Chapter 19

PARTITION DEPENDENCE IN DECISION ANALYSIS, RESOURCE ALLOCATION, AND CONSUMER CHOICE*

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Abstract

In this chapter we explore a wide range of judgment and decision tasks in which people are called on to allocate a scarce resource (e.g., money, choices, belief) over a fixed set of possibilities (e.g., investment opportunities, consumption options, events). We observe that in these situations people tend to invoke *maximum entropy heuristics* in which they are biased toward even allocation. Moreover, we argue that before applying these heuristics, decision makers subjectively partition the set of options into groups over which they apply even allocation. As a result, allocations vary systematically with the particular partition that people happen to invoke, a phenomenon called *partition dependence*. We review evidence for maximum entropy heuristics and partition dependence in the following domains: (1) decision analysis in which degree of belief and importance weights must be distributed among possible events and attributes, respectively; (2) managerial decision making in which money and other organizational resources are allocated among risky projects, divisions, and organizational stakeholders; and (3) consumer choice in which individuals make selections among various consumption goods and consumption time periods.

1. INTRODUCTION

Imagine that three graduate students with identical tastes enter a corner grocery store, each planning to purchase 12 frozen dinners to consume over the next couple

of weeks. This store carries three varieties of frozen dinner: chicken parmesan, beef ravioli, and Szechwan beef. The first student decides to spread out her consumption over different flavors by choosing four meals of each variety. The second student notices that the first two dishes are Italian cuisine and the third is Chinese. Hence this student purchases six Italian meals (three chicken parmesan, three beef ravioli) and six Chinese meals (Szechwan beef). The third student notes that the first dish is chicken whereas the latter two dishes are beef. This student purchases six chicken dishes (chicken parmesan) and six beef dishes (three beef ravioli, three Szechwan beef). In this example all three graduate students apply a "maximum entropy heuristic," spreading out their choices evenly over different kinds of meals. In this case the heuristic reflects a desire to seek variety. However, the implication of this strategy depends crucially on how each student subjectively groups the set of options (by meal type, by cuisine, or by meat). Thus, these hypothetical graduate students exhibit preferences that are *partition-dependent*, varying with their subjective partition of the option set.

In this paper we review a number of contexts in which people must allocate a scarce resource (e.g., money, choices, belief) over a fixed set of possibilities (e.g., investment opportunities, consumption options, events). We argue that people act as if they rely on a combination of a maximum entropy heuristic and allocation according to their innate preferences and beliefs. To the extent that they rely at all on a maximum entropy heuristic their allocations will be partition-dependent, varying systematically with the way in which they subjectively partition the set of possibilities. We use the term "maximum entropy" to refer to an even allocation over all possibilities that have been identified (i.e., reflecting maximum disorder or minimum information). We use the term "heuristic" to refer to cognitive strategies that people use to simplify otherwise complex judgments (note that this differs from the definition of heuristics as "attribute substitutions" as in Kahneman & Fredrick, 2002).

To provide evidence for this account we review a number of disparate allocation domains that are of interest to management scholars: (1) decision analysis in which degree of belief and importance weights must be distributed among possible events and attributes, respectively; (2) managerial decision making in which money and other organizational resources are allocated among risky projects, divisions, and organizational stakeholders; and (3) consumer choice in which individuals make selections among various consumption goods and consumption time periods. For each domain we first characterize the particular maximum entropy heuristic and its possible psychological sources. Next, we review studies that have documented partition dependence by experimentally manipulating the relative accessibility of alternative partitions. Finally, we review any moderators of partition dependence that have been identified. We conclude with a general discussion in which we summarize these results, address the possibility of demand effects in the studies cited, distinguish partition dependence from related phenomena, discuss other dependencies implied by the present account, and identify priorities for future research.

2. REVIEW OF EMPIRICAL WORK

2.1. Partition dependence in decision analysis

Decision analysis is used in a wide range of industries to address a broad array of important organizational decisions such as financial forecasting and budget allocation, R&D project selection, bidding and pricing, and more general corporate strategic planning (Keefer, Kirkwood & Corner, 2004). The use of such techniques in organizations is influenced by such factors as managerial attitudes, organizational structure, and industry characteristics (See and Clemen, 2003).

Tools of decision analysis typically allow considerable discretion in how to structure the assessment task. The analyst must define the problem space including: relevant options under consideration (decision nodes), key uncertainties (chance nodes), and relevant attributes of potential consequences. Once a decision problem is explicitly defined, the analyst, sometimes with the assistance of an expert, elicits a utility function as well as probabilities of all relevant events and weights of all relevant attributes. Whereas utility functions are typically derived from a series of choices (e.g., Wakker & Deneffe, 1996; Abdellaoui, 2000), probabilities and attribute weights are typically evaluated directly through an explicit allocation among possible events or attributes. We assert that these assessments are distorted by the particular partition of the event or attribute space that is identified by the decision analyst.

2.1.1. Judged probability

Most problems that are submitted to decision analysis involve consequences that are uncertain. These problems therefore require an assessment of the subjective probabilities of events, such as a failure of important equipment or a rise in the price of electricity. Practical procedures for assessing subjective probabilities were characterized by Spetzler and Stael Von Holstein (1975) and similar procedures are still in use today (Clemen, 1996). Typical protocols for probability elicitation are described in Keeney & von Widterfeldt (1991) and Morgan & Henrion (1990). Although these authors provide guidance concerning a number of important steps of the assessment procedure (e.g., identifying and selecting experts, training them in probability elicitation, the probability assessment itself), they have little to say concerning the process of choosing which events should be assessed.

Fischhoff, Slovic, and Lichtenstein (1978) found that when novices and experts judged probabilities of various reasons why a system might fail (e.g., reasons why a car would fail to start) their responses were affected by which causes were explicitly identified (e.g., "dead battery," "ignition system") and which were pruned from the tree and relegated to a residual catch-all category ("all other causes"). In particular, they found that when branches were pruned from the tree, the judged probability of the now more inclusive catch-all category (as assessed by a new group of participants) increased by less than the probabilities of the pruned branches; this probability was instead distributed among the other remaining branches of the tree.

