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A Taxonomy of Decision Biases

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Introduction

One aspect of behavioural decision theory that is of potential value to decision support systems (DSS) researchers and ultimately to systems analysts involved in developing DSS, is the notion of bias in decision making. Decision biases are cognitions or mental behaviours that prejudice decision quality in a significant number of decisions for a significant number of people. They are also termed cognitive or judgement biases.

Decision biases can be viewed as deviations from rational decision making. Many definitions of rationality have been proposed, with the most extreme being that of neoclassical microeconomics (Friedman, 1957). Simon (1978, 1986) presented alternative definitions of rationality, as have Brunsson (1982) and Arrow (1986). The definition of decision rationality adopted by this report is taken from Dawes (1988). For Dawes, a rational choice meets the following criteria: it is based on the decision makers current assets, it is based on the possible consequences of the choice, and when consequences are uncertain, their likelihood should be evaluated without violating the basic rules of probability theory.

It is beyond the scope of this report to provide a comprehensive review of behavioural decision theory. Slovic, Fischhoff and Lichtenstein (1977), Sage (1981), Einhorn and Hogarth (1981), Pitz and Sachs (1984), Taylor (1984), Hogarth (1987), Dawes (1988), Yates (1990), Keren (1996), Crozier and Ranyard (1997), Pinker (1997), and Bazerman (1998) provide general coverage of the area. In addition, Tversky and Kahneman (1974), Kahneman, Slovic and Tversky (1982), Evans (1989, 1992), Caverni, Fabre and Gonzalez (1990), and Sutherland (1992) *inter alia* focus on decision biases. Wallsten (1980), Hogarth (1981), Berkeley and Humphreys (1982), March and Shapiro (1982), Anderson (1986), Keren (1990), Dawes and Mulford (1996), and Gigerenzer (1991, 1996) provide critiques of heuristics and bias theory. The position adopted in this report is that the biases documented in the studies referred to below indicate a predictable propensity of human decision makers towards irrationality in some important circumstances. While the nature of the underlying psychological processes that lead to biased behaviour is the subject of debate, the experimental findings on biases (decision process artefacts) show persistent biasing in laboratory studies. This behaviour has also been shown in many cases to generalise to real world situations albeit with reduced effect (e.g. Joyce & Biddle 1981). Bias generalisation remains an area in need of considerable research.

Excluded from consideration in this report are factors that influence decisions arising from psychological pathology, religious belief, or social pressure (including customs, tradition and hero worship). The role of intelligence and individual differences in decision bias is largely ignored, as are the effects of visceral factors on decision making (Loewenstein, 1996).

The common use of the word "bias" to categorise the behaviours identified in this report is unfortunate as "bias" has a strong negative connotation for most people. However, decision biases are often positive manifestations of human information processing ability, as the action of biases is generally a source of decision effectiveness. Nevertheless, it is the tendency of biases to cause poor decision outcomes in important decisions that is of concern to systems analysts working in a decision support role.

This report reviews the relevant research literature and suggests a common vocabulary of decision biases for information systems researchers. The report is structured as follows: first, biases are identified, given a standard name and description. A table of related concepts or cognates is also provided. Different taxonomies of biases are reviewed and finally, a new taxonomy relevant to decision support systems is proposed.

Descriptions of Decision Biases

In this section each decision bias is identified by a word or phrase that is shown in upper case. Following this, within quotation marks, is a description of the bias. A brief commentary on the bias follows, and finally, citations relevant to the bias are provided in parentheses. Throughout the remainder of the report the word used to identify each bias will begin with a capital letter to indicate that a bias is being discussed. Decision biases are presented in alphabetical sequence.

1. ANCHORING AND ADJUSTMENT

"Adjustments from an initial position are usually insufficient".

A common human judgement pattern is to begin with an initial position and then adjust opinion. In an environment of continuous feedback this can be an appropriate strategy. In most cases however, the amount of adjustment is insufficient. This has been identified experimentally by asking two groups of subjects to estimate a quantity, but giving each group a different initial position. For example, groups are asked to estimate the length of a river that is known to them but one group is told it is over 500 miles, and the other is told that is under 5,000 miles in length. The first group tends to estimate 1,000 miles the second 3,000; the correct answer is 2,300 miles. This simple experiment demonstrates that the anchor quantity tends to dominate judgement in that once a reference point has been suggested the adjustment from that reference point to the final judgement is usually insufficient. Even when the anchor is determined randomly and the subjects are aware of the arbitrary nature of its determination they still fall subject to the Anchoring and Adjustment bias. Another example of the Anchoring and Adjustment bias is the first impression syndrome, where people fail to correct or adjust their opinion of someone after an instant assessment at their first encounter.

(Tversky & Kahneman 1974; Slovic, Fischhoff & Lichtenstein, 1977; Joyce & Biddle,

1981, Einhorn & Hogarth, 1986; Bazerman, 1990; Chapman & Johnson, 1994; Ganzach, 1996; Estrada, Isen & Young, 1997; Hinsz, Kalnbach & Lorentz, 1997)

2. ATTENUATION

"A decision making situation can be simplified by ignoring or significantly discounting the level of uncertainty."

Perhaps the crudest way to cope with an uncertain decision environment is to simply consider it as certain. For example, some companies are surprised to find the market for their product has changed dramatically by the exploitation of a new technology even when they were fully aware of its existence. The Swiss watch industry's dismissal of digital technology is a dramatic case of regarding a task environment as more certain than an unbiased analysis would indicate. A large amount of the research on Attenuation comes from system theory and cybernetics, particularly in relation to the channel capacity of communication between two systems or two elements of a system. While attenuating an information flow can be functional in that it enables a person to cope with a complex, information rich environment the dysfunctional aspects of Attenuation arise from the often arbitrary and inconsistent processes that act to exclude information (i.e. the most relevant and important items may be excluded).

(Gettys, Kelly & Peterson, 1973; Slovic, 1975; Miller, 1978; Beer, 1981; Hogarth, 1987)

3. BASE RATE

"Base rate data tends to be ignored in judgement when other data is available."

This bias arises when base rate data is ignored or significantly devalued when other data classes are available. The normative approach to combining base rate data with specific or diagnostic data is given by Bayes theory. The Base Rate bias suggests that humans are not intuitively "Bayesian".

The classic experiments on the Base Rate effect usually involve providing subjects with a specific case description together with a vague or implied base data series. For example, graduate students ignore base rate data on graduate specialisation areas when assessing the likelihood of a student belonging to a particular academic area. If the written personality sketch tends to represent an engineer, students predict, by assigning a very high probability (often 1.0) that the student is an engineer even though they know that there are many more graduate students in the humanities than in engineering.

Base rate data does seem to be used correctly when no specific evidence or description is given. However the bias is so persistent that people even ignore base rate data when obviously irrelevant or useless specific evidence is provided. The Base Rate bias may be due to the possibility that concrete current information more easily provides access to cognitive scripts than does abstract information or prior statistics. Base rate data

may however, only be ignored when the subject feels that it is irrelevant to the judgement situation. Saliency and representativeness explanations can be seen as contributing factors to information relevance. If base rate data is perceived to be more relevant than specific data it will dominate the judgement and vice versa.

(Kahneman & Tversky, 1972,1973; Tversky & Kahneman, 1974; Lyon & Slovic, 1976; Bordiga & Nisbett, 1977; Lichtenstein et al., 1978; Bar-Hillel & Fischhoff, 1981; Joyce & Biddle, 1981; Christensen-Szlanski & Beach, 1982; Tversky & Kahneman, 1982; Fischhoff & Beyth-Marom, 1983; Hogarth, 1987; Bar-Hillel, 1990; Kleiter et al., 1997)

4. CHANCE

"A sequence of random events can be mistaken for the essential characteristic of a process."

The Chance bias arises when people mistake a random process as a persisting change. It acts against the normative principle of statistical independence that suggests that if events are independent, knowledge of one event outcome should have no bearing on another succeeding event. People who expect a corrective movement towards perceived fairness after witnessing a run of independent events are subject to the negative consequences of the Chance bias. For example, many people believe that a black win at the roulette table is highly probable (even approaching certainty) after a series of ten red wins. Studies that show Chance effects in statistically literate scientists support the major implication of this bias; humans are generally poor at perceiving randomness.

(Smedslund, 1963; Ward & Jenkins, 1965; Lathrop, 1967; Tversky & Kahneman, 1971,1973,1974; Kahneman & Tversky, 1972; Langer, 1977; Lopes, 1981; Hogarth, 1987; Lopes & Oden, 1987; Wagenaar, 1988; Ayton, Hunt & Wright, 1989)

5. COMPLETENESS

"The perception of an apparently complete or logical data presentation can stop the search for omissions."

