THE INFORMATION SEARCH BEHAVIOUR OF INDIVIDUALS IN EXPERIMENTAL MARKETS

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(Ph.D. Thesis)

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SYNOPSIS

Individual consumers as well as managers within any organisation regularly make purchasing decisions. Some of these decisions will relate to product or service markets that are characterised by homogeneity in all aspects except price. There may be a benefit, therefore, from searching for a lower price. The bulk of this thesis is concerned with investigating individual search behaviour when making purchases in such circumstances. After a comprehensive review of formal search models, together with the corresponding experimental evidence, a series of new experiments are described that, in particular, uncover several heuristics that might govern search behaviour in practice. A large number of simulated purchases is used to assess the performance of these heuristics in comparison with the optimal, theoretical model. A related judgemental bias - functional fixation - is also reviewed in detail and tested experimentally. Finally, the understanding of individual search behaviour is further developed using a research experiment set in a more complex, and less highly structured, business decision context.

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THESIS EXTRACTS

Title of article	Journal	Chapter
Articles accepted for publication		
Better Heuristics for Economic Search - Experimental and Simulation Evidence (with Andrew Martin)	Journal of Behavioral Decision Making	5 (+ part of 3 and 4)
Some Experimental Evidence on Functional Fixation - A Research Note	Accounting, Organizations and Society	8 (+ part of 7)
Competitive Tendering and Under-Capacity: An Incident Process Case	Issues in Accounting Education	9
Information and Decision Making: A Search for Method and Understanding (with Kevin Keasey)	Managerial and Decision Economics	9

CHAPTER

ONE

CHAPTER ONE

AN OVERVIEW

INTRODUCTION

This thesis is concerned with the information search behaviour of individuals required to make decisions in experimental markets characterised by incomplete information. Mostly, its specific focus is individuals' behaviour when purchasing common consumer products and services. Clearly, in general, such choices may involve weighing-up many characteristics of information (price, quality, size etc...) across each alternative item being considered. Payne (1976) as well as Paquette and Kida (1988) provide concise reviews of possible decision strategies in these multi-dimensional situations, including decision strategies characterised by reduced processing requirements.

In general though, the scope of this thesis is limited to product and service markets that are homogeneous in all aspects except price. Decisions are made, therefore, on a single-dimensional basis. Decision makers, having already established the specific type or model of product (or service) they wish to purchase, must simply decide for how long it is worth shopping around for a suitably low price. This decision will depend on the individual's search cost, together with his knowledge (if any) of the price distribution.

Accordingly, the thesis seeks to contribute to the existing literature on information search behaviour in the following three ways :

(i) The presentation of a detailed, but concise, synthesis of the empirical evidence concerning market price dispersion, the economic models that prescribe optimal search behaviour, and the experimental evidence regarding observed price search behaviour.

(ii) The discovery and development of several new search strategies that describe observed behaviour well, and perform well when compared with an optimal model, in varying prior knowledge conditions concerning the distribution of prices.

(iii) The presentation of new evidence concerning Human Information Processing capabilities; specifically the ability of individuals to use information sets in different ways in order to meet different objectives (for example, a price quote can be used not only as an offer to sell at that price, but also as information with which to update the searcher's knowledge of the underlying price distribution).

The above work develops some links between decision making strategies and information search behaviour in the context of a highly structured task environment - the <u>searching</u> for a low price. These links are extended, so that an additional objective of the thesis is :

(iv) The exploration of the role of information search in a relatively unstructured task environment - the <u>setting</u> of a price under conditions of uncertainty and incomplete information. Again, though, the context is such that the price set is the only criterion on which ultimate decisions will be taken.

BACKGROUND

First, though, as existing, formal search models are embedded in the framework of expected utility theory, the major characteristics and limitations of this decision making paradigm are briefly reviewed.

Over the second half of the twentieth century, expected utility theory has been the major conceptual paradigm in decision making. Although most of the theoretical developments within the model are relatively recent, its foundations can be traced back more than 250 years to Cramer (1728) and Bernoulli (1738) who sought to explain the St. Petersberg Paradox. This relates to the situation below, as stated in Machina (1987, p 122).

> "Suppose someone offers to toss a fair coin repeatedly until it comes up heads, and to pay you $1 if this happens on the first toss, $2 if it takes two tosses to land a head, $4 if it takes three tosses, $8 if it takes four tosses, etc. What is the largest sure gain you would be willing to forego in order to undertake a single play of the game?"

The expected value, $E(n)$, of this game at the n^{th} toss is given by

$$E(n) \quad = \quad \sum_{r=1}^{n} p_r . 2^{r-1}$$

where p_r is the probability of gaining a head on the r^{th} toss. Thus, E(n) = n/2 , and so, if there is no limit set on n, the game has an infinite mathematical expectation. The paradox is that most individuals would value the game at a low, finite amount.

In attempting to unravel this paradox, Cramer (1728) and Bernoulli (1738) proposed that individuals did not maximise expected monetary value, but rather maximised expected utility, arguing, for example, that a gain of $200 was not necessarily worth twice as much as a gain of $100. Bernoulli suggested a logarithmic utility function that exhibited diminishing increases in utility for equal increments in wealth, and he demonstrated that expected utility of the game ($\Sigma(1/2)^r \log e(2r)$) was indeed finite.

