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Degrees of Uncertainty: An Overview and Framework for Future Research on Experience-Based Choice

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ABSTRACT

A striking finding has emerged recently in the literature: When decision makers are faced with essentially the same choice, their preferences differ as a function of whether options are described or are ''experienced'' via observation and feedback. For example, when presented the described choice: (A) A 90% chance of $0 and a 10% chance of $10 or (B) $1 for sure, people tend to prefer (A). But when those same two options are experienced through observation of ''draws'' from two payoff distributions that match the described options, the modal preference reverses. Why? This is just one question that the papers in this special issue address. In addition, they address the rich repertoire of issues that arise when one considers experience-based choices. The decisions-from-experience paradigm—with its focus on the acquisition and integration of information prior to choice, as well the choice itself—taps many of the fundamentals of psychology (learning, memory, encoding, knowledge representation, modelling) thus inspiring novel and fruitful avenues for research. This paper reviews recent research on experience-based choice, and highlights the contribution of the papers in the special issue. The paper introduces a framework that places different types of decisions along a continuum of uncertainty about what one is choosing between, which emphasizes the rich and varied role of ''experience'' in decision making. It ends by identifying important unsolved questions that are ripe for future research. Copyright © 2009 John Wiley & Sons, Ltd.

KEY WORDS decision making; risky choice; uncertainty; experience; learning

DECISIONS FROM EXPERIENCE AND FROM DESCRIPTION

Imagine being asked to choose between the following options: (A) A 90% chance of winning $0 and a 10% chance of winning $10, or (B) $1 for sure. What would you choose? Now imagine sitting in front of a

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computer displaying two unmarked buttons. You are asked to make repeated choices and discover that clicking on one button delivers a pay-out of $10 some of the time and a pay-out of $0 at other times, whereas clicking on the other button always pays out $1. How would you allocate your choices? Which button would you end up preferring? Now imagine a third scenario where you can click the buttons for as long as you like, at no cost, but then make a single choice for a real payoff. How long would you click the buttons in order to sample outcomes from these options? How would you sample? And, most importantly, which option would you end up choosing?

What if the computer in the second and third scenarios had been programmed to deliver the *same payments*, on average, as those described for the first scenario? Intuitively, you might think that because you would be faced with essentially the same options in the three scenarios, you would make the same choice. But this intuition would be wrong: the patterns of choices in these scenarios are strikingly different (e.g. Barron & Erev, 2003; Hertwig, Barron, Weber, & Erev, 2004; Weber, Shafir, & Blais, 2004). In the first—a *decision from description*—the modal choice is the gamble—the 10% chance of $10. In the second and third—both varieties of *decisions from experience*—the reverse is true—people prefer the sure thing; the definite payoff of $1. Why does this happen?

The papers in this special issue are devoted to investigating the intriguing differences in responding that are observed when people face decisions from experience and description (e.g. Barron & Leider, 2009; Hau, Pleskac, & Hertwig, 2009; Koritzky & Yechiam, 2009; Lejarraga, 2009; Rakow & Rahim, 2009). More than that, they address the rich repertoire of issues that arise when one considers experience-based choices. In contrast to decisions from description, in which outcomes and their respective probabilities are specified unequivocally to the decision maker, decisions from experience require participants to explore an environment and learn the probabilities and outcomes associated with each option. This element of exploration invites important questions such as how people sample, how much they sample, the mental representations they create, and the role that memory might play (e.g. Hau et al., 2009; Lejarraga, 2009; Rakow & Rahim, 2009). The fact that decision-relevant information is necessarily built up over time makes decisions from experience a good medium for exploring sequential information processing (Barron & Leider, 2009). Moreover, the ''richness'' of the decisions-from-experience paradigm—with its focus on the acquisition and integration of information prior to choice, as well as the act of choice itself—arguably lends itself to more complete investigations of individual differences in cognitive processes than can be achieved with ''standard'' choice paradigms (Koritzky & Yechiam, 2009).

Bringing these issues to the fore highlights not only intriguing empirical data, but also provides opportunities to create and test computational models of the proposed underlying cognitive processes. One of the key contributions of this special issue is an extensive model competition in which several groups of researchers competed to provide the best model of performance in each of the three types of decisions described above: *description, repeated decisions with feedback and one-shot decisions following sampling* (Erev et al., 2009). The results were illuminating. In addition to revealing important information about the incompatibility of models for the different types of decisions (i.e. one model *does not* fit all); the competition process was innovative and integrative and stands as a useful template for future similar endeavours in many areas of cognitive science.