The Completeness bias has two major forms. The first is when a presentation (either printed or verbal) is perceived as being definitive; all aspects or consequences seem to have been covered. The second form of the bias is when a data display appears logical or believable. Consider the table of sales estimates discussed in the Regression bias section (Table 2). When asked which column of the table is most likely to be closest to the actual outcome most managers select "Regressed B". This is probably because this column appears more logical in the sense that the dollar figures are not rounded to the nearest \$500,000 and therefore appear more realistic. However, the results in this column are no more likely than those of "Regressed A". Whichever version of the Completeness bias is in action the effect is the same, to curtail the search for more data regarding the decision. (Fischhoff, Slovic & Lichtenstein, 1978; Hogarth, 1987)

6. COMPLEXITY

"Time pressure, information overload and other environmental factors can increase the perceived complexity of a task."

Various environmental factors can influence decision quality in a negative manner. These factors act to amplify the negative impact of decision biases. Task stress, that is stress that arises and is restricted to the decision at hand, is one aspect of the Complexity bias.

The relationship of task stress to decision quality is called the Yerkes-Dodson Law (Yates, 1990) and is shown in Figure 1. A common source of task stress is extreme time pressure on decision making. Other factors that can make a task seem more complex than is warranted include its perceived importance, the volume of data presented from all sources (including the Redundancy bias) and task novelty.

(Pollay, 1970; Einhorn, 1971; Janis, 1972; Wright, 1974; Koriat et al., 1980; Payne, 1982; Pitz & Sachs, 1984; Yates, 1990; Maule & Edland, 1997; Ordonez & Benson, 1997)

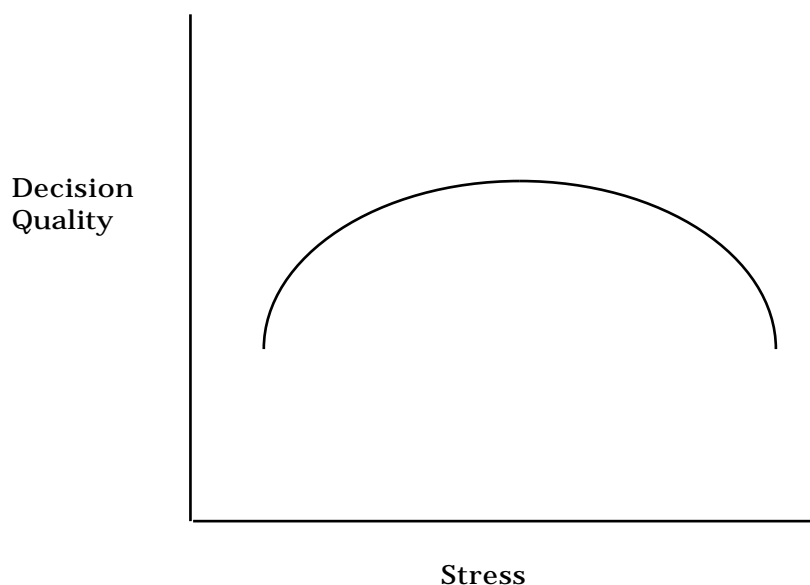


Figure 1: The Yerkes-Dodson Law

7. CONFIRMATION

"Often decision makers seek confirmatory evidence and exclude search for disconfirming information."

The Confirmation bias acts against one of the foundations of scientific method: information that refutes a hypothesis is more valuable than information that supports the

hypothesis. In the following example from Einhorn and Hogarth (1978) subjects were asked to check the claim that an analyst always successfully predicts a rise in the market i.e. whenever they publish a favourable report the market does actually rise. Cards with the analyst's predictions on one side and the actual outcome on the other were presented as in Figure 2. Which cards would you turn over in order to provide the minimum evidence to evaluate the analyst's claims?

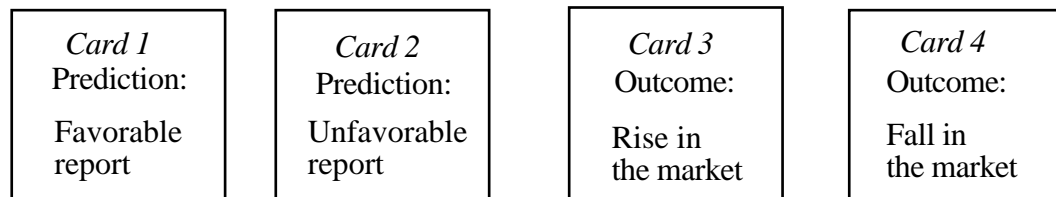


Figure 2: A Selection Task

The two most popular responses are "card 1" and "card 1 and card 3". People who make such selections are searching for confirming information and ignoring the value of disconfirming information. The scientifically correct answer is "card 1 and card 4". Card 1 allows the testing of the claim - turning it will immediately reveal whether the outcome was a fall or rise and thereby test the claim. However it does not test the situation of when the analyst makes a favourable report and the market falls. Only card 4 can test this outcome. Card 2 is irrelevant, as unfavourable reports have nothing to do with the claim. Card 3 will add no new information because if the other side is a favourable report, card 1 has already tested this case and if it shows an unfavourable report it is irrelevant to the claim.

The Confirmation bias can also occur as a fact/value confusion where strongly held values are presented as facts and information that contradicts ones values is ignored. Fact/value confusion could also be seen as the intersection of the Confirmation and Conservatism biases.

(Cyert, Dill & March, 1958; Simon, 1958; Wason, 1960; Einhorn & Hogarth, 1978,1986; Fischhoff & Beyth-Maron, 1983; Hogarth, 1987; Evans, 1989; Bazerman, 1990; Russo, Medvec & Meloy, 1996, Heath, 1996)

8. CONJUNCTION

"Probability is often over-estimated in compound conjunctive problems."

Conjunctive events are compound events where each element of the compound contributes to the final outcome. For example, a building project is a conjunctive event when all elements must be completed on schedule for the final outcome to be on time.

Compound conjunctive events should be assessed according to the multiplication rule of probability theory.

The Conjunction bias acts when people fail to use such a rule and severely overestimate the probability of conjunctive events. This explains the often-excessive optimism displayed by systems analysts in estimating the total time required to complete a complex project. It is not unusual for the sum of time estimates for the individual stages of the project to be much greater than the total project estimate.

(Chesnick & Harlan, 1972; Bar Hillel, 1973; Cohen, Tversky & Kahneman, 1974; Yates, 1990; Teigen, Martinussen & Lund, 1996; Bazerman, 1998)

9. CONSERVATISM

"Often estimates are not revised appropriately on the receipt of new significant data."

The Conservatism bias in some ways is similar to the Base Rate bias in that it has to do with the revision of opinion with the receipt of new information. The Base Rate bias has the effect of overweighing new concrete or sample data. Conservatism seems to have an opposite effect. Under Conservatism people do not revise judgement on receipt of new data. Conservatism acts to protect the waste of the prior cognitive effort of making a decision. This is irrational according to the "future prospects" aspect of the definition of rationality. Conservatism is different to Base Rate, as the latter does not rely on stored data or a previous decision.

(Peterson, Schneider & Miller, 1965; Phillips & Edwards, 1966; Phillips, Hays & Edwards, 1966; Edwards, 1968; DuCharme, 1970; Sage, 1981; Fischhoff & Beyth-Marom, 1983; Hogarth, 1987; Highhouse, Paese & Leatherberry, 1996; Nelson, 1996)

10. CONTROL

"A poor decision may lead to a good outcome inducing a false feeling of control over the judgement situation."

Understanding the level of control a person believes they have over a given situation is a complex issue beyond the scope of this report. Some psychotherapists attempt to manipulate the client's feeling of control in an attempt to overcome a range of pathologies (Dawes, 1988). It is important for everybody to have a feeling of some control over their life but when such control is in reality minimal and an important decision is to be made, the outcome can be disastrous.

For a systems development task, the Control bias arises when subjective probabilities of an event are systematically assessed to be higher than the relevant objective probabilities. Merely thinking about an event can induce the Control bias. Rigorous planning can also induce the bias. For example, MIS departments that develop strategic plans for the application and management of information technology in an organisation often feel more in control of the situation than is actually warranted.

(Tversky & Kahneman, 1974; Langer, 1975; Langer & Roth, 1975; Dawes, 1988; Koehler, Gibbs & Hogarth, 1994; Budescu & Bruderman, 1995; Greenberg, 1996)

11. CORRELATION

"The probability of two events occurring together can be overestimated if they can be remembered to have co-occurred in the past."

The concept of correlation does not develop in a human until about 14 or 15 years of age. Once a correlation has been committed to memory it is quite resistant to change. This seems to be true despite the possibility of small sample effects or complete error in correlation. In some cases Correlation effects can override the receipt of new, contradictory information. An example of the Correlation bias is believing a particular city to have an undesirable climate because the only occasion that the person was there it was cold and raining heavily. In fact it may have a highly desirable climate. The Correlation bias may be a major cause of superstitious behaviour.