Two centuries later, Von Neumann and Morgenstern (1944) were the first to offer a formal axiomatic basis for expected utility theory (EUT) as a rational decision making model. Its foundations are laid by the five basic axioms (as adapted from Schoemaker, 1982, pp 531-532, and Ezzamel and Hart, 1987, p 140) reproduced below. In each case, **x > y** denotes that an individual prefers alternative x to alternative y, while **x ≈ y** denotes indifference between the two. Finally, **L(r,x,y)** denotes a lottery offering a probability r of receiving x and a probability (1-r) of receiving y, where $0 < r < 1$.

Completeness - For the entire set of uncertain alternatives, $x > y$, or $y > x$, or $x \approx y$. This preference is consistent such that, if $x > y$, then $L(p,x,y) > L(q,x,y)$ if and only if $p > q$.

Transitivity - If $x > y$ and $y > z$, then $x > z$. Also, if $x \approx y$ and $y \approx z$, then $x \approx z$.

Substitution - If $x \approx y$, and if z is any other alternative, then $L(p,x,z) \approx L(p,y,z)$.

Measurability - If $x > y$ and $y > z$, then there exists a unique probability p such that $L(p,x,z) \approx y$.

Compound Lotteries - A compound lottery, whose outcomes are also lotteries, is equally attractive as the simple lottery that would result when multiplying probabilities in accordance with standard probability theory. That is, $L(p,L(q,w,x),L(r,y,z)) \approx L'$, where L' offers a probability pq of receiving w, $p(1-q)$ of receiving x, $(1-p)r$ of receiving y, and $(1-p)(1-r)$ of receiving z.

These axioms are designed to provide a systematic and consistent ordering of an individual's preferences over the whole set of possible, alternative outcomes.

Regardless of whether the EUT model is being used for descriptive, predictive or prescriptive purposes, it has several limitations. These are discussed below under three sub-headings; (1) the validity of the underlying axioms, (2) direct empirical evidence, and (3) bounded rationality.

(1) EUT - the validity of the underlying axioms

Research experiments have uncovered violations of all five axioms that lay the foundations of EUT. These findings limit its general applicability as a theory of choice, although admittedly sometimes the violations occur in unusual, one-off circumstances. The results below represent a brief indication of the findings of research studies rather than an exhaustive list.

Regarding the completeness axiom, Mosteller and Nogee (1951), in one of the earliest experimental tests of EUT, discovered that subjects on repeated measures of preferences were inconsistent in their responses. Further evidence, on what has become known as the "preference reversal" phenomenon, was reported by Lichtenstein and Slovic (1971) in a classroom experiment, and by the same authors (1973) in a real-life setting, where customers staked their own money at a Las Vegas casino.

Systematic and predictable violations of the transitivity axiom were shown by Tversky (1969). He suggested that violations were most likely to occur where choices involved evaluation of items over several dimensions. Inconsistencies may occur if the relative, subjective importance of specific dimensions changes during the course of the choice process.

The third axiom, substitution, was investigated in some depth by Kahneman and Tversky (1979) as a generalisation of Allais' (1953) paradox. Outcomes obtainable with certainty seemed to carry disproportionately higher weights than those which were uncertain, that is the result of a lottery.

Coombs (1975) tested the measurability axiom by requiring subjects to rank three gambles in order of preference, where one was a probability mixture of the other two, and should, therefore, be ranked in-between. Nearly 50% of subjects ordered it otherwise.

Finally, Bar-Hillel (1973) discovered evidence that the compound lotteries axiom was violated, subjects tending to over-estimate the probability of conjunctive events, and under-estimate the probability of disjunctive events.

(2) EUT - direct empirical evidence

It might be argued that the non-optimal behaviour exhibited by subjects in some of the illustrations above would not be reproduced in real world situations. The apparent axiomatic violations are merely a reflection of the hypothetical nature of the experiments.

While such an argument carries a degree of plausibility, the over-riding conclusion of empirical research studies is that people have difficulty focusing on both probabilities of outcomes and magnitudes of outcomes at the same time, leading to seemingly sub-optimal behaviour.

For instance, Kunreuther et al (1978) found that most home owners in flood plain areas were not covered by flood insurance, despite the availability of up to 90% federal subsidies. That is, home-owners were unwilling to purchase flood insurance for, say, $200, where insurance organisations would normally charge $2,000. Although the insurance company's estimate will include a profit margin, this is unlikely to be substantial given the highly competitive nature of the insurance industry. Thus, the implication is that individuals perceive the risk to be considerably lower than do the "expert" actuaries employed by the insurance organisations. In turn, this suggests that people may have difficulty assessing low probability, high loss events. Robertson (1974) reported similar evidence concerning the general reluctance to wear safety belts in motor vehicles.

In contrast, Eisner and Strotz (1961) discovered a surprisingly high demand for aeroplane flight insurance, when compared with the demand for cheaper, regular life insurance. This suggests that, at other times, people focus more on the loss dimension than the probability dimension.