These investigators and most that followed have attributed pruning bias to the availability heuristic: people can more easily recall or imagine instances of a particular category when that category is described in greater detail – thus the causes that are out of site are out of mind. Fox and Clemen (2004) observed that the availability account of pruning bias cannot explain more general instances of partition dependence. For instance, they showed that unpacking an event (e.g., the next top-ranked business school according to *Business Week* will be a school other than Wharton) into a disjunction of obvious constituents and a catch-all (Chicago or Harvard or Kellogg or Stanford or another school other than Wharton) does not lead to higher judged probabilities, whereas assigning these constituent events to separate branches that are assessed individually does lead to a significant increase in aggregate judged probabilities.

Fox and Clemen (2004) argued that the pruning bias is an instance of a more general pattern of partition dependence in probability assessment that extends beyond the domain of fault trees and discrete categories of events. They argue further that pruning bias can be attributed in part to a tendency to first allocate probabilities evenly over all events under consideration, and then adjust in response to an evaluation of how those events differ. The tendency to anchor on an "ignorance prior" probability of $1/n$ for each of n branches may reflect an intuitive application of the fallacious "principle of insufficient reason" (e.g., Laplace, 1776; cited in Hacking, 1975, p. 132) according to which events that cannot be distinguished are treated as equally likely. Because adjustment is typically insufficient (Tversky & Kahneman, 1974) probabilities are biased toward even allocation and assessments are therefore partition-dependent.

Evidence for this "ignorance prior" model and partition dependence has been steadily mounting in studies of judgment under uncertainty. Fox and Rottenstreich (2003) found that the language of the probability query can facilitate either a two-fold "case" partition {the target event occurs; the target event fails to occur} or an n-fold "class" partition of similar events {event 1 occurs; event 2 occurs; . . . ; event n occurs} and corresponding biases toward 1/2 or $1/n$. For instance, when asked to judge the probability that "the temperature on Sunday will be higher than any other day next week" the median response of University of Chicago undergraduates was .30 (as if they had anchored their judgments on 1/2 and adjusted somewhat), but when asked to judge the probability that "next week, the highest temperature of the week will occur on Sunday" the median response was .15 (as if they had anchored their judgments on 1/7 and found little need to adjust). Moreover, responses of 1/2 were more common under the former wording whereas responses of 1/7 were more common under the latter wording. Taking a different approach, See, Fox, and Rottenstreich (2004) presented participants with objects flashing on a computer screen that could take on one of four shapes (triangle, circle, square, diamond) and one of two colors (gray, black). Subsequent estimates of relative frequency were biased toward 1/4 for shapes and 1/2 for colors. Finally, evidence of partition dependence in judgment of conditional probabilities is provided by Fox & Levav (in press).

The interpretation of pruning bias in terms of anchoring on the ignorance prior suggests that this phenomenon will be observed in a wide array of situations, including those that involve assessing probabilities for dimensional spaces. For instance, in one study Fox and Clemen (2004) asked members of the Decision Analysis Society (a group of academics and practitioners who study decision analysis) to assess probabilities that the total number of members in the society five years in the future would fall into various ranges. Half assessed the probabilities for the ranges {400 or less, 401–600, 601–800, 801–1,000, more than 1,000} whereas half assessed the probabilities for the ranges {1,000 or less, 1,001–1,200, 1,201–1,400, 1,401–1,600, more than 1,600}. The median judged probability that the membership would total more than 1,000 was 12% for the first group, in which this was one category out of five (ignorance prior = 20%), but it was 27% for the second group, in which this was the sum of four categories out of five (ignorance prior = 80%).

Although the foregoing example suggests that even experts are not immune to partition dependence in judging probabilities, the ignorance prior model suggests that this bias will be less pronounced when people have more knowledge or information that they can use to distinguish among events. This prediction seems to be supported by experimental data. Fox and Clemen (2004) asked MBA students in a decision models class (in which they had received prior training in probability theory and the use of decision trees) to judge the likelihood that the Jakarta Stock Index (JSX) and the NASDAQ index would close in various ranges at the end of the current calendar year. Participants evaluated the probabilities of the ranges {below 1,000, 1,000–2,000, 2,001–4,000, above 4,000} for one index and the ranges {4,000 or below, 4,001–8,000, 8,001–16,000, above 16,000} for the other index. Each participant assigned himself to an experimental condition based on the last digit of his local telephone number: if the number was odd (even), the participant was asked to write "NASDAQ" over the first (second) tree and "JSX" over the second (first) tree. Results demonstrated both pronounced partition dependence and a pronounced knowledge effect: for the unfamiliar JSX (median knowledge rating was 0 on a 0–10 scale), the median respondent reported probabilities that coincided precisely with the ignorance prior, judging the probability that the index would close at 4,000 or below to be 25% if this was a single branch (i.e., respondents with an odd telephone number) but 75% if it was the sum of three branches (respondents with an even telephone number). For the familiar NASDAQ (median knowledge rating was 7 on a 0–10 scale), the median respondent judged the probability that the index would close at 4,000 or below to be 25% if this was a single branch but 50% if this was the sum of three branches – a striking inconsistency, but significantly less pronounced than the corresponding effect for JSX. Similar knowledge effects were documented by See, Fox & Rottenstreich (2004) using their learning paradigm: when participants were given an enhanced opportunity to learn the frequency of objects (a training period that featured more repetitions of objects that were presented more slowly) partition dependence diminished significantly, though it did not disappear entirely.