(Smedsland, 1963; Ward & Jenkins, 1965; Chapman, 1967; Chapman & Chapman, 1969; Golding & Porer, 1972; Tversky & Kahneman, 1973,1974; Piaget & Inhelder, 1975/1951; Shweder, 1977; Crocker, 1981; Alloy & Tabachnik, 1984)

12. DESIRE

"The probability of desired outcomes may be assessed to be greater than actually warrants."

The Desire bias is in some sense related to the Control bias but does not relate to past decisions or experiences; rather it has to do with wishful thinking, the importance of the outcome to the decision maker, and greed. As with Control, subjective probabilities are set significantly higher than objective probabilities. People who want to win a lottery, get a particular job, or have their football team win, can easily overestimate success even when they already have, or have access to information that should abate their desire. While some element of overconfidence is functional, the Desire bias can seriously reduce decision quality.

(Einhorn & Hogarth, 1986; Hogarth, 1987; Dawes, 1988; Budescu & Bruderman, 1995; Olsen, 1997)

13. DISJUNCTION

"Probability is often under-estimated in compound disjunctive problems."

Disjunctive events are compound events where elements of the compound are not required to combine to create the final outcome. For example, for a computer to fail only one of a large number of key elements has to fail. Disjunctive events should be assessed using the addition rule of probability theory.

The Disjunction bias acts when people under-estimate the likelihood of

disjunctive compound events occurring. An example of this is the almost universal under-estimation of the likely failure of large computer networks. (Cohen, Chesnick & Harlan, 1972; Bar Hillel, 1973; Tversky & Kahneman, 1974; Bazerman, 1998)

14. ESCALATION

"Often decision makers commit to follow or escalate a previous unsatisfactory course of action."

Escalation involves increasing the commitment of resources to a decision even after the previous decision is known to have been incorrect. Rational decisions should be based on the assessment of future possibilities and probabilities. This implies that the past and present are relevant to judgement only to the extent that they provide information that can be used to assess future events. In general this involves the abandonment of sunk or non-recoverable costs associated with the decision. Escalation can be rational if the costs of abandonment, or non-escalation, outweigh the benefits. This could arise when the decision maker's reputation could be seriously damaged and the economic cost of escalation is low.

Bazerman (1998) describes Escalation as being either "unilateral" and caused by internal factors, or "competitive" and resulting from a desire to win or overcome active opposition. Non-rational Escalation is strongest when the failure of the prior decision can be attributed to random external factors and when the decision maker feels close to the attainment of a goal. People are less likely to escalate if an active decision or intervention is required.

Escalation can be viewed as a meta-bias. The decision biases underlying Escalation include Confirmation, Adjustment, Framing, and Success. Other psychological factors such as motivation, peer and social pressure can also induce non-rational escalation of commitment to a course of action.

(Staw, 1976,1981; Staw & Ross, 1978; Teger, 1980; Northcraft & Wolf, 1984; Brockner & Rubin, 1985; Schwenk, 1986; Drummond, 1994; Beeler & Hunton, 1997; Bazerman, 1998)

15. FRAMING

"Events framed as either losses or gains may be evaluated differently."

Framing, a complex bias addresses deviations from the normative rules of cancellation, transitivity, dominance and invariance. Framing is an extremely important bias for decision support systems and information systems in general, as it has to do with the impact of the structure of information display or presentation on human information processing.

Table 1: A Test of Invariance

Problem 1 (Survival Frame) (N=247)

Surgery: Of 100 people having surgery 90 live through the post-operative period, 68 are alive at the end of the first year and 34 are alive at the end of five years.

Radiation Therapy: Of 100 people having radiation therapy all live through the treatment, 77 are alive at the end of one year and 22 are alive at the end of five years.

Problem 2 (Mortality Frame) (N=336)

Surgery: Of 100 people having surgery 10 die during surgery or the post-operative period, 32 die by the end of the first year and 66 die by the end of five years.

Radiation: Of 100 people having radiation therapy, none die during treatment, 23 die by the end of one year and 78 die by the end of five years.

An example of the Framing bias in medical decision making, taken from McNeil et al. (1982) is the choice between two cancer therapies. The two problems in Table 1 are presented differently but both contain the same basic data. Normative theory holds that formulation should have no effect on rational choice. Each formulation of the data was presented to experienced physicians (to consider if decades of training and experience effect the bias), cancer patients (who have an important stake in the decision) and graduate business students with a strong statistics background (who should be aware of the normative principle). The overall percentage of people that chose radiation varied from 18% in the survival frame to 44% in the mortality frame. The effect was the same for all three groups of subjects suggesting that the Framing bias is resistant to domain education, motivation or stakeholding, and statistical literacy.

The most influential explanation of the Framing bias is prospect theory (Kahneman & Tversky, 1979; Tversky & Kahneman, 1986). Prospect theory holds that when choices are framed as gains or losses they are evaluated relative to a neutral point. Information is framed and edited such that the value of a choice can be assessed according to the persons value function for the task. An example value function is shown in Figure 3. This value function predicts that people will tend toward risk aversion for gains (i.e., the marginal value received from each additional amount of gain falls dramatically) and risk seeking for losses. Further, given the shape of the function, reaction to losses is likely to be more extreme than the reaction to gains.

A major implication of prospect theory for decision support systems is that how

the data is framed in output reports or screens may be more important than technical information systems concerns such as data modelling methods, data accuracy and currency.

(Lichtenstein & Slovic, 1971,1973; Hogarth, 1975,1987; Grether & Plott, 1979; Kahneman & Tversky, 1979,1984; Tversky & Kahneman, 1981,1986; McNeil, Pauker, Sox & Tversky, 1982; Fischhoff, 1983; Keller, 1985; Christensen, 1989; Wang, 1996; Kunberger, 1997)

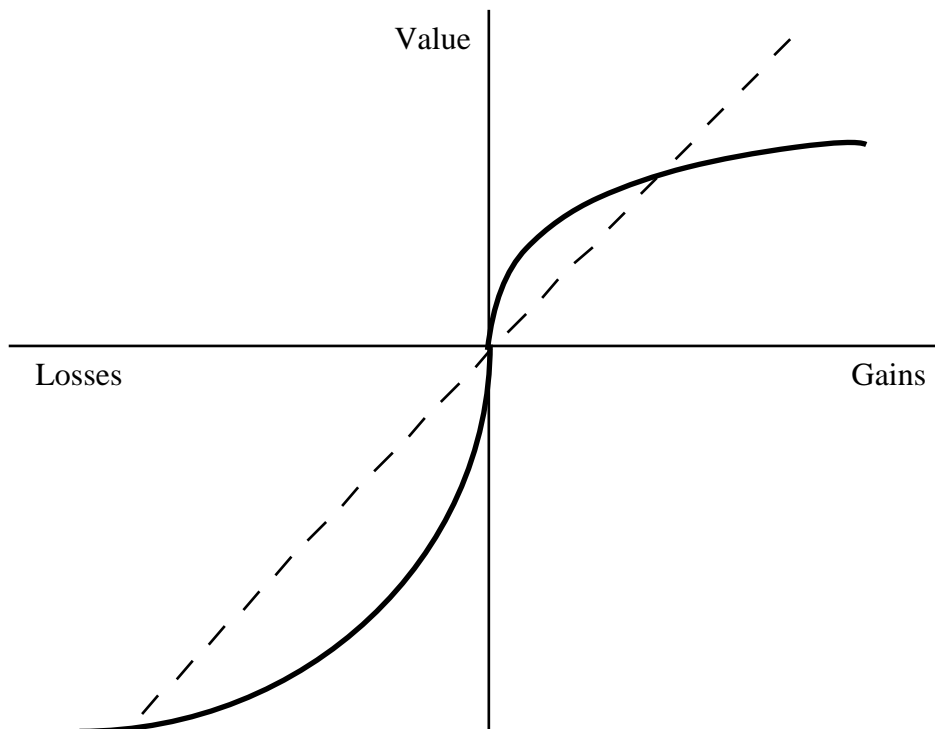


Figure 3: A Value Function from Prospect Theory

16. HABIT

"An alternative may be chosen only because it was used before."

Habit is an indicator of the avoidance of cognitive work in decision making and represents the extreme case of bounded rationality. While habit can be functional in many cases, especially in simple decisions where the outcomes are relatively unimportant, it can be dysfunctional for some important decisions. Habit is a broader concept than Conservatism and Confirmation but the basic process could be the same as it acts to prevent the search and consideration of new information. A common example of the Habit bias is irrational consumer brand loyalty.