We begin this overview paper by reviewing the basic phenomena in the decisions from experience literature and examine some of the explanations for why people respond differently to decisions from description and those from experience. We then present a theoretical framework for conceptualizing decision making in these tasks according to the degree of uncertainty one has about the options one is choosing between. We argue that this framework captures the distinctions of interest between described and experience-based choice. We end by highlighting what we see as the important next steps for this research programme. The papers presented in the special issue are noted, and their contributions emphasized, at the relevant sections of this introductory paper.

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Table 1. The fourfold pattern for decisions from description and experience

	Description		Experience	
	Gains	Losses	Gains	Losses
Small probabilities	Risk-seeking	Risk-aversion	Risk-aversion	Risk-seeking
Medium and large probabilities	Risk-aversion	Risk-seeking	? Risk-aversion?	? Risk-seeking?

Note: that for small probabilities the patterns of risk-seeking and aversion differ for description-based and experience-based problems. For medium and large probabilities we speculate that the pattern will be similar for problems (this ''speculation'' is indicated by the presence of question marks).

Why are reversed preferences in experience and description interesting?

The current dominant account of choices between *described* gambles is that of prospect theory (Kahneman & Tversky, 1979). Many text book discussions illustrate the concepts of decision weights and value functions that are key to prospect theory, by unpacking a *Fourfold Pattern*—four aspects of human choice behaviour that the theory captures (e.g. Newell, Lagnado, & Shanks, 2007). Table 1 displays this fourfold pattern both for the standard description-based problems (those for which prospect theory was formulated) and for experienced-based problems. The table highlights that it is the way in which events with a small probability of occurring (i.e. *rare*) are treated which differs across the two formats. Specifically, in decisions from description, people tend to attribute more weight to low-probability events than their objective probability of occurrence warrants (e.g. Prelec, 1998). This is shown by risk seeking in the domain of gains (e.g. buying lottery tickets) and risk aversion in the domain of losses (e.g. buying insurance). In the above example, risk-seeking for gains means that people prefer the gamble (option A) in the described version because the small chance (10%) of winning $10 is attributed more weight than is warranted.

However, as we noted in the opening paragraphs, in decisions from experience the opposite behaviour is observed. Rather than choosing the gamble, participants given the above example tend to show risk-aversion for a gain. That is, the rare event appears to be *underweighted*. This is demonstrated by the preference for the sure thing (option B). This ''surprising'' violation of the predicted pattern of choice is what first sparked widespread interest in the comparison of description and experience-based choice (Barron & Erev, 2003). To date, there is little evidence of a difference in patterns of choice under description and experience when the probabilities are moderate to large (e.g. Weber et al. 2004, Problems 2 and 6)—see Table 1. Nevertheless, the ''gap'' between described and experienced-based choice behaviour with small probabilities has led some researchers to call for separate theories to explain choice in the two situations (Hertwig et al., 2004; Weber et al., 2004).

MIND THE GAP?

Is the apparent ''gap'' between choices made from experience and description something that decision researchers should be mindful of? We suggest that it is, hence this special issue—and our presentation of the explanations for this gap that follows in the next subsection. However, arguably, there is a more important gap between experience-based and description-based choice in terms of the processes that they require. Comparing the different ways in which we acquire the information upon which we base our decisions raises awareness of the many factors that can influence what information is used when choices are made, including the acquisition, the representation, the weighting and the integration (or lack there-of) of information prior to deciding. In some ways the ''new'' focus on experience-based decision making is a return to questions that vexed researchers from the 1930s to the 1960s (e.g. when and why do people maximize versus probability match: Goodnow, 1955; Humphreys, 1939; Peterson & Ulehla, 1965). However, far from a regress, bringing

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the roles of experience, sampling, memory and learning to the fore further facilitates the integration of ''typical'' judgment and decision making (JDM) phenomena and related areas in cognitive psychology. In a recent comprehensive review, Weber and Johnson (2009) highlighted what they termed the ''growing maturity'' of the JDM field by organizing their review according to *psychological processes* (attention, encoding, memory, learning) rather than simply listing phenomena that show deviations from the predictions of normative models. Newell and Bröder (2008) made a similar point in their discussion of how research into multi-attribute judgment is both informed by and informs related research into the processes underlying memory and categorization. In other words, many fruitful avenues can be explored under the banner of experience-based-choice as the papers in this issue demonstrate.