(3) EUT - bounded rationality

The rational economic man postulated by EUT is assumed to have "global rationality". That is, as described by Simon (1955, p 99) :

> "(he) is assumed to have knowledge of the relevant aspects of his environment which, if not absolutely complete, is at least impressively clear and voluminous. He is assumed also to have a well-organised and stable system of preferences, and a skill in computation that enables him to calculate, for the alternative courses of action that are available to him, which of these will permit him to reach the highest attainable point on his preference scale."

Thus, an individual is assumed to <u>know</u> his utility function (or preference scale), to <u>know</u> all possible consequences of decisions he might take now or at any time in the future, and to be able to perform lengthy, non-trivial calculations.

This is an uncomfortable set of assumptions. First, in terms of the ability to store sufficient information to attain "global rationality", consider the extract below from Ries and Trout (1981, p 77) :

> "(The average supermarket today) has 10,000 different products or brands on display. This means that a young person has to sort out and catalogue 10,000 different names in his or her head.
>
> When you consider that the average college graduate has a speaking vocabulary of only 8,000 words, you can see the problem. The kid spends four years in a university and ends up 2,000 words down."

Further, several researchers have discovered substantial inaccuracies in the way that individuals perform even slightly complex calculations that require the evaluation of uncertainty (see, for example, Bar-Hillel, 1982; Salop, 1987).

These criticisms have led to the idea of global rationality being replaced by the idea of "bounded rationality" : not everything can be known in advance, and so decisions will often be based on incomplete information about alternatives and outcomes. In addition, there are relevant costs associated with acquiring, storing and processing information. Hence, as Newell and Simon (1972) conclude, individuals will use various heuristics or rules of thumb in performing complex tasks, in order to keep the information processing demands of the situation within the bounds of their limited mental capacity. This, in turn, implies a willingness to "satisfice" rather than maximise; that is, to seek an outcome that achieves some target level of adequacy, rather than one that is necessarily the best possible.

The findings reported in this section suggest that while Expected Utility Theory may provide the basis for a solution to any purchase decisions, in practice, individuals are more likely to employ simple heuristics to arrive at such choices.

Three important research questions follow. What kinds of heuristics might actually be used?, ... what are their implications for individual search behaviour?, ... and how well do these heuristics perform in comparison with a theoretically optimal decision making model? The work that follows in the next nine chapters explores these issues.

In attempting to answer the three questions above, an experimental research approach is adopted. Laboratory experimentation in economics and related studies has two important properties. First, the economic environment is totally controlled by the experimenter; second, the experimenter has virtually unrestricted access to his subjects. Such experiments (in economics) have their origins as far back as the early eighteenth century in the development of the St. Petersberg Paradox discussed above, but as Roth points out (1988, p974):

> " ... it is probably only in the last ten or fifteen years that laboratory experimentation can be clearly seen to have truly begun its now steady and sustained transformation from an occasional curiosity into a regular means for investigating many kinds of economic phenomena."

Roth's article provides a detailed methodological overview of the role and scope of experimental research in economics. He concludes that, broadly speaking, it is a justifiable method of investigation, though warning that (1988, p1023):

> " ... the major pitfall to be aware of ... is that, since decisions made in the design of the experiment cannot be regarded as random samples from the space of possible design choices, there is room for an experimenter's prior beliefs about the likely outcome of the experiment to influence the outcome, through these design decisions. Sometimes this is explicit, deliberate, and desirable, as when the experimenter wishes to demonstrate that some phenomenon is possible, rather than general. The danger is of inadvertently reading experimental evidence as supporting an overly general conclusion based on observations made in special cases."

Care is taken in the design of the new experimental work described and analysed in Chapters 5, 6, 8 and 9 to avoid this potential pitfall.

OUTLINE OF THESIS

The thesis is organised as follows. **Chapter 2** examines the empirical evidence regarding market price dispersions. The evidence shows that price dispersion is found commonly, and, in some cases, can be substantial. Thus, "shopping around" for a low price may yield significant benefits.

Chapter 3 reviews the theoretical models that have been developed over the last few decades to prescribe optimal behaviour in this single-dimensional purchase setting. Essentially, a consumer should set a "reservation" price prior to commencing search, and then continue searching until a price has been located lower than or equal to this target value. Purchase should then be undertaken at this price.

Chapter 4 discusses the experimental studies that have been carried out to investigate search behaviour in markets with price variation, and also, in particular, to test the optimal, theoretical models above. The research findings reported in Chapter 4 lead to the suggestion and formulation of several rules of thumb that may better encapsulate observed behaviour than the more complex and computationally demanding reservation price strategy.

The two subsequent chapters describe some new experimental and simulation work that extends this theme further. New search rules are presented which fit well with observed behaviour, and perform well in comparison with an "optimal" model that has full knowledge of the underlying price distribution parameters. In particular, **Chapter 5** focuses on situations where searchers either have <u>no</u> initial knowledge of the underlying price distribution, or have <u>full</u> knowledge of its shape (normal) and its defining parameters (mean and standard deviation).

