion that, consistent with the rank principle and DbS, people's judgments about the acceptability of their own behavior (e.g., alcohol consumption) are influenced by perceptions of their ranked position within their community rather than their true position. Thus an individual who is in fact in the most heavily drinking 1% of the population, but who incorrectly believes that he or she is only in the top 20%, will be much less concerned than if they correctly perceived the distribution. This suggests a foundation for successful interventions through the provision of more psychologically salient social norms (Perkins 2003).

A sampling approach may therefore offer a process-level account of across-individual variation in judgment and decision making, although research is at an early stage. Next, we suggest that the same basic model can offer a useful perspective on within-individual variation.

A key source of variation in individual decision making is given by the context of choice options available at the time when a decision is made. For example, the amount of money that people will pay for a given product, or the size of food portion they choose, is highly dependent on the context of available

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options. Effects of choice context on judgments and real-world behavior are both ubiquitous and large. Thus food consumption is heavily influenced by both the context of available options and the amount consumed by social companions (for a brief review, see Wansink et al. 2009), leading to up to 30% differences in consumption. Removing a 12 fl oz option from a menu of soft drinks leads around 25% of consumers, who previously chose a 16 fl oz drink, to switch to a larger one; that is, the 16 fl oz option is chosen less often when it becomes the smallest available option (Sharpe et al. 2008). Consumption—not just purchase—is affected. Similar and substantial, rank-based context effects are seen in financial choices and decision making. Thus substantial within-individual variation in choice can emerge from changes in choice context. Such results argue strongly against the assumption of stable, context-independent within-individual preferences and are therefore difficult to account for within the framework of conventional accounts of decision making derived from economic theorizing. Sampling models such as DbS, in contrast, are starting to be applied to the within-individual variation in decision making and choice that results from shifts in the decision-making environment.

The predictions of DbS, as a rank-based alternative to conventional models derived from economics, can be tested experimentally. Recently, using an incentive-compatible procedure designed to elicit willingness-to-pay (the BDM procedure), we found that the amount of their own money that participants were willing to pay to purchase a bag of mixed sweets of a given size was strongly influenced by the relative ranked position of the bag's size in an array of nine choices (Becker et al. 1964). Participants paid up to 50% more for a given bag when it was the fourth smallest than when the same size of bag was the second smallest in the choice array (range and mean held constant). Moreover, given doubts about the true incentive-compatibility of the BDM procedure (Mazar et al. 2009), we replicated strong effects of rank when passersby were merely given the option of purchasing (again with their own money) a bag of chocolates from a display.

In summary: alternative models of decision making can offer a perspective on within-individual variation that is difficult for conventional models to grasp.

Conclusion

There is considerable evidence of within-individual variation in decision making even when the decision environment remains, in normative terms, unchanged. Such variation can result from a multitude of sources, such as fatigue, mood variation, or changes in choice context. Such variation is difficult to account for in a motivated fashion by models of decision making derived from economic approaches, despite the success of economic approaches in accounting for within-individual changes in strategy choice in game scenarios.

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Evolutionary accounts of across-individual variation in decision-making personality are beginning to emerge and have been developed much further in nonhuman animals. There remains a need for further integration of descriptive approaches to human personality with ecological approaches to animal personality; more research is needed to provide evolutionarily plausible accounts of the adaptive function of mood variation.

Finally, alternative sampling models of decision making exist that have been derived from psychophysics rather than economics. Although at an early stage of application, these models may shed light on within- and between-individual variation in decision making, thus holding out the prospect of a more unified account of both within- and across-individual variation than has previously been possible.

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