2.1.2. Attribute weighting

A second discretionary judgment in decision analysis is the allocation of weights to attributes. For example, a consulting firm choosing among different potential sites for a new branch office might consider the cost of living, weather, health care, transportation, and so forth in each of the cities it is considering. Attribute weighting entails two main tasks. First, the analyst must identify the relevant objectives (attributes) to be considered (see Keeney and Raiffa, 1976; Keeney, Renn and von Winterfeldt, 1987). Usually the analyst has flexibility concerning the level of specificity or detail to include in the assessment. For instance, our consulting firm might consider cost of living as a single attribute or might break this attribute down into separate ratings of housing costs, utility costs, food costs, etc. Second, one must attach a numerical weight to each of the attributes that have been identified (for a review of techniques see von Winterfeldt and Edwards, 1986). Although both tasks (attribute identification and attribute weighting) have been separately addressed in the literature, there has been only a smattering of attention to the interaction between them. For example, some studies have found that varying the structure and formulation of attributes can have a substantial impact on the measured multiattribute utility function (see, e.g., Fischer, Damodaran, Laskey and Lincoln, 1987). However, none of these studies have examined factors influencing how people allocate weights across attributes.

Weber (1983) explored the influence of attribute selection on attribute weighting. He asked participants to place weights on various attributes to be used in deciding which automobile to purchase. One group of participants was presented with a set of four attributes whereas a second group was presented with a set of five attributes in which one of the four initial attributes (cost per mile) was split into two more specific attributes (depreciation per mile and yearly operating costs). Results showed that the sum of weights on the more specific attributes was significantly higher than the weight of the original attribute from which the specific attributes were derived. The weights attached to the other common attributes (i.e., those that were not split in either condition) were identical.

Weber, Eisenführ and von Winterfeldt (1988) replicated and extended this finding. These researchers asked business students to evaluate hypothetical future jobs. Participants were provided with a value tree that included three basic objectives (job security, income and career opportunities) that could be split into two more specific attributes. This setting allowed the experimenters to manipulate the level of detail of the value tree by presenting eight groups of respondents with eight different combinations of general and specific attributes. Results of this study document a strong bias in which splitting attributes leads to an increase in aggregate weight. In one group, for example, respondents assigned a weight of .30 to the attribute "job security," but when this attribute was split a second group assigned weights of .20 and .24, respectively, to the attributes "stability of the firm" and "personal job security." Weber et al. (1988) demonstrated the robustness of this "overweighting bias" using a variety of weight elicitation methods (Edwards, 1977; Green and Srinivasan, 1978; von Winterfeldt and Edwards, 1986).

Although participants in the studies of Weber et al. did discriminate among attributes (about 80% of the respondents had a ratio "largest vs. smallest weight" larger than 3 when there were 4 or more attributes to evaluate) there is clear evidence of partition dependence in their allocation of weights. Apparently, these respondents tended toward maximum entropy when evaluating attributes. The nature and psychological sources of this behavior (and whether the tendency reflects anchoring on even allocation or hedging in that direction) have yet to be identified. Langer and Fox (2004) obtained further evidence of naïve diversification in allocation among two simple three-outcome lotteries whose returns both depended on the roll of a particular die.

2.2. Partition dependence in resource allocation

One of the fundamental decisions faced by managers is how to allocate resources among diverse projects, firm units, or stakeholders. First, managers must often allocate discretionary funds among uncertain prospects (e.g., research and development projects) or fixed capital budgets among different divisions of a firm. In these cases they may trade risk against reward, factor in such considerations as relative need and projected return on investment, and/or take into account the perceived correlation among returns in the portfolio of projects. Second, managers must frequently allocate benefits and burdens among organizational actors in as just a manner as possible. Because all of these allocation decisions entail distribution of a scarce resource over a fixed set of alternatives, maximum entropy heuristics may be implicated and partition dependence may be observed. We consider each domain in turn.

2.2.1. Allocation among risky and uncertain projects

Relatively little descriptive research has been completed to date on allocation decisions by managers among risky or uncertain projects. However, there has been some illuminating and relevant work on personal investment decisions. Samuelson and Zeckhauser (1988, pp. 31–33) reported that about a half of a large sample of university employees allocated their retirement funds equally between stocks and bonds. These authors argued that employees rely on equal division in addition to or in place of more fundamental concerns, such as security or growth potential. Benartzi and Thaler (2001) showed that investors rely more generally on "naïve diversification" strategies in which they allocate $1/n$ of their investment savings among the n investment opportunities offered to them. These researchers asked UCLA employees to allocate hypothetical retirement savings between two funds, called A and B. In one manipulation, fund A was a stock fund and fund B was a bond fund. In another manipulation, A was a stock fund but B was a "balanced" fund that invested half of its assets in stocks and half in bonds. In a third condition, A was the "balanced" fund and B was a bond fund. In every condition participants exhibited a strong tendency toward naïve diversification, allocating close to half of their savings to each fund with little regard to distinguishing features of these funds. In fact, precisely even allocations were chosen by 34% of the respondents in the first condition, 21% in the

second condition and 28% in the third condition, and even allocation was the modal response of all three groups.

Benartzi and Thaler documented a similar trend in field data from actual investments in 170 retirement savings plans obtained from Money Market Directories. In addition to confirming the experimental results, the empirical data allowed Benartzi and Thaler to observe the use of the $1/n$ heuristic when the number of available investment opportunities is larger than two. The average number of funds offered to any individual investor in their sample was 6.8, of which 62% were equity funds. The data showed that, in fact, nearly 62% of the total investment was allocated to equities. Moreover, the correlation between the percentage of investment options in a plan that were equity funds and the proportion of savings in the plan allocated to equities was positive and statistically significant.

If people are biased to allocate investment funds evenly over the options that have been identified, then the particular way in which the investment space is partitioned should influence the resulting distribution of funds. For instance, a typical 401(k) savings plan partitions the investment space by the particular investments that happen to be offered. In one survey of UCLA employees, Benartzi and Thaler (2001) found that participants who were presented with a stock investment and a bond investment allocated a mean 54% of their retirement savings to stocks. However, participants who were offered a stock investment and a mixed stock/bond investment allocated a mean 46% to the first fund, which implies an investment of 73% of their savings in stocks.