(Gettys, Kelly & Peterson, 1973; Slovic, 1975; Hogarth, 1987)

17. HINDSIGHT

"In retrospect the degree to which an event would have been predicted is usually over-estimated."

After hearing of an unusual election result a commentator reports "I knew that candidate X would win", a gambler sighs when a card is turned and says, "I thought so", an information system is pronounced as not supporting the users and the systems analyst claims "I predicted this". All are probably examples of the Hindsight bias. Hindsight acts to increase people's confidence in their decision making abilities but it also reduces their ability to learn from past events. In some sense it is related to Testimony and other memory biases in that the knowledge of an event occurrence seems to effect recollection.

Hindsight may be caused by the action of Tversky & Kahneman's general heuristics with insufficient adjustment from current knowledge, the new information being more concrete or vivid thereby crowding out prior knowledge and evidence consistent with the outcome being more available in memory.

(Fischhoff & Beyth, 1975; Fischhoff, 1975,1982; Langer & Roth, 1975; Fischhoff, Slovic & Lichtenstein, 1977; Buchman, 1985; Dawes, 1988; Bazerman, 1990; Connolly & Bukszar, 1990; Polister, 1989; Mazursky & Ofir, 1997; Ofir & Mazursky, 1997)

18. IMAGINABILITY

"An event will be judged more probable if it can be easily imagined."

Imaginability is a result of the human ability to construct abstract models from memory. For example, if the dangers of an expedition formed to investigate a previously unexplored area are difficult to imagine then the explorer is likely to seriously underestimate the probability of accident or mishap. Imaginability is probably some function of experience, memory and intellect.

(Tversky & Kahneman, 1974, Lichtenstein et al., 1978, Taylor & Thompson, 1982)

19. INCONSISTENCY

"Often a consistent judgement strategy is not applied to an identical repetitive set of cases."

Inconsistency is a common judgement pattern even for experienced decision makers in a specialist domain. For example, in a university department the two tasks that are most likely to be affected by this bias are graduate admissions and examination marking. This is despite the significant experience, training and capability of the academics involved in these tasks. The causes of Inconsistency are not known with certainty but include boredom, distraction, fatigue, and the general human desire for variety.

(Bowman, 1963; Kunreuther, 1969; Goldberg, 1970; Einhorn, 1972; Brehmer, 1976; Showers & Charkrin, 1981; Moskowitz & Sarin, 1983; Hogarth, 1987)

20. LINEAR

"Decision makers are often unable to extrapolate a non-linear growth process."

The Linear bias suggests that when forecasting or identifying change, humans tend to approximate using a linear function. When the change process is in reality exponential in nature the Linear bias can seriously affect judgement quality. The Linear bias is resistant to attempted reduction by changing the presentation of data from tabular to graphical displays.

Growth processes are better perceived when inverse functions are used. For example, using the number of square miles per person for estimation of population density rather than the number of people per square mile may improve judgement. Importantly for DSS, the continuous monitoring of a growth process is liable to produce the strongest bias.

(Cohen, Chesnick & Harran, 1972; Bar-Hillel, 1973; Wagenaar & Sagaria, 1975; Wagenaar & Timmers, 1979; Mackinnon & Wearing, 1991; Arnott, O'Donnell & Yeo, 1997)

21. MODE

"The mode and mixture of presentation can influence the perceived value of data."

The mode of presentation or transmission of information can systematically influence judgement. Managers for example prefer verbal to written reports and within verbal reporting prefer face to face dialogues to telephone conversations. The relative mixture of qualitative and quantitative data presented may bias judgement. In general, anecdotal opinion from a conversation is given more weight than a table of numbers on a computer printout. In turn, computer output is often given more weight than a hand-written report. Given that the actual information is the same in all of the modes mentioned above, it is irrational *ceteris paribus* to weight different modes differently in judgement.

(Mintzberg, 1973; McKenney & Keen, 1974; Payne, 1976; Russo, 1977; Kotter, 1982; Remus, 1984; Hogarth, 1987; Saunders & Jones, 1990; Carey & White, 1991; Vessey, 1994; Dusenbury & Fennema, 1996; Bhappu, Griffith & Northcraft, 1997)

22. ORDER

"The first or last item presented may be over-weighted in judgement."

From a normative viewpoint the sequence of presentation of events or information should have no impact on judgement. Descriptive studies repeatedly show that in some cases earlier events are more heavily weighted (the primacy effect) while in others the most recent event is over weighted (the recency effect). For example, when interviewing job applicants the first and the last may be given a higher rating than is warranted because of this bias. On a lower level of abstraction, the sequence of data items presented on an enquiry screen may be more important in determining the decision outcome than the data

itself.

(Ronen, 1973; Budescu, Au & Chen, 1997; Anderson, 1981; Yates & Curley, 1986; Dawes, 1988; Chapman, Bergus & Elstein, 1996)

23. OVERCONFIDENCE

"The ability to answer difficult or novel questions is often over-estimated."

Substantial overconfidence is a common but not universal judgement pattern. Most experiments on this bias attempt to measure the degree of a subject's metaknowledge (i.e. how much they know about how much they know) through the analysis of almanac questions. The Overconfidence bias is strongest for difficult questions where the domain is relatively unknown to the subject. Experts show significantly less overconfidence than naive subjects do; in some tasks showing no Overconfidence at all. Underconfidence is not uncommon in expert judgement.

Russo and Schoemaker (1992) suggest that Overconfidence is a complex behaviour caused by Adjustment, Confirmation, Hindsight, Recall and Similarity biases as well as some physiological and motivational causes. A large academic literature addresses Overconfidence in terms of judgement accuracy, in particular the calibration of judgement accuracy.

(Oskamp, 1965; Howell, 1972; Fischhoff, Slovic & Lichtenstein, 1977; Koriat, Lichtenstein & Fischhoff, 1980; Sage, 1981; Lichtenstein, Fischhoff & Phillips, 1982; Schwenk, 1986; Bazerman, 1990; Yates, 1990; Paese & Feuer, 1991; Sniezek & Buckley, 1991; Russo & Schoemaker, 1992; Brenner, Koehler, Liberman & Tversky, 1996, Dawes & Mulford, 1996; Yates & Lee, 1996; Keren, 1997)

24. RECALL

"An event or class will appear more numerous or frequent if its instances are more easily recalled than other equally probable events."

Ease of recall from memory is to a large extent determined by the familiarity, salience, and vividness of the event being recalled. If a person is asked to recall what primary school was like, it is usual for them to relate a particularly vivid incident such as a schoolyard confrontation with a bully. While this is easy to recall it may not be representative of the school experience. There are evolutionary reasons for the Recall bias but in many decision situations it can lead a decision maker to overweigh easily remembered information to the detriment of more relevant memories or new information. (Tversky & Kahneman, 1971,1973,1974,1981; Kahneman & Tversky, 1972; Fischhoff, Slovic & Lichtenstein, 1978; Combs & Slovic, 1979; Taylor & Thompson, 1982; Hogarth, 1987; Bazerman, 1998)

25. REDUNDANCY

"The more redundant and voluminous the data the more confidence may be expressed in its accuracy and importance."

Redundancy occurs when people overestimate the probability of occurrence or the importance of an event or data set that is repeatedly presented to them. Sporting coaches use this effect by repeatedly telling their teams or individual athletes that they are "the greatest". The Redundancy bias can also arise when the same message is received from a number of sources; they may all be in error. This bias can also be induced when the quantity of data being presented or perceived as being presented to the decision maker is very large.

(Ward, 1965; Ward & Jenkins, 1965; Tversky & Kahneman, 1974; Estes, 1976; Remus & Kotterman, 1986; Arkes, Hackett & Boehm, 1989)

26. REFERENCE

"The establishment of a reference point, or anchor can be a random or distorted act."

This bias is in one sense part of Anchoring and Adjustment. People like to judge situations starting from a reference point and then adjust judgement. Such a strategy is normally rational and yields effective decisions. It also greatly reduces cognitive work in decision making. However if the reference point is arbitrary or if the establishment of the reference point is biased by a number of other factors, judgement will be adversely effected. An example of the Reference bias is the common practice of using the salary of an interviewee's previous job as a starting point in negotiating a salary for a new position. The previous salary may have been set in a arbitrary way, may have been carried forward from a more senior position after redeployment, may have been high because of a short term contract situation, or a host of other explanations. Such possibilities are rarely considered and yet the decision to employ is usually an important or strategic decision, in economic as well as professional terms for any organisation.

(Tversky & Kahneman, 1974; Sage, 1981; Bazerman, 1998)

27. REGRESSION

"That events will tend to regress toward the mean on subsequent trials is often not allowed for in judgement."