In contrast, **Chapter 6** considers the situation where searchers have <u>partial</u> prior knowledge of the price distribution. That is, some prices from the distribution are known to the searcher in terms of magnitude, but not in terms of location. Neither is the searcher aware of the representativeness of these prices. This setting more accurately reflects real-world purchase decisions in a single-dimensional context, than do the no knowledge and full knowledge situations.

Although, in general, the search strategies proposed in Chapters 5 and 6 are reduced processing strategies, and therefore attempt to economise on the "mental effort" required for their adoption, they may still be affected by various judgemental biases. **Chapter 7** examines the relevant findings of the Human Information Processing literature, with particular emphasis on one potential source of bias - functional fixation - that seems to have an influence on single-dimensional price search processes. This phenomenon relates to the difficulty that some individuals have in finding a second function for an object that they are familiar with using in one certain way. Where individuals have partial initial knowledge of a price distribution, there exists a tendency to view subsequent price quotes only as offers for sale, rather than also as pieces of data with which to update their knowledge of the price distribution. Accordingly, a new experiment, designed and undertaken to investigate functional fixation is described and assessed in **Chapter 8**.

Essentially, the price search studies above investigate individuals' search behaviour in a highly structured task environment, where there is a single, clear objective, and where the type and form of extra information available is fully known in advance. Two implications of the reported results are first, the choice of a decision making strategy or rule will have an influence on subsequent search behaviour, and second, such strategies are not necessarily determined at the outset, but may formulate over time.

Many decision situations will be far less well structured than this. Not only is there incomplete information, but also a decision maker may not necessarily be aware of the exact nature and type of information available, nor its direct relevance (if any) for the task at hand. **Chapter 9** describes an experiment designed to investigate individual search behaviour in a more unstructured environment, and is aimed in particular at discovering the general applicability of the findings above from the highly structured price search studies.

Finally, **Chapter 10** summarises the main findings of the thesis, and suggests various extensions, implications and applications.

CHAPTER

TWO

CHAPTER TWO

PRICE DISPERSION - THE EMPIRICAL EVIDENCE

INTRODUCTION

This thesis is concerned with decisions that hinge on one key characteristic, but where that characteristic has an underlying distribution of values rather than a single, constant value. Usually, this characteristic carries a value that can be measured in monetary terms - for example, the price at which an everyday consumer product is sold or a service provided, or the wage rate at which an employment contract is reached. As these problems are essentially equivalent in terms of formal search theory, discussion will be restricted mostly to the former - the search for a suitably low priced homogeneous product or service.

In a world of perfect competition and perfectly efficient markets whose participants act rationally, have complete knowledge of the market, and identical transactions costs, the price for which any two homogeneous products are offered for sale, and sold, would be the same. No benefit could be gained from shopping around, and so a product would simply be purchased at the first sales outlet visited. A formal theory of search in this context would be trivial. In the real world, however, this is not the case. The prices of apparently homogeneous products and services vary. This chapter examines the empirical evidence for such price dispersion.

By way of introduction, and before discussing the more extensive surveys that have been reported in the research literature, the results of a recent, personal survey are presented. Several local Van-Hire organisations were contacted with a view to seeking a price quote for the hire of a van for private removal purposes. Specifically, the required "product" was an 18 cwt. Transit Van for one day with an unlimited mileage facility. All such organisations were canvassed that (a) advertised within the "Van and Lorry Hire" section of the Coventry Yellow Pages by means of a box advertisement (as opposed to a single line entry), and (b) were located in the Coventry/Kenilworth area - that is, within five miles of and easily accessible from the University of Warwick. Contact was made by telephone, a total of 12 organisations meeting all the requirements. Table 2:1 lists the price quotes received.

TABLE 2:1

TRANSIT VAN HIRE PRICE QUOTATIONS

Supplier	Price per day £
Avis	40.65
Brady Self-Drive	37.38
BRS Truck Rental	44.28
Budget Rent-a-Van	28.50
Ford Rent-a-Van	33.93
G. Y. Transport Hire	31.63
Kenilworth Garage Van Hire	25.00
Kenilworth Vehicle Rental	29.90
Newtown Car and Van Hire	33.50
J. & R. Pedley Vehicle Hire	46.00
Quinton Van and Car Hire	26.00
Swan National	34.43

Source : Telephone contact on 24 May 1990

All vans were less than two years old, and all price quotes were fully inclusive of VAT and insurance. Some suppliers also required a deposit for fuel (the vans all came with full tanks of petrol), usually amounting to £25 or £30, but in all cases this was fully refundable. It is not considered, therefore, to significantly effect the homogeneity of the products. In terms of other service characteristics, all suppliers included temporary membership of one of the leading national breakdown organisations.

The price quotes listed in Table 2:1 have a mean of £34.27 and a standard deviation of £6.76, while the highest price is nearly double the lowest. If a coefficient of variation is defined as the ratio between the standard deviation and the mean, expressed as a percentage, then its value here is 19.7%, indicating a large degree of variation. Given that search costs are likely to be relatively small, each search mostly being limited to telephone charges together with the opportunity cost of a few minutes, then it may be worthwhile for an individual, wishing to hire a van, to shop around for a low price quote.