Langer and Fox (2004) extended the notion of partition dependence in risky allocation by presenting participants with hierarchical allocation tasks. In one study MBA students were asked to allocate 401(k) savings among stocks (a passively managed S&P 500 fund), bonds (long-term US Treasury bills) and real estate (a geographically diversified real estate investment trust). Two of these investments were assigned to one fictional vendor and the third investment was assigned to a second fictional vendor. Following the description of all investments, participants were asked to allocate funds first to vendors, then to specific investments. If participants allocate savings evenly to the vendors then evenly to the funds offered by a given vendor, one would expect 50% of savings to go to the fund offered by the singleton vendor and 25% to each of two funds offered by the other vendor. Indeed, Langer and Fox found that participants allocated dramatically more money to a particular investment if it was assigned to the singleton vendor than if it was assigned to the other vendor. For instance, participants allocated a median of 38% of their savings to real estate when it was assigned to the singleton vendor, but they allocated a median of only 20% or 24% to real estate if it was paired with bonds or stocks, respectively. The authors replicated this effect using simple well-defined chance lotteries and incentive-compatible payoffs.

Thus far we have reviewed evidence of partition dependence in decisions made by individuals allocating personal funds among investment opportunities and chance lotteries. The question arises whether this phenomenon would extend to decisions made by large firms allocating investment funds among divisions. There is some

empirical support in field data for the notion that firms are biased toward even allocation across divisions. For instance, Scharfstein (1999) examined capital budgeting data from divisions of 165 large conglomerates and documented a tendency to underinvest in well performing divisions and overinvest in poorly performing divisions (as compared with stand-alone industry peers). Other papers (Lamont, 1997; Shin and Stulz, 1997; Berger and Ofek, 1995) offer further evidence of cross-subsidization between divisions. Some authors attribute this "equal allocation" pattern to agency problems and "corporate socialism" in the budgeting process (Scharfstein and Stein, 2000). Although we acknowledge that social factors may contribute to such effects we conjecture that the tendency to spread out funds among divisions may in fact be driven by a more cognitive instinct to rely on naïve diversification with insufficient adjustment on the basis of factors that distinguish divisions.

New studies by Bardolet, Fox & Lovallo (2004) provide preliminary evidence that: (1) the bias toward equal allocation of capital resources among divisions occurs even in the absence of social factors; and (2) the procedure for budgeting and the hierarchical organization of the firm can give rise to dramatic partition dependence in budgeting decisions. These authors asked executive MBA students to take the role of the manager in charge of the capital allocation process in a hypothetical corporation. This firm had three main product divisions (Home Care, Beauty Care, and Health Care), each with a different number of regional subdivisions (Home Care subdivisions were located in the U.S., Europe and Latin America; Beauty Care subdivisions were located in the U.S. and Europe, and Health Care had a single subdivision located in the U.S.). Participants were provided with a brief description of the different divisions and subdivisions, together with some data concerning past performance and future prospects. One group of respondents (representing a firm with centralized decision making) was asked to divide the available capital among the six subdivisions. A second group (representing a firm with decentralized decision making) was asked to divide the capital only among the three major divisions (Home Care, Beauty Care and Health Care). Note that in both experimental conditions firm characteristics were held constant and the "Health Care (U.S.)" subdivision was one of the groups to which capital was to be assigned. Responses exhibited pronounced partition dependence: the median allocation to "Health Care (U.S.)" was 33% in the decentralized firm (in which it was one of three major functional divisions among which capital was divided) but only 20% in the centralized firm (in which it was one of six subdivisions among which capital was divided).

The psychological basis of naïve diversification has not yet been uniquely identified. It may be that people view spreading out their investments and contributions as a "safe" or risk-averse decision that usually reduces variance in the probability distribution over outcomes. Alternatively, naïve diversification could be viewed as an obvious and defensible default in the face of innumerable allocation possibilities; indeed, previous studies have documented a host of situations in which people choose according to "reason-based" decision rules rather than which option offers the highest perceived value (Shafir, Simonson, & Tversky, 1993). If this is the case one might expect people to shift from naïve diversification to an alternative decision

rule when the former becomes difficult or impractical to apply – for instance, when the number of investment funds is rather large. Although Benartzi and Thaler (2001) observed no change in the behavior of investors in plans with more available options, they noted that the number of options in the plans in their sample was small and hypothesized that people would stop naively diversifying if they were offered a larger number of options. Indeed, Huberman and Jiang (2004) recently reported that when the number of available funds in 401(k) plans rises above a manageable quantity, people shift from naïve diversification to concentrating their investment in a small number of relatively safe funds.

Several factors seem to moderate the extent to which people rely on naïve diversification and therefore exhibit partition dependence. First, as mentioned above, people seem to rely less on these strategies as the number of options increases beyond a manageable number (Huberman & Jiang, 2004). Second, knowledge of relevant markets or investments may moderate the magnitude of partition dependence, just as substantive expertise seems to moderate partition dependence in probability judgment. We note that Langer and Fox (2004) found no significant knowledge effect when they asked respondents to rate their own knowledge in one of their experiments; however, their participants were MBA students whose financial and statistical backgrounds did not vary widely. Third, reliance on naïve diversification may diminish with increasing motivation of the decision maker. For example, Scharfstein (1999) observed that multi-business conglomerates were less prone to "corporate socialism" (i.e., a bias toward diversification) when their managers had a larger equity stake in the company. Finally, we speculate that the magnitude of adjustment from even allocation may be influenced by variation in an investor's confidence in his or her ability to predict the return on particular investments. Past research suggests that decision makers are more willing to act on domains of uncertainty about which they feel knowledgeable or competent (Heath & Tversky, 1991) relative to salient standards of comparison (Fox & Tversky, 1995; Fox & Weber, 2002). We suspect that when making allocation decisions among uncertain prospects, each prospect is compared against others in the option set and/or potential opportunities in the same investment category (e.g., other possible stock indices). Indeed, French and Poterba (1991) reported that investors in the USA, Japan and the UK allocate 94%, 98% and 92% of their overall equity investment, respectively, to domestic equities, showing a strong "home bias" that is difficult to defend on normative grounds (see also Kilka & Weber, 2000). Similarly, investors in regional telephone companies tend to invest overwhelmingly in companies located in their home state (Huberman, 2001) and Finnish investors tend to invest in companies whose headquarters are located closer to their homes and whose CEO shares their ethnicity (Grinblatt and Keloharju, 2001).