In an example of this bias based on Bazerman (1998) a systems analyst is assisting a manager with their forecast of the sales in nine department stores for the next year. The firm's economic research consultants have forecast total group sales to increase by 10% to \$99,000,000. Table 2 shows the base or current year's results for each store in the group. Most managers faced with this common judgement will apply a 10% increase to each store in order to predict the next year. In doing so they are likely to be subject to the Regression bias. If the base year is a perfect predictor of performance then this approach

is rational. If no prediction is implied by the base year performance then each store should have an equal share of the forecast revenue. The most likely situation is for sales to regress towards the mean. Two different regressed forecasts are shown in the last two columns of the table. While people do take regression into account for extreme events (such as a bottom of the ladder football team beating the top ranked team) they generally do not cater for regression in less extreme but still important situations.

(Kahneman & Tversky, 1973; Einhorn & Hogarth, 1981; Joyce & Biddle, 1981; Bazerman, 1998)

Table 2: Regression Effects in Sales Forecasting

STORE	Base Year	Perfect Prediction	No Prediction	Regressed A	Regressed B
1	12,000,000	13,200,000	11,000,000	13,000,000	12,833,333
2	11,500,000	12,650,000	11,000,000	12,500,000	12,396,010
3	11,000,000	12,100,000	11,000,000	12,000,000	11,901,002
4	10,500,000	11,550,000	11,000,000	11,500,000	11,352,068
5	10,000,000	11,000,000	11,000,000	11,000,000	11,000,000
6	9,500,000	10,450,000	11,000,000	10,500,000	10,534,290
7	9,000,000	9,900,000	11,000,000	10,000,000	10,101,070
8	8,500,000	9,350,000	11,000,000	9,500,000	9,642,197
9	8,000,000	8,800,000	11,000,000	9,000,000	9,240,030
TOTAL	90,000,000	99,000,000	99,000,000	99,000,000	99,000,000

28. RULE

"The wrong decision rule may be used."

Even if a decision maker is relatively free of all other decision biases during the bulk of the decision making process they may apply the wrong decision rule during choice. For example, when using a decision tree as a framework for making a decision, a different result is possible depending on whether expected monetary value or expected subjective utility is being maximised.

The classification of decision rules has been the subject of considerable research. Hogarth (1987) classifies decision rules according to how they approach conflict or allow value tradeoffs in choice i.e. between compensatory and non-compensatory models. Sage (1981) approaches decision rule classification by analysing which aspects of a decision situation are considered in decision making. Sage's classification is shown in Figure 4.

(Slovic, 1975; Sage, 1981; Hogarth, 1987; Goodwin & Wright, 1991)

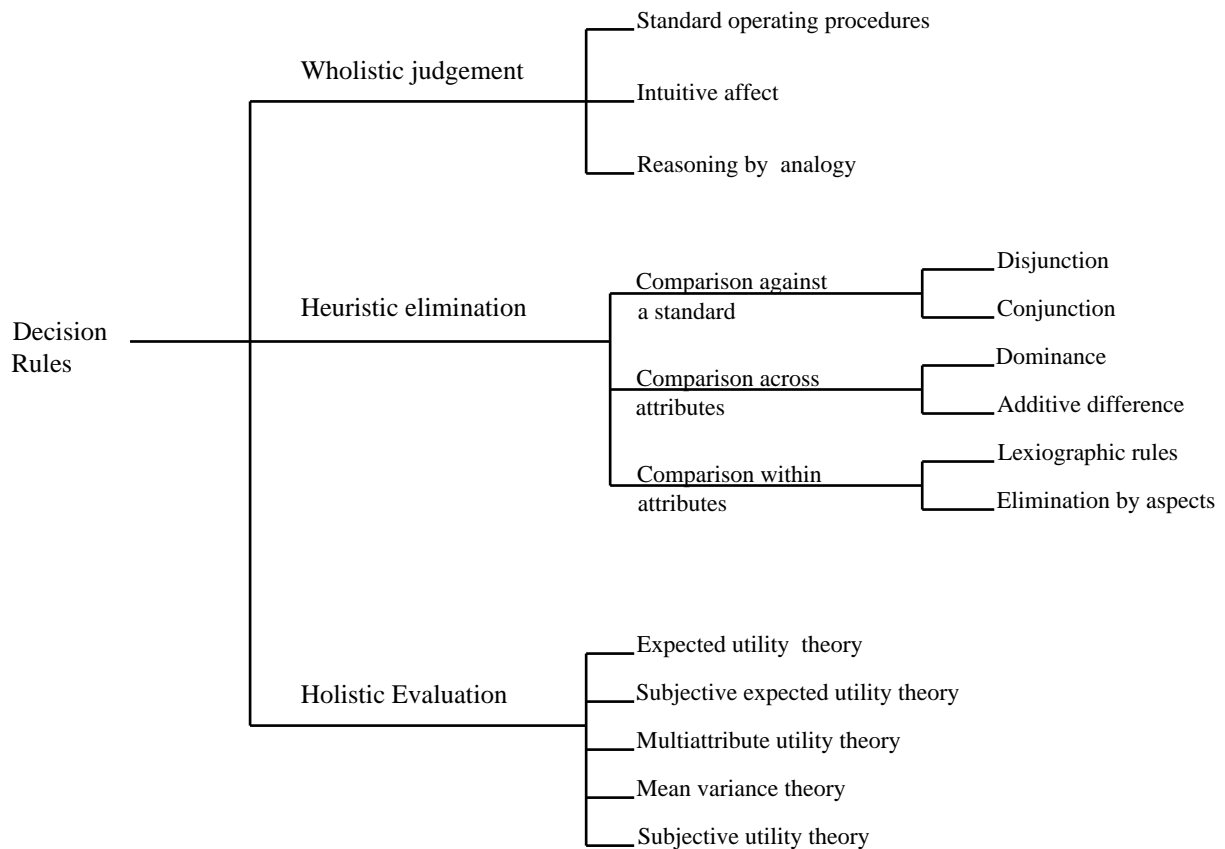


Figure 4: Sage's Hierarchical Structure of Decision Rules

29. SAMPLE

"The size of a sample is often ignored in judging its predictive power."

Sampling is a fundamental human activity that is vital in reducing the perceived complexity of the task environment. The "Law of Large Numbers" holds that relatively large samples will be highly representative of the population they are drawn from. The Sample bias arises when this law is thought to hold for small samples. The Sample bias has been found to hold even for academic psychologists who specialise in statistics when they design experiments or consider changes to non-significant experiments.

(Lee, 1971; Tversky & Kahneman, 1971,1974; Kahneman & Tversky, 1972,1973; Sage, 1981; Nisbett et al., 1983; Bazerman, 1990; Sedlmeier & Gigerenzer, 1997)

30. SCALE

"The perceived variability of data can be effected by the scale of the data."

When information is displayed graphically by a decision support system, the type of scale used can influence human information processing. Using relative or absolute scales, linear or logarithmic scales for the same data set can radically affect the perception of the data. A special case of the Scale bias relates to the persistent human tendency to misjudge

very large differences between quantities. People find it difficult to appreciate quantum differences but are quite good at perceiving differences within the range of one power of ten.

(Remus, 1984; Ricketts, 1990)

31. SEARCH

"An event may seem more frequent due to the effectiveness of the search strategy."

When attempting to recall an event, or some data, the way that the search is conducted can bias the recall. For example, are there more words in the English language that start with "r" or for which "r" is the third letter? Most people reply "start with r" which is incorrect. People are taught throughout their schooling to order words in alphabetical sequence; for example, this report's bias listing is sequenced alphabetically for ease of search. It is therefore easier to recall words that begin with "r". The correct linguistic rule is that consonants are far more likely to occupy the third rather than the first character position in an English word.

(Galbraith & Underwood, 1973; Tversky & Kahneman, 1973,1974; Bazerman, 1998)

32. SELECTIVITY

"Expectation of the nature of an event can bias what information is thought relevant."

The classic experiment on Selectivity (Bruner & Postman, 1949) asked subjects to look at each of a series of playing cards for a short time and name each card. Some of the cards were wrongly coloured e.g. a black ace of hearts. Subjects in general misreported these trick cards. If people expect hearts cards to be red *a priori* it is difficult, for some subjects impossible, to perceive a black heart. The Selectivity bias acts to exclude information that is not consistent with a person's experience.

A special case of the Selectivity bias is where important information is excluded from decision making because of the person's education, affiliation, profession or trade. For example, a clinical psychologist may see a patient's problem in terms of psychological trauma, a medical practitioner in terms of chemical imbalance in the brain, and a faith healer in terms of the action of demons. The same business problem is often perceived differently by the finance, marketing and production departments. Systems analysts and computer programmers will see different problems as important within a system development task.