Minding the gap in decisions from feedback

Recent interest in decisions from experience can be traced to Barron and Erev (2003). They explored ''decisions from feedback'' (or ''small-feedback based decisions''), where participants made repeated (e.g. 400) choices between unlabelled alternatives, and saw the (small) monetary payoff earned from each choice. The alternatives were programmed to return payoffs as determined by the experimenter. Choices in several experiments implied underweighting of small probabilities (see also Erev & Barron, 2005)—which contrasts with choices for described decisions, where overweighting small probabilities is the norm (see above).[1] This discrepancy is shown by a difference in choice proportions for described and experienced choices (hereafter the ''description-experience, or D-E, gap''). For instance, a sure payout of 3¢ was preferred to a 10% chance of 32¢ (otherwise nothing) on two-thirds of trials in decisions from feedback, but only half the participants stated this preference in description-based choice (Barron & Erev, 2003, p. 225).

Despite the fact that the underweighting pattern is very strong in decisions from feedback, the reason for its presence is still not completely understood. Current explanations range from feedback having a ''diffusing'' effect that lessens the ''threat'' of low probability negative events (e.g. Barron, Leider, & Stack, 2008) to the possibility that repeated feedback reduces attention to individual choices (e.g. Yechiam, Erev, & Barron, 2006). Whatever the reason, and there is likely to be more than one, exploring the gap in decisions from feedback is problematic because this paradigm makes it difficult to disentangle choice and information acquisition (i.e. to dissociate ''exploitation'' and ''exploration'', respectively). The only way to learn about an option is to choose it, even if one fears this choice is suboptimal. Therefore, the D-E gap may emerge because description permits a ''pure'' choice, whereas experience requires a different pattern of ''choice'' in order to learn about the options.

To address this difficulty, Hertwig et al. (2004) introduced the decisions-from-sampling paradigm. This paradigm separates the observation of outcomes (i.e. ''experience'') from the action of choice. First the participant engages in ''no-cost sampling'' where he/she gains knowledge of the option payoffs by observing outcomes from each option without consequence (''wins'' or ''losses'' are observed but not accrued/incurred by the participant). Often, the participant controls the number and order of observations made within this phase. Then the participant makes a one-shot choice between these options, receiving payment according to the outcome obtained from their chosen option.

Minding the D-E gap in decisions from sampling

The shift to the decisions-from-sampling paradigm creates other problems of interpretation. Key among these is the observation that, when sampling is truly random, many participants in an experience-based choice

[1]Specifically, Barron and Erev (2003) obtained a number of effects that depart from the predictions of prospect theory, all of which were associated with lower weighting for small probabilities in experience-based choice.

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condition will ''experience'' payoffs that can differ markedly from the ''programmed'' payoffs that are read by participants in a description condition. For instance, consider a participant faced with the two computer buttons in the example described in the opening paragraph (programmed payoffs of $1 versus $10 with probability .1, otherwise $0). She might only sample 6 or 7 times from each button—typically, median samples in these experiments are around 15 samples (i.e. observations) in total (Hertwig et al., 2004; Rakow, Demes, & Newell, 2008). This means that she might never encounter the $10 outcome associated with one of the buttons and thus perceive the choice as one between a certain outcome of $0 and a certain outcome of $1. On this evidence, the choice would be straightforward (see Hau, Pleskac, & Hertwig, 2009; Hertwig & Pleskac, 2008).

Analysis by Hertwig et al. (2004) indicated that such sampling variability, which results in unrepresentative samples for some individuals, contributes to the D-E gap—a result that was replicated by Rakow et al. (2008). Subsequently, some have argued that such ''biased samples'' account for the D-E gap in its entirety (Fox & Hadar, 2006), or, at least, substantially (Rakow et al., 2008). If the D-E gap in one-shot decisions from sampling does purely depend upon sampling variability, then the need for new theories of the mapping between payoffs and choice is brought into question (Camilleri & Newell, 2009a; Fox & Hadar, 2006; Hadar & Fox, 2009; Rakow et al., 2008).