2.2.2. Fair division of benefits and burdens

Managers must frequently make decisions concerning the allocation of benefits and burdens among organizational actors. A great deal of research on distributive justice has found that people are sensitive to the perceived fairness of distributions

of both tangible resources and working conditions (e.g., Adams, 1965; Deutsch, 1985; Leventhal, 1976; Rescher, 1966). Whether an allocation is perceived to be fair is highly context-dependent and such assessments can vary with the type of resource being allocated (e.g., monetary versus nonmonetary; benefits versus costs) and the distributional norm that the judge invokes (Deutsch, 1985). Common allocation norms include (but are not limited to) merit, effort, ability, need, equity, or equality (Deutsch, 1985; Rescher, 1966). In many allocation settings, equality (i.e., equal division among parties) is the most obvious and simple rule to apply (Messick and Schell, 1992; Messick, 1993). Yaari and Bar-Hillel (1984; see also Bar-Hillel & Yaari, 1993) examine participants' intuitions concerning just allocation of divisible entities (i.e., benefits or burdens) among individuals who have no prior claims on those entities. They argue that "equal treatment of equals" is considered the default distribution but that people find departures from even allocations warranted in response to differences in needs, tastes, or beliefs of the individuals in question.

To the extent that people apply the equality heuristic in assigning benefits and burdens, the final allocation should depend crucially on the way in which the set of people is partitioned. Indeed, Fox, Ratner and Lieb (2004) asked participants to imagine that they are executors of an estate, charged with allocating money to the deceased's grandchildren, two of whom were children of one son and four of whom were children of a second son. Respondents in the *hierarchical* condition were first asked how much they would allocate to the children of each son, and then were asked how much they would allocate to each of the grandchildren. Note that if the equality heuristic is applied at the level of sons and then at the level of grandchildren, 1/4 of the money will be allocated to each of the two children of the first son ($1/2 \times 1/2 = 1/4$) and 1/8 of the money will be allocated to each of the four children of the second son ($1/2 \times 1/4 = 1/8$). Respondents in the *non-hierarchical* condition were simply asked how much they would allocate to each of the grandchildren. Note that the equality heuristic in this case implies that 1/6 of the money will be allocated to each of the six grandchildren. Thus, the authors predicted that participants would be more likely to allocate money evenly on a *per stirpes* basis (by son) in the hierarchical condition and they would be more likely to allocate money evenly on a *per capita* basis (by grandchild) in the non-hierarchical condition. Indeed, respondents were about three times as likely to allocate an equal amount to each family of children (i.e., unevenly across grandchildren) in the hierarchical than non-hierarchical condition (25% versus 8.5%). Likewise, 84% of participants allocated equally to each grandchild (i.e., unevenly to the two son's families) in the non-hierarchical condition, whereas only 67% allocated equally to each grandchild in the hierarchical condition.

Apparently more than 90% of participants in the foregoing study relied on some application of the equality heuristic to the level of sons and/or grandchildren. The question arises whether partition dependence will be observed in situations where alternative fairness norms prevail. Fox, Ratner and Lieb (2004) asked participants to allocate financial aid among entering college freshmen whose family household

incomes fell into various ranges. Respondents in the "low-partition" condition assigned percentages to the ranges {< $15,000; $15,001–$30,000; $30,001–$45,000; $45,001–$60,000; $60,001–$75,000; >$75,000}. Respondents in the "high-partition" condition assigned percentages to the ranges {< $75,000; $75,001–$85,000; $85,001–$100,000; $100,001–$120,000; $120,001–$145,000; >$145,000}. Participants were explicitly told that they should "feel free to indicate 0% or 100% for any of the categories below as these income categories were chosen arbitrarily." First, the results showed a strong evidence of need-based fairness norms: mean allocation percentages were largest for the lowest income category in both conditions and allocation percentages decreased monotonically as income level increased. Second and more important, participants were sensitive to the stated categories: the mean percentage of financial aid allocated to families with incomes less than or equal to $75,000 was 96% in the low-partition condition (in which this comprised five of six income categories), but only 48% in the high-partition condition (in which this was one of six income categories). Thus, participants seemed to rely on both need-based allocation and even allocation over all specified categories.

We suspect that partition dependence will be less pronounced in situations where people have: (1) clearer criteria to distinguish among individuals or groups of individuals in allocating resources, and (2) greater cognitive resources to distinguish among individuals or subgroups. In support of this latter assertion, Roch, Lane, Samuelson, Allison and Dent (2000) argued that when people request a share of some common resource pool they tend to anchor first on an equal division (i.e., invoke the equality heuristic) then adjust their request in a self-serving manner (e.g., following norms that are based on the order of picking, number of people sharing the resource pool, etc.). The authors found that when participants were placed under cognitive load by being asked to remember a long string of numbers they were less likely to access rationale for adjustment and therefore made requests that were closer to the default equal allocation.