(Bruner & Postman, 1949; Simon, 1955,1956; Dearborn & Simon, 1958; Cyert, Dill & March, 1958; Tversky & Kahneman, 1971,1974; Kahneman & Tversky, 1972,1973; Schwenk, 1988)

33. SIMILARITY

"The likelihood of an event occurring may be judged by the degree of similarity with the

class it is perceived to belong to."

Bill is an accountant. What is Bill like? Is he likely to be conservative? Is he likely to wear glasses? The answers to these questions can be subject to the Similarity bias in which knowledge about a stereotype can override other considerations. Although in Bill's case the class (accountants) is given, in a more complex decision situation the perception of which class an event or entity belongs to can be subject to bias as well.

(Bar-Hillel, 1973; Tversky & Kahneman, 1973; Horton & Mills, 1984; Hogarth, 1987; Joram & Read, 1996)

34. SUBSET

"A conjunction or subset is often judged more probable than its set."

The subset bias acts contrary to the conjunction rule of probability theory that holds that the probability of the occurrence of the conjunction of two sets cannot be more probable than the occurrence of one of the sets

An example of this bias (after Tversky & Kahneman, 1982) is when people are asked to rank the most likely of the following match possibilities for a famous tennis player:

1. player x will win the match.
2. player x will lose the match.
3. player x will win the first set and then go on to lose the match
4. player x will lose the first set and then go on to win the match

In general, people choose the selection 4 as being more probable than selection 2. A Venn diagram of the tennis player's career history in Figure 5 makes the situation clearer. To lose the first set and win the match can never be more probable than winning the match. (Cohen et al., 1956; Tversky & Kahneman, 1983; Bazerman, 1990; Thuring & Jungermann, 1990; Briggs & Krantz, 1992)

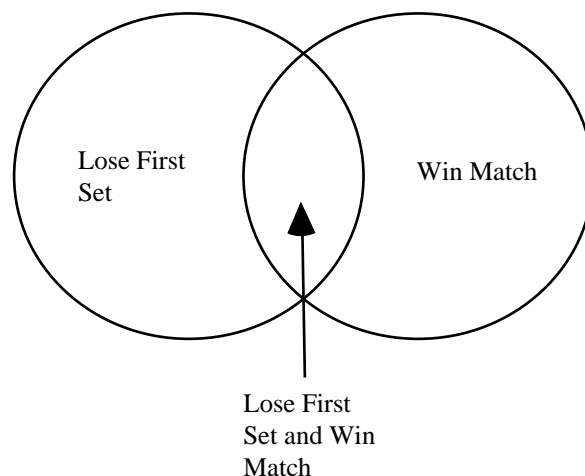


Figure 5: The Subset Bias in a Tennis Match

35. SUCCESS

"Often failure is associated with poor luck and success with the abilities of the decision maker."

The Success bias is related to, but is subtly different from the Control bias. Control addresses situations where poor decision processes have a desirable outcome. Success has to do with a common behaviour pattern of believing that successful decision outcomes are a result of the persons decision making prowess. However failure is attributed to external factors such as unfair competition, weather, timing, and luck. The coach of a sporting team will rarely attribute a victory to good luck but a close loss is invariably unlucky.

(Howell, 1972; Langer & Roth, 1975; Miller, 1976; Nisbett & Wilson, 1977; Ross, 1977; Hogarth, 1987)

36. TEST

"Some aspects and outcomes of choice cannot be tested, leading to unrealistic confidence in judgement."

Often the nature of a task prevents a rigorous evaluation of the decision outcome. When outcomes cannot be evaluated or tested people can overestimate their abilities as decision makers for that task. For example, how good is a staff selection panel's decision making? The decision outcomes (i.e. people selected) can be observed at work and if they are performing well the panel may be congratulated. The Test bias arises in this case because to rationally evaluate the performance of the panel, candidates who were unsuccessful at interview would also need to be evaluated. The adequately performing employee may in fact have been the poorest candidate. The Test bias involves using observed frequencies rather than observed relative frequencies in judgement.

(Wason, 1960; Smedsland, 1963; Ward & Jenkins, 1965; Estes, 1976; Fischhoff; Slovic & Lichtenstein, 1977; Einhorn & Hogarth, 1978; Einhorn, 1980; Christensen-Szalanski & Bushyhead, 1981; Hogarth, 1987)

37. TESTIMONY

"The inability to recall details of an event may lead to seemingly logical reconstructions which may be inaccurate."

The Testimony bias is a result of using cues based on *post fact* information. How the task or question is structured will affect recall or testimony. For example, the following questions taken from Hogarth (1987) relating to an automobile accident are likely to result in different speed estimates:

- how fast were the cars travelling when they *hit* ?
- how fast were the cars travelling when they *collided* ?

- how fast were the cars travelling when they *smashed* ?

The Testimony bias is strongest when misleading and complex questions are asked.

Testimony is exacerbated by the Redundancy bias through an increase in the frequency of retelling or the questioning of evidence.

(Snyder & Uranowitz, 1978; Loftus, 1980; Wells & Loftus, 1984; Hogarth, 1987; Ricchiute, 1997)

Decision Bias Cognates

The decision biases documented in the previous section often appear in psychology, management and information systems literatures under different names. For example, Subset has been termed "the conjunction fallacy" by many authors, and as such is easy to confuse with the Conjunction bias. A non-exhaustive collection of decision bias cognates is presented in Table 3.

Taxonomies of Decision Biases

A significant problem faced by a systems analyst interested in using decision bias theory to in the development of a decision support system is the difficulty of diagnosing the presence of biases for a given task. This is exacerbated by what appears on first reading as extremely fine differences between a number of biases. For example, Recall, Similarity and Search are very similar biases in their effect of reducing the effectiveness of the use of memory in decision making. One method of making bias research more accessible is the development of a taxonomy of biases. This section describes a number of taxonomies that are useful in understanding the interrelationship of decision biases.

The first published taxonomy of decision biases was Tversky and Kahneman (1974). Amos Tversky & Daniel Kahneman are recognised as the founders of cognitive bias theory and their 1974 *Science* paper was the first codification of the area. They based their classification on their own theory of general judgemental heuristics. Following Bazerman (1998), these heuristics can be described as:

Availability - People assess the subjective probability of an event by the degree to which instances are available in memory.

Representativeness - People assess the likelihood of an occurrence by the similarity of that occurrence to the stereotype of a set of occurrences.

Table 3: Decision Bias Cognates

Bias	Cognates	Reference
Adjustment	insufficient adjustment	Bazerman (1998)
Attenuation	best guess strategy ignoring uncertainty	Hogarth (1987) Remus & Kottemann (1986)
Base Rate	insensitivity to prior probabilities of outcomes	Tversky & Kahneman (1974)
Chance	concrete information misconceptions of chance	Hogarth (1987) Tversky & Kahneman (1974)
Completeness	gamblers fallacy	Wagenaar (1988)
Complexity	logical data display	Hogarth (1987)
Confirmation	decision environment confirmation trap selective perception expectations desire for self fulfilling prophecies fact-value confusion	Hogarth (1987) Bazerman (1998) Hogarth (1987) Sage (1981) Sage (1981) Sage (1981)
Conjunction	inertial effect	Cohen <i>et al</i> (1972)
Control	illusion of control	Langer (1975)
Correlation	illusory correlation	Bazerman (1998)
Desire	wishful thinking	Schwenk (1988)
Escalation	non rational escalation of commitment entrapment	Bazerman (1998) Brockner <i>et al</i> (1982)
Framing	question format	Hogarth (1987)
Habit	rules of thumb	Hogarth (1987)
Imaginability	biases of imaginability	Tversky & Kahneman (1974)
Linear	non-linear extrapolation inability to extrapolate growth processes	Hogarth (1987) Remus & Kottemann (1986)
Recall	ease of recall availability	Sage (1981) Hogarth (1987)
Redundancy	bias due to the retrievability of instances illusion of validity repetition implication of strength of relationship	Tversky & Kahneman (1974) Tversky & Kahneman (1974) Arkes, Hackett & Boehm (1989) Remus & Kottemann (1986)
Regression	regression to the mean	Bazerman (1998)
Rule	justifiability	Hogarth (1987)
Sample	representativeness insensitivity to sample size law of small numbers inferring from small samples	Sage (1981) Tversky & Kahneman (1974) Tversky & Kahneman (1971) Remus & Kottemann (1986)
Scale	powers-of-ten information bias	Ricketts (1990)
Search	bias due to the effectiveness of the search set limited search strategies	Bazerman (1998) Remus & Kottemann (1986)
Selectivity	selective perception	Schwenk (1988)
Similarity	representativeness	Hogarth (1987)
Subset	conjunction fallacy	Tversky & Kahneman (1983)
Success	fundamental attribution error success/failure attribution	Sage (1981) Hogarth (1987)
Test	outcome irrelevant learning structures outcome irrelevant learning systems	Hogarth (1987) Sage (1981)
Testimony	logical fallacies in recall logical reconstruction	Hogarth (1987) Schwenk (1988)

Anchoring and Adjustment - People make assessments by starting from an initial value and adjusting this value to arrive at the final decision.