The issue central to this thesis is to ascertain appropriate search strategies to adopt in such circumstances, balancing the costs of search with the expected likelihood of finding a lower price. For instance, where an individual commences his search without prior knowledge of the price distribution, one of the simplest search models is to canvass three suppliers only, accepting the lowest price quote received (this is rule G, discussed in Chapter 5). Returning to the Transit Van illustration, if it is assumed that all 12 suppliers have an equal a priori chance of being approached, then elementary probability theory reveals that adoption of the three-search model would result in a 25% chance of not receiving a quote less than £30, and a 55% chance of not receiving either of the two most favourable quotes - £25.00 and £26.00.

As stated above, the main focus of this thesis is to understand the search behaviour of individuals: included in this is an evaluation of particular search strategies that perform well in circumstances where price dispersion exists in otherwise homogeneous product markets. It is not concerned with why such price dispersion exists. Some possible explanations, however, are outlined below.

First, it may be that organisations adopt cost-based pricing policies. This might create substantial variations in price due to differences in the actual costs incurred in production of a good, differences in managers' perceptions of the relevant costs associated with production, or differences in the way in which certain costs are built-up; for instance, there may be variations in overhead allocation procedures or in depreciation policy. Further, the number of vehicles owned may effect unit costs. An organisation with double the fleet size of a competitor may incur only slightly more general administrative expenditure. Its apportioned administrative cost per vehicle will be just over half that of the competitor. Empirical surveys by, for example, Skinner (1970), and Atkin and Skinner (1975) provide supporting evidence of cost-based pricing policies. In the former study, questionnaires were sent to all members of the Merseyside Chamber of Commerce. Out of 172 responses, 70% claimed to use cost-plus pricing, of whom 57% used it for pricing all products.

Alternatively, prices charged may reflect deliberate responses to perceived market conditions or desired strategic positioning. Thus, a firm may be adopting a "penetration price" policy, sacrificing profit for higher volume through price cutting, and thereby establishing a wider market base before gradually raising prices closer to a profit maximising level. Other firms may be adopting a "price skimming" policy, this time charging higher prices and sacrificing profits for lower unit sales, perhaps due to capacity constraints. Finally, a firm that predicts that potential customers will not shop around much, if at all, for alternative quotations, may concentrate efforts on ensuring that their firm is canvassed more than the average, possibly by placing more noticeable advertisements. If prospects are reluctant to search, this should result in a high level of acceptances even where prices charged are relatively high. To some extent, the impact of this was reduced in the informal study above, by restricting the suppliers canvassed to those using box-sized advertisements.

Another explanation for price dispersion is that the vans are not truly homogeneous, and price differences are merely reflecting variations in quality or reliability. While such factors may account for part of the dispersion, they are unlikely to account for it all, especially as care is taken at the outset in specifying the particular product.

Stigler (1961, p214) concludes similarly :

> "...price dispersion is a manifestation - and, indeed, it is the measure - of ignorance in the market. Dispersion is a biased measure of ignorance because there is never absolute homogeneity in the commodity, if we include the terms of sale within the concept of the commodity. Thus, some automobile dealers might perform more service, or carry a larger range of varieties in stock, and a portion of the observed dispersion is presumably attributable to such differences. But it would be metaphysical, and fruitless, to assert that all dispersion is due to heterogeneity."

PUBLISHED EVIDENCE OF PRICE DISPERSION

A small number of published surveys have been concerned with discovering empirical evidence for price dispersion. Stigler, again in his 1961 paper (p 214), presents two examples of such dispersion; one relating to anthracite coal, the other to an automobile. The prices for anthracite coal were bids for federal government purchases, while the automobile prices, for an identical model, were those quoted after an "average amount of haggling". This does raise some doubts about the objectivity of the latter study. Table 2:2 reproduces the two sets of prices.

Again, there is a noticeable degree of price dispersion though the coefficient of variation (defined as before) is small for the anthracite coal, and virtually negligible at 1.7% for the Chevrolets.

TABLE 2:2

ASKING PRICES FOR TWO COMMODITIES

A : Anthracite Coal, Washington DC, April 1953

Price per ton $	Number of Bids		
15.00 - 15.50	2		
15.50 - 16.00	2		
16.00 - 16.50	2	**Mean**	$ 16.90
16.50 - 17.00	3	**Std. Dev.**	$ 1.15
17.00 - 18.00	1	**Coeff. of Var.**	6.8%
18.00 - 19.00	4		

B : Chevrolets, Chicago, February 1959

Price $	Number of Dealers		
2350 - 2400	4		
2400 - 2450	11	**Mean**	$ 2436
2450 - 2500	8	**Std. Dev.**	$ 42
2500 - 2550	4	**Coeff. of Var.**	1.7%

The price dispersion phenomenon is also evident in the labour market. Stigler (1962), in his second seminal paper in the information search field, presents an example concerning wage offers in the labour market, based on the USA national sample of wage offers to new graduates each year. The results are summarised in Table 2:3.