2.3. Partition dependence in consumer choice

Consumers are often called on to make multiple selections of goods and services from a menu of possibilities. Rational choice theory assumes that decision makers select sets of options that maximize their aggregate utility of consumption. Thus, normatively equivalent procedures for eliciting preferences should not affect consumers' choices. Recent investigations of multiple choices by consumers have revealed instead that they often sacrifice pleasure of consumption in order to obtain assortments with greater variety. Simonson (1990) observed that when students were asked to choose three snacks to be consumed one-at-a-time over the following three weeks, they tended to choose a variety of different items, but when they were asked on three consecutive weeks to choose a single snack to be consumed immediately they instead tended to request the same item each time. More recently, Ratner, Kahn, and Kahneman (1999) found that even when choices were made sequentially people often chose less-preferred items in order to secure greater variety. Several explanations

have been advanced to explain variety-seeking behavior, including: concerns about satiation (e.g., McAlister, 1982), a desire for novelty and change (e.g., Venkatesan, 1973), and risk aversion due to uncertainty concerning future preferences (Kahn & Lehmann, 1991; Simonson, 1990; for an early review see McAlister & Pessemier, 1982).

Recent work has demonstrated that the implications of variety-seeking behavior depend crucially on the way in which the set of options is subjectively grouped. For instance, in one study Fox, Ratner, and Lieb (2004) asked participants to choose three films from a list of six. Participants were told that some of them would receive free video rentals of all of their choices. For each film participants received information concerning the title, actors in starring roles, classification (drama, action, or comedy), country of origin (Australia, Canada, or Britain), and a brief plot synopsis. Participants in the "genre partition" condition saw the movies grouped together by genre (Action, Comedy, Drama), with two films for each category. Participants in the "country partition" condition saw the same six movies grouped together by country of origin (Canada, Britain, Australia), with two films for each category. The authors hypothesized that participants would seek more variety over the attribute that is made accessible through the grouping manipulation (genre versus country). The results reveal strong evidence of partition dependence: 47% of participants chose videos from all three genres in the genre partition condition but only 20% did so in the country partition condition; similarly, 63% of participants chose videos from all three countries in the country partition condition but only 47% did so in the genre partition condition.

Similar results were obtained in a follow-up study using a more subtle manipulation of physical grouping. Four familiar varieties of candy (e.g., tootsie rolls, starlight mints) were displayed in three large plastic bowls. For all participants, one bowl contained two flavors (in separate piles), and the other two bowls each contained a single flavor. When participants selected five candies to take home with them they acted as if they were diversifying over bowls and were roughly 50% more likely to choose a type of candy when it was placed on a bowl by itself than when it was placed in a bowl with another type of candy. Interestingly, this tendency to spread out consumption over bowls was significantly diminished among participants who were asked to remember an eight-digit number while making their selections, suggesting that cognitive load may interfere with higher cognitive motives to diversify.

Partition dependence in consumer choice appears to be moderated by the strength and accessibility of preferences among options. Fox, Ratner and Lieb (2004) replicated the aforementioned video selection study by asking graduate students to choose three different bottles of white wine from a list of six that were either grouped by grape (Chardonnay, Pinot Grigio, Sauvignon Blanc) or by region of origin (Australia, California, Italy). In addition, participants were asked to indicate the number of bottles of white wine that they had purchased in the previous twelve months. The results revealed partition dependence that was more pronounced among respondents who had purchased fewer bottles of wine, thereby supporting the notion that expertise moderates reliance on variety-seeking over accessible categories.

More direct evidence for the notion that strength and salience of preferences, rather than expertise per se, moderates partition dependence was obtained in a follow-up study in which MBA students were asked to complete two tasks: (1) choose three items from a list of eight snacks available in their student kiosk that were grouped into three categories, {cookies, crackers, fruits & veggies} or {cookies & crackers, fruits, veggies}; (2) rate how attractive they found the prospect of consuming each of these items. Results revealed partition dependence that was less pronounced among participants who had rated items before choosing (so that hedonic preferences were more accessible when they subsequently chose), and among participants who exhibited stronger hedonic preferences (as measured by a higher variance in attractiveness ratings over items).

3. DISCUSSION

The studies reported in this paper support the notion across a wide range of domains that when people allocate scarce resources (belief, attribute weights, money, choices) among a fixed set of options (events, attributes, projects, individuals or groups, consumption choices) they tend to invoke *maximum entropy heuristics* in which they distribute the resource evenly across all options and adjust to the extent that they distinguish among them. Such even allocation strategies require people to first subjectively partition the set of options into groups. In many (if not most) situations there is no single canonical partition and the relative accessibility of alternative partitions is influenced by spurious factors such as the elicitation procedure (e.g., hierarchical versus non-hierarchical), convenient category cutoffs, or physical groupings. Thus, allocations tend to exhibit *partition dependence*, varying systematically with the partition that happens to be most accessible to the decision maker. Moreover, we have seen that the relative accessibility of alternative partitions can be manipulated experimentally. The heuristics reviewed in this paper and associated manifestations of partition dependence are summarized in Table 1. We conclude this chapter with a discussion of possible demand effects, related phenomena, extensions of the present work, and areas for future research.

3.1. Demand effects

We have argued that partition dependence violates rational choice theory because it gives rise to allocations that differ across strategically equivalent elicitation modes. However, one might be concerned that the method of eliciting allocations or describing possibilities could, in fact, communicate information to participants in the studies cited. For instance, rational probability assessors may infer that all events for which they are asked to assign probabilities must have a nontrivial likelihood of occurrence otherwise they would not be asked about these events. Similarly, a rational judge might infer that different income ranges that have been identified by the experimenter for allocating financial aid must have approximately equal representation in the population. This argument suggests that partition dependence is

Table 1. Summary of Research on Maximum Entropy Heuristics and Partition Dependence.