Researchers have taken a number of approaches to address this problem of the incomparability of experienced samples and described payoffs. One method has been to fix the sample so that the programmed payoffs are encountered in experience-based choice (e.g. Ungemach, Chater, & Stewart, 2009); another is to increase incentives, which encourages participants to draw larger samples, bringing observed payoff probabilities closer to programmed ones (e.g. Hau, Pleskac, Kiefer, & Hertwig, 2008). Both manipulations reduce the size of the D-E gap, but the gap remains. However, these manipulations may do more than make observed payoffs more representative of programmed payoffs—they may also change the nature of the ''free'' sampling phase that precedes choice. For instance, in order to observe a rare event on exactly 2.5% of observations, it is necessary to force the participant to draw 40 observations from the option in question; so that the event is ''correctly'' observed 1 in 40 times (e.g. Ungemach et al., 2009, Problem 6). This necessarily changes the experience of pre-decisional sampling from a process of active exploration towards one of passive observation, a change that has been shown to make a difference to patterns of choice (Newell & Rakow, 2007; Rakow et al., 2008). Therefore, another approach has been to give participants freedom of exploration in experience-based choices, but then to describe the samples seen by each participant in the experience condition to a yoked ''partner'' in the description condition (Rakow et al., 2008). Most recently, Camilleri and Newell (2009b) have used a design algorithm that, whilst allowing participants freedom to draw as large or small a sample as they like, provides some incremental correction to the sequence of observations to increase the number of participants who observe payoffs comparable to the programmed payoffs. With these latter two methods (yoking or sequence augmentation), the D-E gap is seen to disappear almost entirely. Thus the picture is somewhat perplexing, and debate remains as to whether the D-E gap depends purely upon sampling variability in the observed sample. (For example, Hau et al. (2009) offer a reinterpretation of the Rakow et al. (2008) data challenging the claim that the gap disappears when a yoking procedure is used).

Beyond sampling variability in decisions from sampling

Several explanations of the D-E gap look beyond sampling variability in the environment and consider cognitive processes involved in acquiring and assessing information about the payoff distributions. These have focussed on the differential decision weighting functions for probabilities under conditions of description and experience. Some explanations have focussed on the possibility that participants average outcomes over the sample, rather than encode event probabilities (Hau et al., 2008; Hertwig & Pleskac, 2008). This allows participants to approximate an expected value decision maker, equivalent to applying a

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linear weighting to probabilities (see Hau et al., 2008; Ungemach et al., 2009)—thereby avoiding the tendency to overweight small probabilities as instantiated in prospect theory (Kahneman & Tversky, 1979).

Another possibility is that participants draw a sub-sample of their observations from memory. Then the number of participants underweighting small probabilities (because their mental sample under-represents rare events) should exceed the number who overweight small probabilities (when the mental sample over-represents rare events). Because such samples are small, this should amplify the effects of sampling variability described above (Hertwig et al., 2004), as the smaller the sample, the greater the expected skew in the binomial distribution. Most models of memory would predict that such (re)sampling from memory would make recent observations disproportionately more frequent in mental samples. It follows that more recent observations will predict choice more effectively than more distal ones. Such recency was observed by Hertwig et al. (2004), and by Rakow et al. (2008) for active sampling but not for passive observation of outcomes, but was not observed by Ungemach et al. (2009) or by Hau et al. (2008). Moreover, Ungemach et al. (2009) report highly accurate recall for the number of times that the rare event was observed, implying that experience may generate an accurate representation of simple payoff distributions.

A further possibility is that observing outcomes in experience-based choice allows decision makers to see which option delivers the best outcome most of the time. Decision makers are then ''tempted'' to select this option (Yechiam & Busemeyer, 2006; Yechiam, Druyan, & Ert, 2008). This is usually equivalent to preferring the option with the best median payout—thereby reducing the impact of extreme events (i.e. very low or very high value outcomes that occur with low probability). Support for this account comes from studies where foregone payoffs (outcomes for unselected options) are provided. This increases the underweighting of rare negative events (Ert & Erev, 2007; Yechiam & Busemeyer, 2006), consistent with the explanation that seeing ''what works best'' most of the time increases temptation for a risky alternative that only occasionally delivers a very poor outcome.

Thus while some data are consistent with cognitive accounts that predict lower weighting of rare events for decisions from sampling than for decisions from description, the picture is again perplexing. Recency comes and goes with seemingly subtle changes in methodology. The absolute weighting of small probabilities is not entirely clear—sometimes underweighted, sometimes merely weighted less heavily than when described (e.g. Hau et al., 2008; Rakow et al., 2008; Ungemach et al., 2009). In other words, sometimes the modal preference differs between description-based and experience-based choice consistent with over- and under-weighting of rare events, respectively. In other cases, modal preferences are identical for both modes of decision, but choice proportions differ between modes and imply less overweighting of small probabilities (or more underweighting of small probabilities) for experienced-based choice than for decisions from description. Moreover, such inferences must often be made when the statistical properties of the samples that participants observed have not been controlled to match the described choices.