TABLE 2:3

MONTHLY HIRING RATES OF LARGE CORPORATIONS FOR COLLEGE GRADUATES, 1958 - 1960

Occupation	Number of Companies	1958	1959	1960
		Mean Salaries ($)		
Engineering	66	472	493	515
Accountancy	40	421	435	457
Sales	29	410	426	447
General Business	41	403	416	431
		Coeff. of Var. (%)		
Engineering	66	4.0	4.2	4.3
Accountancy	40	6.5	6.9	6.4
Sales	29	8.8	8.2	9.1
General Business	41	8.6	9.0	8.6

It is much more difficult to find true homogeneity in labour markets as there are so many employee benefits which are non-trivial to evaluate : for instance, a happy work force, peaceful surroundings, sports and social facilities, as well as promotion prospects and the expected scale and timing of future salary increases. Nevertheless, across the three years of Table 2:3 annual salary increases are fairly standard at around four to five percent. For each occupation, the coefficients of variation show little deviation from year to year, indicating a stable, recurrent wage rate dispersion. There are small differences, however, in the amount of dispersion between different occupations. Again, then, there is an empirical justification for shopping around for a better offer.

Pratt, Wise and Zeckhauser (1979)

The most extensive published survey on price dispersion was conducted by Pratt, Wise and Zeckhauser (1979), and concentrated on consumer products and services. The authors compiled a sample of 50 products and services by selecting pages randomly from the Yellow Pages section of the Boston Telephone Directory, and choosing the first item line on each selected page. The sample was reduced by eliminating items where price information was expected to be, or proved to be, difficult to ascertain (for example, airport construction), or insensitive (funeral quotes). For the remaining 39 items, a relatively standardised product (or service) was chosen, as an attempt to ensure homogeneity. Every listed supplier was contacted by telephone and asked to specify the price at which he would be willing to sell. A summary of the price statistics obtained is reproduced and extended in Table 2:4, while further details of the specific products and services chosen are presented in Appendix 2:1 at the end of this chapter.

TABLE 2:4

PRICE DIFFERENCES ACROSS 39 PRODUCTS AND SERVICES

Product/Service	No.of Firms	Mean Price $	Std. Dev. $	Max/ Min	Coeff. of Var. %	Shape Param. (*)
Air conditioners	14	16.74	4.23	2.50	25.3	5.5
Aquarium	12	17.38	3.66	2.16	21.1	3.8
Auto tune-up	15	39.57	7.27	1.83	18.4	7.0
Bicycle	7	144.77	6.34	1.11	4.4	24.3
Board poodle	13	4.00	.68	1.83	17.0	8.4
Boat	15	602.87	104.89	1.97	17.4	9.6
Calculator	12	123.44	12.27	1.42	9.9	16.5
Camera	15	329.12	29.78	1.42	9.0	28.8
Canvas goods	14	40.46	28.87	6.38	71.4	.5
Carnations	7	.33	.14	2.50	42.4	.5
Chlorine	7	1.79	.79	5.00	44.1	2.6
Concrete	11	38.50	2.01	1.26	5.2	26.9
Developer	15	1.44	.14	1.33	9.7	18.0
Diamond appraisal	12	7.71	2.01	2.00	26.1	6.2
Dry cleaning	20	2.08	.35	2.12	16.8	10.4
Electrodes	12	30.71	9.55	2.86	31.1	1.2
Flying instruction	9	29.67	4.15	1.70	14.0	15.7
Fuel oil	15	.38	.11	2.11	28.9	18.7
Horoscope	4	30.00	16.83	5.00	56.1	.6
Liquor	11	7.47	.65	1.23	8.7	16.8
Lumber	14	10.91	1.04	1.37	9.5	15.0
Microwave oven	5	451.50	26.15	1.16	5.8	15.9
Mufflers	19	28.58	4.97	1.57	17.4	3.5
Office furniture	15	109.45	9.03	1.35	8.3	22.0
Paint	22	8.19	.58	1.39	7.1	26.7
Peanuts	8	.53	.17	2.09	32.1	.6
Pet washing	8	15.63	2.00	1.50	12.8	16.7
Printers' envelopes	14	39.54	9.12	2.50	23.1	7.2
Rebuilt alternator	14	38.02	2.96	1.29	7.8	2.4
Repair clarinet	8	44.28	13.78	2.33	31.1	.9
Service station	15	13.69	1.46	1.48	10.7	16.9
Skates	15	42.83	3.53	1.39	8.2	18.1
Stationery	15	92.82	5.62	1.25	6.1	20.7
Styling brush	12	4.33	2.01	6.67	46.4	3.9
Teeth cleaned	13	16.85	3.76	2.08	22.3	2.8
Towing	10	14.04	3.57	2.50	25.4	5.2
Turntable	9	68.55	12.37	1.30	18.0	.9
Vocal instruction	12	14.79	5.17	2.65	35.0	.5
Watch cleaned	12	15.78	5.98	3.50	37.9	2.3

(*) ... this is a maximum likelihood estimate of the shape parameter of the gamma distribution to which the observed prices were fit.