Tversky and Kahneman's taxonomy, using the standard bias names defined in this report, is shown in Table 4. The Tversky and Kahneman (1974) taxonomy still remains influential. The major problem with the taxonomy is its core concept of general heuristics. While biases can be experimentally identified, general heuristics as a theoretical explanation for human decision making is untestable. They do however retain some intuitive appeal as a partial explanation of the action of some biases (Bazerman, 1998). A further problem is that it is difficult to include all the biases identified since 1974 (including those identified by Tversky and Kahneman themselves) in the taxonomy. Some biases, for example Framing, are likely to span all three heuristics.

Table 4: Tversky & Kahneman's Taxonomy	
Heuristic	Bias
Representativeness	Base Rate Sample Chance Similarity Redundancy Completeness Regression
Availability	Recall Search Imaginability Correlation
Anchoring and Adjustment	Anchoring & Adjustment Conjunction Disjunction Overconfidence

Remus and Kottmann (1986) developed a taxonomy of biases from an information systems perspective as part of a project to develop an "artificially intelligent statistician". They developed a three level taxonomy that at the highest level is divided into those biases that are associated with presenting data to the decision maker and those that effect information processing. Their taxonomy is shown, with appropriate translation of descriptors, in Table 5. The table shows the three levels with the highest shown in bold text. This is sub-divided into categories or major biases that are shown in Italics in the left-hand column. The right hand column shows the lowest level of the taxonomy.

One of the most comprehensive and cited bias taxonomies is that of Hogarth (1987). Hogarth classifies biases according to which component of his model of human judgement they may be related. This model of judgement contains three main entities: the person, the task environment and the actions resulting from the judgement. Hogarth's model (Figure 6) shows that decision making occurs within a task environment. Within this environment, the person or decision maker is represented by a schema. The operations of decision making within the schema are decomposed into acquisition, processing and output.

Table 5: Remus & Kottemann's Taxonomy	
Biases Associated with Presenting Data to the Decision Maker	
<i>Irrelevant Information</i>	
<i>Data Presentation Biases</i>	Order Completeness Mode
<i>Selective Perception</i>	Functional Selectivity Confirmation Conservatism
<i>Frequency</i>	Recall Base Rate Correlation Redundancy
Biases in Information Processing	
<i>Heuristics</i>	Similarity Habit Adjustment Inconsistency
<i>Misunderstanding of the Statistical Properties of Data</i>	Chance Sample Attenuation
<i>Search</i>	
<i>Conservatism</i>	
<i>Linear</i>	

Output is located jointly in the schema and task environment and in some cases is considered to be contiguous with action. For Hogarth, biases occur or "intervene" at each stage of the model. They also arise as a result of interactions between different components of the model. The biases that Hogarth associates with each part of the model (expressed in this report's standard names) are documented in Table 6. Hogarth's model of human judgement remains a useful model for decision support systems analysts and his taxonomy provides strong clues as to which biases to consider at different stages of development.

Schwenk (1988) while not proposing a taxonomy of biases does identify those biases that are most likely to effect strategic decision making in a business environment. Since many decision support systems address tasks that are novel, *ad hoc* and/or difficult, the issue of which biases are relevant for strategic decisions is of interest to the systems analyst. The biases identified by Schwenk as being most relevant are Recall, Selectivity, Correlation, Conservatism, Sample, Regression, Desire, Control, Testimony, and Hindsight.

Other reviews of decision biases that offer to some extent a taxonomy of biases include Slovic, Fischhoff and Lichtenstein (1977), Einhorn and Hogarth (1981), Pitz and Sachs (1984), Sage (1981), Isenberg (1984), Hink and Woods (1987), Keren (1990), and Bazerman (1998).

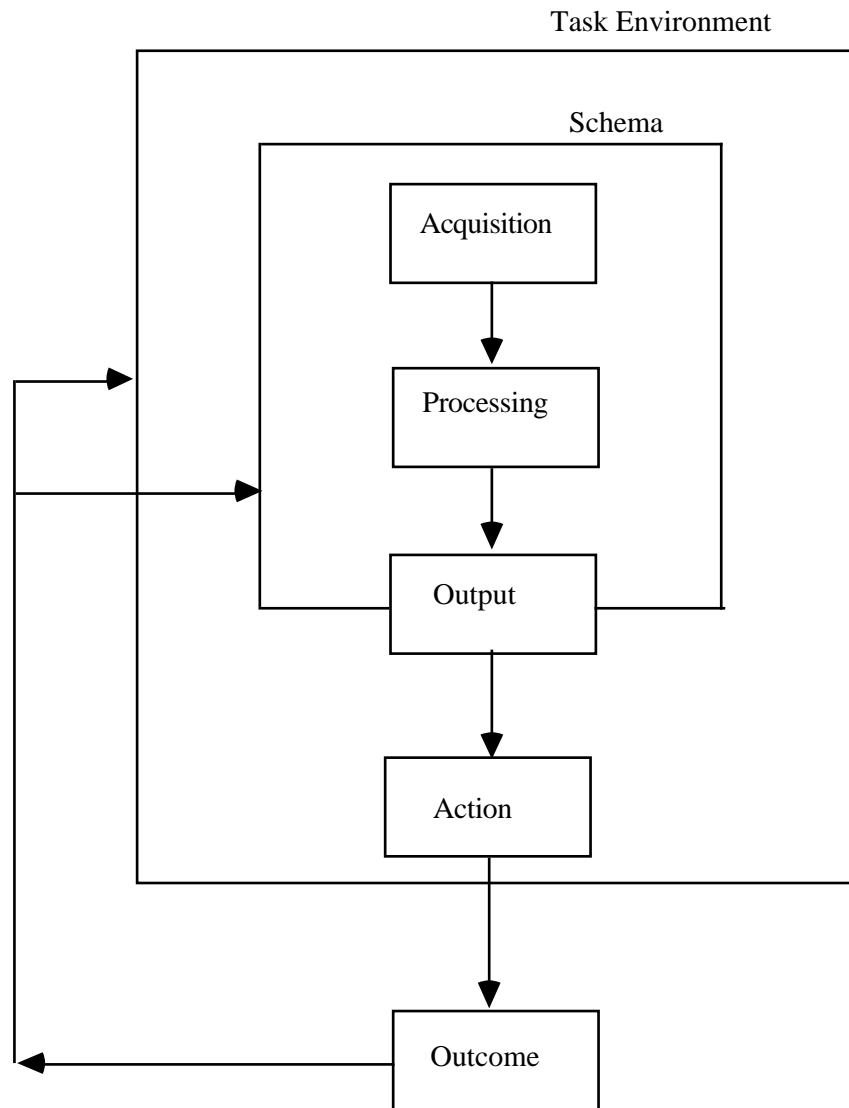


Figure 6: Hogarth's Model of Human Judgement

Table 6: Hogarth's Taxonomy

Model Stage	Biases
Acquisition	Recall Functional Selectivity Confirmation Conservatism Test Base Rate Correlation Completeness Scale Mode Order Framing
Processing	Inconsistency Conservatism Linear Adjustment Habit Similarity Sample Rule Regression Attenuation Complexity Consistency Completeness Scale Mode Order
Output	Framing Desire Scale Control
Feedback	Test Chance Success Testimony Hindsight

A Bias Taxonomy for Decision Support Systems

The discussion in the previous section serves to suggest some of the desirable characteristics of a taxonomy of decision biases. A taxonomy should consolidate knowledge in the area and should help to clarify the relationships between different aspects of decision making. Because information systems is a professional or applied discipline (in that systems analysts and designers have to develop systems that are both useful and used) a taxonomy should also help clarify the systems development task environment for both the user and the analyst. In doing so the classification categories must be supported by research and be generally accepted. The definition of categories should not be artificial or forced. A taxonomy should be internally consistent in that it should not confuse different levels of abstraction within the classification. The definition of the levels of the taxonomy should complement the ability of humans to process information regarding the classification. This implies *ceteris paribus* that each component of each level of the taxonomy should contain no more than 7±2 items. Finally, a good taxonomy should be inclusive to the extent that its structure should not exclude important aspects of the area. This catalogue of the desirable attributes of a taxonomy is ambitious in the sense that it is difficult for a taxonomy to meet all of the above requirements.

None of the bias taxonomies discussed in the previous section are perfectly suited to assist systems analysts involved in the development of decision support systems. In addition each of them violates at least two of the desirable criteria. The Kahneman and Tversky taxonomy is based on empirically untestable general heuristics and only includes a small number of the biases identified in this report. Many of the remaining biases are not easily classified under one or more of the general heuristics.