The D-E gap: New approaches in this special issue

A number of papers in this special issue delve more deeply into the D-E gap using the decisions-from-sampling paradigm. As noted earlier, Erev et al. (2009) present an extensive data set, comparing decisions from sampling with decisions from description across 60 choice problems alongside the results of a model competition that sheds light on, among other things, the weighting of probabilities in decisions from sampling. The model competition provides at least a partial resolution to the debate about whether more than one theory of risky choice is needed to explain differing responses under description and experience. This issue has been a focus of recent exchanges (e.g. Fox & Hadar, 2006; Hertwig et al., 2004)—however, the modelling work emphasizes that, unless sampling/learning behaviour is taken into account, models simply cannot capture experience-based choices. Thus, at some level we must have more than one theory of risky-choice. The unresolved question is whether such a new theory applies solely to how, and what, information is acquired in an inevitably noisy environment, or, whether it extends to *how this information is used at the point*

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of choice (i.e. once it has been gathered, cf. Rakow et al., 2008). Rakow and Rahim (2009) and Hau et al. (2009) continue this debate about the extent and interpretation of the D-E gap by exploring statistical accounts (i.e. dependent upon sampling variability) and cognitive accounts of the gap in decisions from sampling. Hau et al. explore how the size of the sample impacts upon choice, and report a D-E gap even when samples are large and representative of the underlying payoff distribution. Their findings speak against a purely statistical account of the D-E gap. However, in a developmental investigation of individual differences in sampling, recency effects and patterns of choice, Rakow and Rahim find minimal evidence of a role for cognitive limitations in the gap.

BEYOND THE GAP

Many authors have motivated their work by appealing to the underlying similarity of decisions from experience in the psychology laboratory and a host of decisions—big or small—that people encounter outside the experimental setting. To name but a few: Vaccination recommendations on the basis of physician experience (Hertwig et al., 2004), foraging choices (Weber et al., 2004), the daily decision to use safety devices (Erev, 2007), decisions based on person perception (Rakow et al., 2008), the evaluation of innovation (Rakow & Miler, 2009) and reactions to (possible) disaster—both seen (e.g. terrorist attacks—Yechiam, Barron & Erev, 2005) and as-yet unseen (e.g. catastrophic climate change—Weber, 2006). Indeed, if one thinks about it, one rarely faces a ''real'' decision where the payoffs are known precisely and described unambiguously. In their contribution to the special issue, Koritzky and Yechiam build on the notion that experience-based choices might provide a better insight into real-world decision making. They provide a compelling argument for the use of experience-based decision tasks for assessing individual risk-taking behaviour. Koritzky and Yechiam's thesis is that experience-based tasks, with their more opaque presentation of outcomes and probabilities, are less susceptible to social desirability biases that can creep in for more transparent description-based tasks. Their results support this intriguing conjecture.

More generally, if the purpose of laboratory research is to provide a model for the decisions that people encounter, one could argue that description-based choice is an incomplete model, as it misses important components of many everyday decisions such as acquiring and collating payoff information. On this basis, decisions from experience provide an important additional means to model a large class of ''real world decisions.'' Thus, the features that distinguish decisions from experience from other classes of decision, as well as those that are held in common with other types of decision, need to be understood. The following section discusses these shared and distinguishing features with a view to developing a framework in which experience-based decisions can be placed.

The characteristics of decisions from experience

We are grateful to Hau et al. (2009, this issue) for drawing our attention to Knight's (1921) risk-uncertainty dichotomy and his more refined description of three kinds of probability. In *Risk, Uncertainty and Profit* Knight (1921) contrasted ''risk'' (measurable probabilities) with ''uncertainty'', which he described as ''unmeasurable'' (p. 20). Later in the book, he divided risk into situations involving *a priori probabilities* (where mathematical regularities permit precise calculation of risk) and *statistical probabilities* (where empirical observation allows the measurement of risk with error). *Estimation*, or ''subjective probability'' (p. 233) is then reserved for cases of ''true uncertainty''—situations where the long-run frequency of events cannot be used to derive statistical probabilities (pp. 231–232). We, and some others, have previously used the term ''decisions under risk'' interchangeably with ''decisions from description'', on the basis that decision makers are (generally) *not informed* of the precise payoff probabilities in laboratory studies of decisions from experience. However, under Knight's dichotomy, experience-based choice can correctly be described as

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decision making under risk, because the decision maker encounters choices where probabilities are *measurable*—albeit the interesting situation where these probabilities are not explicitly expressed. As Hau et al. (2009) point out, the decisions-from-experience paradigm permits exploration of decisions with ''statistical probabilities'', as defined by Knight (1921).