It is noticeable that the items selected cover a wide range of products and services, and a wide range of prices; the mean price of three of the items is less than \$1, while the mean price of six exceeds \$100, including one - the boat - whose average retail price was greater than \$600. Regarding price dispersion, the average coefficient of variation across all 39 items was 22% (similar to that for the transit vans). Only one product - the Raleigh bicycle - had a coefficient of variation below 5%, while two items - the canvas goods and the horoscope reading - had coefficients exceeding 50%. Further, for 18 of the 39 items, the highest price quoted was more than double the lowest, the most extreme examples being; in percentage terms, the styling brush with prices ranging from \$1.50 to \$10.00, and, in absolute terms, the Johnson 9.9 hp. outboard motor boat with prices ranging from \$425 to \$839.

A least squares regression relationship was formulated by comparing the logarithms of the estimated standard deviations (σ) with the logarithms of the estimated means (μ), yielding :

$$\log_e \sigma = -1.517 + 0.892 \log_e \mu$$
$$(r^2 = 0.87)$$

Thus, doubling the mean price is associated with an 86% increase in the standard deviation ($2^{0.892} = 1.86$). As the authors state (1979, pp 205, 211) :

> "...this 86% figure might seem puzzlingly high, for unless search costs increased dramatically with the price of the product, the expected gains from searching would lead to ratios between standard deviation and price that declined rapidly with price.The explanation may lie with the infrequent purchase of expensive products, which reduces the incentive of a buyer to search. Less searching, in turn, allows greater variability among prices.
>
> ....in fact, Sam Peltzman, who commented on this paper at the AEA meetings, selected all of our products that were "unambiguous" consumer goods - 32 in all - and distinguished frequently purchased goods from the others. Using a dummy variable, D, to represent frequently purchased goods, he obtained the following result :
>
> $$\log_e \sigma = -1.161 + 0.836 \log_e \mu - 1.015\,D$$
> $$(r^2 = 0.87)$$
>
> Thus, the standard deviation of a frequently purchased good is estimated to be about 36% ($e^{-1.015} = 0.36$) of that of an infrequently purchased good with the same mean."

To explore the nature of price distributions further, a maximum likelihood estimate of the shape parameter (α) of the gamma distribution was fitted to the observed prices of each product or service.

That is, the probability density function of the distribution is of the form :

$$f(x) = \frac{1}{\Gamma(x)} x^{\alpha-1} e^{-x} \qquad \text{for } x > 0$$

$$= 0 \qquad \text{elsewhere}$$

where α is a positive constant and $\Gamma(x)$, the gamma function, is defined by :

$$\Gamma(x) = \int_0^\infty y^{\alpha-1} e^{-y} \, dy$$

The final column of Table 2:4 presents the value of α fitted for each product and service. Seven of the 39 items have α values less than one, indicating an exponential-like distribution. Fourteen have values between one and nine indicating price distributions skewed to the right, while the remaining 18 items, with α values greater than nine, are essentially normally distributed.

SUMMARY

All these empirical surveys concede that although attempts were made to select standardised products, quality differentials undoubtedly exist - for instance, there may be factors such as location, credit policy, service quality, and accompanying services. Their overriding conclusion, however, is that relatively standardised products and services may vary substantially in price across several suppliers, and a large part of this phenomenon is a measure of market participants' ignorance, or their reluctance to search, given positive search costs and divergent beliefs. Furthermore, although markets are, perhaps, becoming more sophisticated and more efficient, the price variations do not appear to lessen over time. Indeed, the levels of dispersion discovered in the 1979 Pratt, Wise and Zeckhauser survey and the 1990 Transit Van Hire survey are far higher than those reported by Stigler nearly 30 years ago.

Thus, there is an empirical basis for the theory of search in markets for products and services that are homogeneous across all aspects except price. A synopsis of this search theory is presented in Chapter 3. In addition, the evidence here provides some justification for the use of normal price distributions in the experimental studies described in Chapter 5 and Chapter

6, as more price distributions fitted the normal price distribution than any other.

APPENDIX 2:1

This appendix contains further details of the 39 products and services whose prices were canvassed in the 1979 Pratt, Wise and Zeckhauser survey (see Table 2:4).

Air conditioners ... repair
Aquarium ... 20 gallon fishtank
Auto tune-up ...'67 Camaro V8, parts, labour, points, plugs, timing
Bicycle ... Raleigh Grand Prix
Board poodle ... price/day, standard poodle, approx. 50 lbs.
Boat ... Johnson 9.9 hp. outboard motor, 15" shaft, manual start
Calculator ... Texas Instruments SR-50
Camera ... Konica, Autoreflex T(3), f1.7 lens, chrome, split image
Canvas goods ... cover for pick-up, 70" x 98", 3 mats, glove snaps
Carnations ... white, 200 loose, undelivered
Chlorine ... liquid, 15% strength, price/gallon
Concrete ... 3000 lbs (type or grade), price/cubic yard
Developer ... Dektol, 1 lb 2oz
Diamond appraisal ... 3 one-karat rings, price/item
Dry cleaning ... 2-piece suit
Electrodes ... E6013, 1/8", 50 lbs
Flying instruction ... aircraft with instructor, rate/hour
Fuel oil ... 500 gallons, price/gallon
Horoscope ... basic charting, including 1-hour discussion
Liquor ... case of Budweiser beer (12 quart bottles)
Lumber ... plywood, fir AC, 1/2" x 48" x 96"
Microwave oven ... RK 4D, Amana
Mufflers ... '67 Camaro, single exhaust
Office furniture ... 4-drawer letter size, HON 214, black
Paint ... acrylic flat latex, Benjamin Moore, satin super white
Peanuts ... 100 roasted in the hull, price/pound
Pet washing ... French cut and shampoo, standard poodle
Printers' envelopes ... 2000 10-size w/4 lines copy, 24 lb, white
Rebuilt alternator ... '67 Camaro V8
Repair clarinet ... repad Selmer clarinet
Service station ...'67 Camaro V8, lube, grease, oil & filter change
Skates ... ice skates, "Black Panther"
Stationery ... Southworth 33C, permanent record, 10 reams
Styling brush ... Dennman Trow
Teeth cleaned ... Dental office
Towing ... initial charge, daytime, 5 mile round trip
Turntable ... BSR 2310X
Vocal instruction ... (musical) price/hour
Watch cleaned ... Clinton 25 jewel, self-winding, with day date