Domain	*Scarce Resource*	*Allocation Space*	*Maximum Entropy Heuristic*	*Representative References*
1. Decision Analysis	Belief	Event Space	Principle of Insufficient Reason	Fox & Clemen (2004)
	Importance Weights	Attributes	?	Weber, Eisenfuhr & von Winterfeldt (1988)
2. Organizational Resource Allocation	Money	Investments	Naïve Diversification	Benartzi & Thaler (2001) Langer & Fox (2004)
	Benefits and burdens	Group Members	Equality Heuristic	Messick (1993) Fox, Ratner & Lieb (2004)
3. Consumer Choice	Fixed number of choices, money	Consumption Options	Variety-seeking	Simonson (1988) Fox, Ratner & Lieb (2004)

a demand effect whereby a participant considers the assessment as an implicit conversation with the experimenter in which the experimenter is expected to adhere to accepted conversational norms, including the notion that any contribution should be relevant to the aims of the conversation (Grice, 1975; Orne, 1962).

Although we agree that in some instances norms of conversational implicature may play a role in partition dependence, we assert that they do not provide an adequate explanation of this phenomenon for several reasons. First, several of the studies reviewed here demonstrate the robustness of partition dependence even in the presence of monetary incentives (e.g., participants allocated money over chance lotteries in which some of them were to play their choices for real money) or real choices (e.g., all participants selected candies to take home). Second, some studies demonstrate the robustness of partition dependence when participants are explicitly told that the categories into which the space is partitioned are arbitrary and that they should feel free to allocate 0% or 100% to any of the categories identified (e.g., when participants allocated financial aid to families of different income ranges). Third, some studies demonstrate the robustness of partition dependence when participants are explicitly made aware of the different partitions that are being presented to different groups (e.g., when participants assigned themselves on the basis of their telephone number to different partitions of the closing values of stock indices, for which they judged the probability). Fourth, the "demand effect" interpretation cannot readily explain the finding in several studies that participants very often provide precisely even allocations (e.g., the median allocation of probabilities for the Jakarta Stock Index were precisely 1/4 for each of four ranges, regardless of partition condition). It could be argued that conversational norms would imply that an allocation question is relevant only if the experimenter thinks that reasonable respondents will distinguish among the available options. Finally, even if respondents do surmise that there is information conveyed by the particular partition with which they are presented, we assert that people may draw such conclusions not only in the laboratory but also in more naturalistic settings in which the partition is determined by arbitrary factors.

3.2. Related phenomena

The notion that different descriptions of the same problem facilitate different psychological representations – and in turn different responses – has been observed in a variety of other domains of decision making. In prospect theory (Kahneman & Tversky, 1979; Tversky & Kahneman, 1992) choices and attitudes toward risk are affected by how participants subjectively represent options in terms of losses and gains relative to a reference point, and this representation can be manipulated through variations in the framing of options (e.g., Kahneman & Tversky, 1986). For instance, physicians' recommendations varied as a function of whether the possible outcomes of particular treatments were described in terms of survival versus mortality rates (McNeil, Pauker, Sox, & Tversky, 1982). Researchers have also found that the subjective packaging of consequences ("mental accounting") can influence choices. For instance, people generally find positive outcomes more attractive when they are

segregated and they find negative consequences less unattractive when they are integrated (Thaler, 1985, 1999). For example, most respondents in one study thought that a person who had won $50 in one lottery and $25 in another would be happier than a person who had won $75 in a single lottery; similarly, most respondents thought that a person who had received a letter from the IRS saying that there had been a mistake in his tax return and that he owed $100 and another letter from the state income tax authority saying that he owed $50 would be more upset than another person who only received one letter saying that he owed $150 to the IRS due to a mistake in his tax return.

Description-dependence has also been observed in other domains of judgment and decision making, as well as reasoning and problem solving. Events (e.g., precipitation in Chicago next April 1) are often judged to be more likely when they are described as disjunctions of constituent events (e.g., rain or sleet or snow or hail in Chicago next April 1), a phenomenon known as "unpacking" (Rottenstreich & Tversky, 1997; but see Sloman et al., 2004). Similar effects have been observed in pricing of prospects: in one study, participants were willing to pay more for an insurance policy that covered "hospitalization for any accident or disease" than they were for a policy that covered "hospitalization for any reason" (Johnson, Hershey, Meszaros, & Kunreuther, 1993). People are more successful verifying logical statements when they are described in terms of familiar and concrete events than when they are described in more abstract terms (Wason and Johnson-Laird, 1972). People also have an easier time solving challenging puzzles when they are represented using isomorphs that impose lower working memory demands (Kotovsky, Hayes & Simon, 1985).

3.3. Extensions

Although we have argued that partition dependence derives from reliance on maximum entropy heuristics, we assert that partition dependence may also be observed in situations where people apply *minimum* entropy heuristics. If decision makers in some contexts prefer not to diversify but instead mass their allocations on a single category, then the way in which they partition the set of available options will also influence their resulting choices. For instance, suppose that an uncle shopping for holiday gifts for four nieces wishes to give them all the same "kind" of present so that they are not envious of one another. He enters a toy store that sells books, stuffed animals, crafts, and games. If this is the way the uncle categorizes the options then he may select books for all four nieces. If instead he partitions the option set into educational gifts (books and crafts) versus non-educational gifts (stuffed animals and games) he may stick to educational gifts but pick out some books and some crafts; if he partitions the set instead by gifts for individual use (books and stuffed animals) versus gifts for interactive use (crafts and games) then he may favor interactive toys and purchase some crafts and some games. Thus, even in a situation where the uncle invokes a minimum entropy heuristic, the way in which he partitions the option set influences his allocation of choices.

Reliance on maximum entropy heuristics can lead not only to partition dependence but also other systematic dependencies that cannot be easily reconciled with rational choice theory. First, the implications of even allocation may depend on the units being allocated. Langer and Fox (2004) presented Duke University graduate students with two $20,000 portfolios that consisted of Apple and IBM stocks – one portfolio in which an equal number of shares of each stock were purchased and one portfolio in which an approximately even number of dollars were invested in each stock. All participants were also told the prevailing price at which each stock traded (shares IBM stock were much more expensive than shares of Apple stock). One group was asked to choose between these portfolios described in terms of the number of dollars invested in each stock; another group was asked to choose between the same portfolios described in terms of the number of shares invested in each stock. The results were striking: most participants preferred the equal dollars portfolio when both portfolios were described in terms of the number dollars invested, whereas most participants preferred the equal share portfolio when both portfolios were described in terms of the number of shares invested. Langer and Fox replicated this finding using chance gambles and monetary incentives.