Still later in the book, Knight (1921) refined his trichotomy into a continuum of types of uncertainty/probability; anchored at one end by situations of perfect regularity where probabilities can be determined precisely, with the other extreme being typified by situations with so many unique features that estimation alone must be used to determine belief and action (see Hau et al., 2009). Thus, there are *degrees of uncertainty* (referring to types of situation, not to the size of a chance): ''Degrees'', because the boundaries delineating greater or lesser precision in the determination of probabilities are not necessarily clearly defined. For instance, there may be no case with so many unique attributes that it cannot be grouped with *similar* cases (by a more relaxed determination of ''similar''), thereby permitting the calculation of a statistical probability (p. 227)—albeit with acknowledged error. Further along the continuum, typified by insurance-type situations, a more precise calculation of a statistical probability can be sought through a more detailed demarcation of the reference class (e.g. probability of flood vs. probability of flood given location). Knight argued that, with sufficient data and sufficiently precise demarcation of the reference class, the determination of probabilities by empirical evaluation can approach the precision of *a priori* probabilities (pp. 245–248)—although he did acknowledge the considerable practical difficulties associated with doing this.[2]

When described in these terms, we can see the constellation of risky and uncertain decisions as spread along a continuum. From the decision maker's perspective, these decisions differ according to how easily payoff distributions can be calculated. Decisions from experience inhabit the interesting middle ground of this continuum; where precise probabilities are much harder to calculate than for a simple coin-toss or dice game, but easier to ascertain than situations with many unique features (e.g. the probability that a particular business venture succeeds). Because decisions are arrayed along this continuum, we argue that it may be unhelpful to draw too sharp a boundary between described and experienced choices. Rather than speaking of ''description versus experience'', we should focus on ''degrees of experience''. There are several inter-related ''matters of degree'' to which we can point, three of which we briefly discuss.

First, one can legitimately equate *degree of experience* with the volume of observation or the size of the experienced sample. This is considered in studies that explore preference changes over time in decisions from feedback (e.g. Barron & Erev, 2003; Erev & Barron, 2005), or which examine the size of the D-E gap as a function of sample size in decisions from sampling (Hau et al., 2008; Hau et al., 2009; Ungemach et al., 2009). Potentially, degree of experience could pertain to experience garnered over the course of a long period (e.g. the physician observing thousands of patients). Second, there are varying *types of external representation* that include more, or less, experience-like information. At one end of this spectrum is pure case-by-case experience—at the other is a description with no reference to sampled or experienced information. In between these extremes lie descriptions of samples (e.g. indicating sample sizes or giving collated frequencies of outcomes—see Rakow et al., 2008) and experience with partial description (e.g. an un-collated list of past outcomes—see Hau et al., 2009). Third, more than one representation may be available, hence there are varying *mixtures of representation*. For instance, sometimes both fairly ''complete'' forms of payoff description and outcome experience are *simultaneously* available (e.g. Barron & Leider, 2009; Jessup, Bishara, & Busemeyer, 2008; Newell & Rakow, 2007; Yechiam & Busemeyer, 2006). At other

[2]Knight's statistical probabilities have some commonality with what others have called ambiguous probabilities (e.g. Ellsberg, 1961), where lack of knowledge precludes the specification of a single point probability but a distribution of possible event probabilities can be conceived. However, one key point is that Knight (1921) assumed that there are *empirical* observations available when statistical probabilities are computed. In the absence of observations, any judgment concerning which probability values are possible based on knowledge of the situation alone are better described as ''estimates''—i.e. belonging to the world of true uncertainty (Knight, 1921, p. 223).

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times, participants have a description of the possible outcomes (i.e. a partial description), but must learn their probabilities from experience (e.g. Erev, Glozman, & Hertwig, 2008, Study 2; Rakow & Miler, 2009).