Remus and Kottemann's taxonomy suffers from the major being too crude or non-discriminatory to be useful for systems analysis. The next levels of their taxonomy are confused with regard to conceptual hierarchy. For example, the Search bias is not at a higher level of abstraction than Recall or Similarity. Conservatism is paradoxically mentioned at each of the lower classification levels.

Hogarth's model of decision making is of considerable descriptive appeal and is therefore potentially useful for systems analysis. However, the listing of biases relevant to each model stage, as in Table 6, is not as logical as a first reading would suggest. By identifying the biases for each stage at the lowest level of description (the same level used by the descriptive sections of this report) many biases must be listed, perceptually overwhelming the analyst. Further, no justification is given for the omission of biases from each aspect of the judgement model. An example of the seemingly arbitrary omission of biases is with the memory aspects of the feedback stage of the judgement model. The only memory effect identified is Testimony, although Hindsight has a strong memory component. An equally convincing argument can be made for the Similarity bias to be present during feedback. In terms of non-memory effects it is

likely that the Redundancy and Attenuation biases could have a significant negative effect on the feedback aspect of decision making and should be included in Hogarth's list. To some extent every bias is capable of affecting every stage of Hogarth's model. This is particularly true if the model is viewed as recursive and used to describe not only the decision being addressed but also the sub-decisions, sub-sub-decisions and so on.

How then should the 37 decision biases be classified? An effective method is to group them according to some perceived similarity. Such a classification strategy does not lead to a set of categories that exist on a linear continuum; they are relatively discrete groupings. As previously noted, the differences between some of the biases described above are quite subtle (for example, Recall and Similarity) while some differences are quite marked (for example, between Redundancy and Chance). By examining the nature and effect of biases a number of groupings emerge naturally. These groupings are:

- Memory Biases
- Statistical Biases
- Confidence Biases
- Adjustment Biases
- Presentation Biases
- Situation Biases.

A detailed allocation of individual biases to these categories is shown in Table 7.

Memory biases have to do with the storage and recall of information. As such they can be regarded as the lowest level or the deepest of cognitive biases. Hindsight could have been placed in the confidence grouping, as one of its effects is to increase confidence in the decision maker's abilities. However, because its fundamental action effects recall, Hindsight has been classified as a memory bias. Statistical biases are concerned with the general tendency of humans to process information contrary to the normative principles of statistics and in particular contrary to probability theory. The allocation of biases to this classification is relatively straightforward. The Regression bias has not been included however as it is more properly viewed as insufficient adjustment from a reference point and is therefore classed as an adjustment bias. Confidence biases act to increase a person's confidence in their prowess as decision makers. An important aspect of some the confidence biases is the curtailment of the search for new information about the decision task at hand. The biases that are important in this behaviour are Completeness, Confirmation and Test. Adjustment biases align somewhat with Kahneman & Tversky's definition of their anchoring and adjustment heuristic although that heuristic has not been used to justify the classification. Presentation biases should not be thought of as only being concerned with the display of data. Within the acquisition, output and feedback components of Hogarth's model they act to bias the way information is perceived and processed and as such they are some of the most important biases from a decision support systems point of view. Situation biases relate to how a person responds to the general decision situation. They represent the highest level of bias abstraction.

Table 7: A Taxonomy of Decision Biases

1. Memory Biases	Hindsight Imaginability Recall Search Similarity Testimony
2. Statistical Biases	Base Rate Chance Conjunction Correlation Disjunction Sample Subset
3. Confidence Biases	Completeness Control Confirmation Desire Overconfidence Redundancy Selectivity Success Test
4. Adjustment Biases	Anchoring & Adjustment Conservatism Reference Regression
5. Presentation Biases	Framing Linear Mode Order Scale
6. Situation Biases	Attenuation Complexity Escalation Habit Inconsistency Rule

Given the taxonomy of decision biases presented in Table 7, an extension of Hogarth's model of decision making can be conceived. Figure 7 documents such a model and presents the view that all of the identified biases can affect a person during judgement. The person is represented by the schema and biases are shown to effect the judgemental processes within the schema. In addition they are shown to bias feedback to the person from the decision outcome. One consequence of developing a bias taxonomy that is independent of a particular theoretical model of judgement and decision making is that it may be applied to many models. The relationship of biases to judgement shown in Figure 7 could be for Hogarth's model could be as easily applied to more complex models such as that of Mintzberg, Raisingahni and Theoret (1976).

Concluding Comments

The concept of decision bias is of great value to a decision support systems analyst as an understanding of the nature of decision biases gives an analyst a richer perspective on decision support than would otherwise be the case. The taxonomy developed in this literature review makes the experimental research more accessible and provides a tool for focusing attention on the biases most likely to affect the target decision task early in the systems development process. Further work on strategies to reduce the negative effects of decision biases is needed for more effective DSS design.

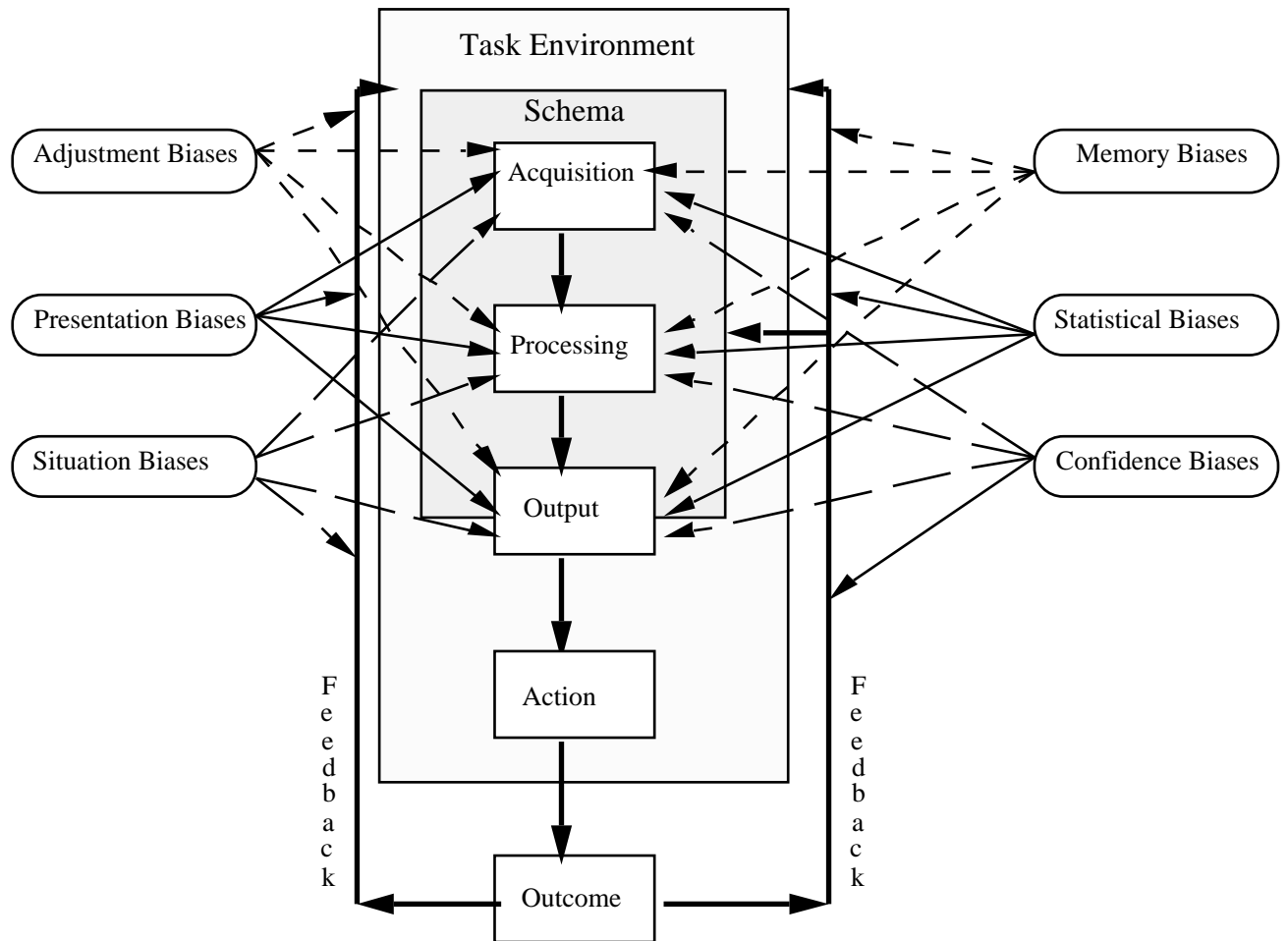


Figure 7: An Extended Model of Judgement

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