Likewise, the decision to allocate benefits or burdens equally can have different implications depending on the particular units that are being allocated. Harris and Joyce (1980; see also Messick & Schell, 1992) presented participants with a scenario in which five partners took turns selling plants at a stand in a flea market. Partners accumulated joint expenses for running the business and each generated different amounts of revenue from their individual efforts. Some participants were asked to allocate a "fair share" of the joint *profits* among the partners. In this case 43% of participants allocated profits equally and only 1% of participants allocated expenses equally. In contrast, a second group was asked to allocate a "fair share" of the *expenses* among the partners. In this case no participant recommended that profits be allocated equally and 38% of participants recommended that expenses be allocated equally.

In addition to partition- and unit-dependence, the impact of maximum entropy heuristics may depend on the particular procedure that is used to elicit judgments or preferences. Benartzi and Thaler (2001) noted that the tendency to allocate retirement savings evenly across investment instruments was much less pronounced if participants were instead asked to choose among different portfolios that were mixtures of base investments. In one study, they asked a first group of participants to allocate savings between a stock fund and a bond fund, and provided these participants with 27 yearly rates of return for each fund, depicted graphically. They asked a second group to choose among five funds that were (unbeknownst to the participants) mixtures of those two base funds, and provided these participants with yearly returns of each mixture as well the average aggregate return for each mixture. The difference between these elicitation modes was dramatic: participants in the "allocation" condition assigned 56% of their hypothetical savings to the stock fund, whereas participants in the "choice" condition assigned 75% of their hypothetical savings to stocks. Langer and Fox (2004) obtained a similar result using well-specified chance gambles and monetary incentives.

3.4. Areas for future research

We have provided evidence that people rely on a variety of maximum entropy heuristics in a number of arenas of judgment and decision making. We have argued further that the way in which the set of events, attributes, or options are described may influence the partition that people subjectively invoke, and therefore the pattern of judgments or choices that they make. Further research is needed to answer several important follow-up questions.

First, it would be useful to further explore moderators of partition dependence in order to better understand the psychological factors that underlie this phenomenon. We have seen that in some cases people adjust more from maximum entropy distributions and are less susceptible to partition dependence when they are more knowledgeable concerning the events, attributes, or options in question. This pattern was observed in studies of subjective probability assessment (Fox & Clemen, 2004) and consumer choice (Fox, Ratner & Lieb, 2004). It would be interesting to see whether this tendency for knowledge or information to moderate partition dependence extends to other domains such as attribute weighting and resource allocation decisions.

In some situations we surmise that maximum entropy heuristics are spontaneous, associative assessments or default strategies that entail a minimum of conscious attention or reflection, and adjustment entails more conscious elaboration of belief or preference. In such cases we suspect that cognitive load manipulations will tend to suppress the adjustment process and exacerbate partition dependence (as in the fairness study of Roch, et al. 2000). In other situations it may be that maximum entropy heuristics represent a conscious tendency to hedge away from spontaneous, associative assessments of underlying belief or preference that discriminate among possibilities. In these cases cognitive load may instead mitigate partition dependence (as in the bowls of candy study of Fox, Ratner & Lieb, 2004). Likewise, we surmise that time pressure will tend to curtail cognitive elaboration and may in some cases exacerbate or mitigate partition dependence. Also, nonconscious priming of motives may activate or compete with a particular maximum entropy heuristic (see e.g., Bargh & Chartrand, 2001). For instance, variety-seeking in consumer choice seems to be more pronounced in public than in private choice settings (Ratner & Kahn, 2002; Ariely & Levav, 2000), suggesting that activation of a social norm may play a role. Perhaps nonconscious priming of words such as "daring," "novelty," "satiation," or "uncertainty" will exacerbate variety-seeking and likewise resulting partition dependence.

In most of the studies reviewed in this chapter alternative partitions have been made more accessible through experimental manipulations. A second topic for future research is to better understand features of natural environments that influence the partitions that people normally invoke. We surmise that in some cases people are influenced by exogenous factors such as decision trees in which partitions are defined by the analyst. Likewise, subjective grouping may be influenced by physical features of an environment, such as the grouping of product varieties on a supermarket shelf. We suspect that in other cases partitions are determined by entirely endogenous factors and that research literature on learning and categorization may

be helpful in better understanding the subjective partitions that people naturally project on their environment.

Finally, we believe that future research ought to address prescriptive methods for overcoming partition dependence. Several approaches might be fruitful. First, to the extent that one might identify a canonical partition, this ought to be made explicit. For instance, a firm trying to assess the probability that a competitive bid will be accepted by a client may find it natural to assess the probabilities that each firm in the running will have their bid accepted, thereby partitioning by firm. On the other hand, in most situations a single, canonical partition cannot be identified. For example, in judging the probabilities of possible future interest rates one year from today, there is no single, obvious criterion by which to parse the event space. In such cases we recommend that managers and consumers invoke multiple partitions and multiple elicitation methods, attempting to actively reconcile any discrepancies that arise. For instance, participants might assess probabilities for various partitions of the same space and also assess confidence intervals, then try to integrate the output of these disparate methods. Finally, we suggest that the relevant judgment or decision making process might be formally modeled so that the extent of the bias across partitions might be measured and thereby subtracted from the relevant assessment. Future research is needed to identify proper parameterizations of such models and assess their validity.

NOTES

* Completion of this project was supported in part by NSF grant SES-0099209 to Craig Fox. We thank Kelly See for helpful discussions.

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