The key point is rather than asking ''What happens in experience-based choice?'' and ''What happens in described choices?'', we may do better to ask ''What is the role of experience?'' and ''What part does the description play?''. This latter question has, for instance, been extensively explored in investigations of framing—but we argue that the part played by experience is poorly understood relative to its importance in a host of everyday decisions.

FUTURE DIRECTIONS

Our analysis above has sought to provide some background to current debates and issues regarding decisions from experience, and to set out a framework that places experience-based choice within the wider context of decision research. In this final section, we identify a number of aspects of decisions from experience that we think should be focussed on if the decisions-from-experience research programme is to progress. These are organized according to four contiguous components of decision making (see Table 2).

Properties of the external choice environment

The majority of recent studies investigating experience-based choice have focussed on choices between two options, each with only one or two outcomes. Even though such decisions are illustrative of basic patterns of choice, they represent only a proportion of the decisions we commonly face. One exception to the focus on two-option choice is the extensive research using the Iowa Gambling Task, which presents participants with four options (Bechara, Damasio, Damasio, & Anderson, 1994; Dunn, Dalgleish, & Lawrence, 2006). However, even here, analysis usually collapses across ''good'' and ''bad'' decks (cf. Huizenga, Crone, & Jansen, 2007) – rendering it, in effect, a two-option task. A striking counter-example to the standard two-option choice experiments can be found in Ert and Erev (2007), whose participants faced repeated choices between 50 options. Investigations involving multiple options have the potential to illuminate the mechanisms by which people eliminate options, in an effort to simplify choice (Beach, 1993; Tversky, 1972).

In the same way that increasing the number of options increases complexity, so too does allowing for more than two outcomes per option. Experience-based choices between continuous payoff distributions are explored in a few papers (Barron & Erev, 2003, Experiment 1; Erev & Barron, 2005; Thaler, Tversky, Kahneman, & Schwartz, 1997). However, choice among options having a ''handful'' of possible outcomes

Table 2. Components of the decision process highlighting possible areas for future research

Properties of the external choice environment
1. Multiple options
2. Multiple outcomes
3. Varying outcome distributions
4. Non-stationary payoff distributions
Types of learning experience
1. Increased exposure time
2. Incidental exposure
Properties of the internal representation
1. Priors about the choice environment
2. Processes of belief updating
Types of choice
1. Feedback versus sampling
2. One-shot versus multi-shot

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has rarely been considered for decisions from experience. Lopes and Oden (1999) illustrate the value of using moderately complex (five-outcome) gambles to test competing theories of description-based choice. Their investigation compared SP/A theory (Lopes, 1987) with cumulative prospect theory (Tversky & Kahneman, 1992)—more recently these data were used to test a radical alternative to the value/utility maximization ''family'' of models (Brandstätter, Gigerenzer, & Hertwig, 2006). Such an approach lends itself to exploring a wide and interesting range of payoff distributions (e.g. skewed vs. symmetrical distributions; low vs. high variance payoffs, which impacts upon the discriminability of options—see Myers & Sadler, 1960). The paper in this special issue by Lejarraga (2009) suggests that as choice environments become more complex people tend to show a preference for experiencing outcome information rather than having it described. The investigation of yet more complex environments will allow the strength of this tendency to be tested. Moreover, decisions from experience are ripe for investigation of another element of environment complexity—decision making in environments where payoff distributions can change (for examples of studies, see Biele, Erev, & Ert, 2008; Rakow & Miler, 2009).

Types of learning experience

Most laboratory studies provide participants with experience that is condensed into a period of a few seconds, or, at most, a few minutes. In contrast, the observations that inform decisions outside the lab may stretch over days, weeks or years (as in the example of the physician discussed above). The moderating role of memory and interference is presumably particularly significant in such situations. Another feature of decisions outside the lab is that, often, the learning that informs decisions is incidental: We may have formed an impression of the options long before we are called upon, or have the opportunity, to choose between them. For instance, we ''experience'' different makes and models of car with great frequency—but may only seek to evaluate this experience on those rare occasions when we want to purchase one. The ability to encode frequencies via incidental learning has been documented (e.g. Betsch, Plessner, Schwieren, & Gütig, 2001; Hasher & Zacks, 1979). However, whether decisions taken on the basis of impressions formed incidentally differ from those taken after purposeful learning is an open question.

A related issue is how different types of learning may lead to different degrees of sensitivity to ''bias'' in the part of the environment that the decision maker has experienced (Fiedler & Juslin, 2006). This emphasis on the interface between the mind and the environment leads us naturally to the consideration of how a decision maker constructs his/her representation of the option payoffs.

Properties of the internal representation of payoffs

Most studies of decisions from experience have examined choices where the participants are told nothing about the options before experience is provided. Although participants can make a few basic assumptions about possible outcomes (e.g. that the experimenter's budget precludes the opportunity of a $1000 prize), their ability to do so is limited relative to many choices made outside the lab. Therefore, it would be valuable to explore the impact of experience when participants have reasonable pre-existing beliefs about the distribution of outcomes. For instance, sometimes one has no description of payoff probabilities, but one does have knowledge of the mechanism by which outcomes are determined (e.g. the potential causes of industrial accidents, or the dealing of hands in complex card games). This knowledge allows one to estimate probabilities before receiving any experience. Subsequent observations *should* allow for improvement upon this estimate and decisions contingent upon the estimate. Just as the simultaneous access to experience and description raises interesting questions (see above), so too does the simultaneous presence of prior beliefs and experience.

One particularly important issue is how (and how accurately) participants represent the knowledge gained during the task. This issue is fundamental for at least two reasons. First, the essence of decisions from

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experience is that payoff information is garnered piece by piece from the environment, and so the modelling of this process is at the heart of the understanding of decisions from experience. Second, models of the representation of knowledge should be a source of novel predictions concerning choice phenomena, which, in turn, allows strong tests of those models. Ungemach et al. (2009) and Gottlieb, Weiss, and Chapman (2007) tested participants' memory for the outcomes they had observed in an experienced-based choice. However, relatively little formal consideration has been given to participants' representation of the payoffs observed in the choice task (and how this is influenced by prior beliefs), even though this is key to several models of decisions from experience (e.g. Erev et al., 2009; Hertwig et al., 2004). We propose that a fruitful area of research is to explore the ''hypotheses'' that participants are generating and perhaps testing as they explore the options in experience-based choice. Some models that could be considered in this endeavour already exist. For instance, particle filter models, which are Monte Carlo techniques for the estimation of the hidden state of dynamically evolving systems, seem particularly apt for exploring how participants update their beliefs about probability distributions (see Brown & Steyvers, 2009). Hadar and Fox (2009) have also recently explored the possible influence of participants' hypotheses about the problems encountered in experienced based tasks, and how these hypotheses might contribute to the D-E gap.

Types of choice

A final technical challenge to the innovative researcher is to gain a better understanding of the relationship between two main paradigms for researching experience-based choice: Decisions from samples and decisions from feedback. For instance, how similar is the choice made from samples totalling 50 observations to the 51st choice of a participant making decisions from feedback? Such questions are necessarily difficult, but they go to the heart of some key issues. How ''active'' are decision makers in their exploration of the options, and how does feedback affect this? How do participants handle the tension between exploration and exploitation? What are the respective roles of repeated choice and repeated feedback?

In one experiment, Barron and Erev (2003) compared choice in one-shot and multi-shot (i.e. repeated) decisions from description, with decisions from feedback. One might expect a transition in choice patterns from ''pure'' one-shot described choice, via multi-shot, to decisions from feedback, because multi-shot decisions share the element of repetition with decisions from feedback. However, in Barron and Erev (2003, Experiment 5), this transition was not reliably observed. An alternative possibility is that it is not repeated choice that is important for revealing the difference between described and experienced decisions. Rather it is the feedback received after each choice which leads to lower weighting of rare events in decisions from feedback (see Jessup et al., 2008).

CONCLUDING REMARKS

Several prominent researchers have accused the field of behavioural decision making of being too concerned with ''cute'' effects, and too little concerned with good theory development (Edwards, 1983; Meehl, 1978). We think that the study of decisions from experience has yielded some interesting findings, and that it will continue to do so. Moreover, whilst more work is always needed, these findings have been the catalyst for genuine theory development. In this respect, the model competition reported by Erev et al. (2009) demonstrates a novel approach to encouraging the development *and* testing of psychological models. Decisions from experience were the test bed that they used—however, the approach is one that researchers in other fields may wish to evaluate for themselves.

Our aim in this introduction to the special issue was to highlight the richness of the experience-based choice paradigm. We think it has the potential to reveal the contribution to decision making of a wide range of

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both psychological and environmental factors, many of which are under-played in other paradigms. We hope that readers of the special issue will be left with the same impression.

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