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CHAPTER

THREE

CHAPTER THREE

FORMAL SEARCH MODELS

INTRODUCTION

The evidence presented in the previous chapter suggests that prices vary, sometimes substantially, across many, common, consumer product and service markets. It may be beneficial, then, for an individual wishing to purchase a given product to search the market for a lower price rather than to accept the first offer received. The extent of this potential benefit will depend on several factors such as the actual distribution of prices and the costs of search.

This chapter reviews formal models of search in this context. First, some simple search models are developed in order to introduce some important, general characteristics that underlie the search process. Following this, a more complex model is derived (in two different ways), and the effect on the model of changing certain key assumptions is investigated.

A SIMPLE SEARCH MODEL

The illustration in this section is based on McKenna (1986, Chapter 9) and concerns an individual's search to purchase an unspecified, consumer product.

Suppose that the product is known to be priced at £60, £70 and £80; these prices being distributed across many suppliers in the proportions 1/4, 1/2 and 1/4 respectively, with no apparent difference in quality. Obviously, the individual would prefer to buy at £60, but she is uncertain which suppliers will be offering to sell at this price. If only one supplier is contacted, then she will expect to receive an offer of £70 since :

$$\begin{aligned} \text{Exp (Price)} &= 1/4\ (60) + 1/2\ (70) + 1/4\ (80) \\ &= 70 \end{aligned}$$

She may do better, however, by contacting two suppliers. Table 3:1 displays the possible outcomes from such a strategy, and demonstrates how her new expected price is calculated.

TABLE 3:1

EXPECTED OUTCOMES FROM TWO SEARCHES

Prices Quoted £	Joint Probability	Lower Offer £	Expected Value £
60 , 60	0.0625	60	3.75
60 , 70	0.25	60	15
60 , 80	0.125	60	7.5
70 , 70	0.25	70	17.5
70 , 80	0.25	70	17.5
80 , 80	0.0625	80	5
			66.25

Contacting a second supplier, then, has lowered the expected value of the best offer from £70 to £66.25, a benefit of £3.75. Note, though, that in this case, unlike before, the expected value cannot equate with the value of any actual offer received. This procedure can be repeated indefinitely, though after the fourth search the calculations start to become prohibitively cumbersome. The more suppliers that are canvassed, the nearer the expected value is to £60. Table 3:2 summarises these expected values for the first six searches, as well as the marginal fall in the expected value for each additional search. It is noticeable that increasing the search sample size yields diminishing marginal returns, as would be anticipated for any stable price distributions. Exactly how many searches would be expected will depend on a comparison of the marginal costs of search with the marginal expected benefit.

If it is assumed that each visit to a potential supplier involves a fixed, known cost, c (an assumption that will be retained for the majority of this chapter), then clearly it will not be worthwhile continuing search if the fall in the expected value of the best offer is less than c. For example, suppose the unit search cost is £1.50. Referring to Table 3:2, a sample size of three is worthwhile, whereas extending the sample to four would not be, as the marginal expected benefit is only £1.18. Similarly, if the unit search cost is £2.00, then the optimal sample size is two. This demonstrates an important result within search theory :

- the amount of search <u>falls</u> as the cost of search <u>increases</u>.

TABLE 3:2

THE EFFECT ON EXPECTED VALUE OF SAMPLE SIZE

Sample Size	Probability that best offer is			Expected Value	Fall in Expected Value
	£60	£70	£80	£	£
1	.250	.500	.250	70.00	
2	.437	.500	.063	66.25	3.75
3	.578	.406	.016	64.38	1.87
4	.684	.312	.004	63.20	1.18
5	.763	.236	.001	62.38	.82
6	.822	.178	.000	61.78	.60

The main drawback of this kind of search model is the requirement for the sample size to be fixed, and selected prior to the commencement of the search process. Suppose the sample size has been set at three, as in the above example. Then, even if an offer of £60 - the minimum price possible - is located on the first contact, two more suppliers would have to be searched. This is both wasteful and unrealistic.

So, rather than adopting the current strategy :

- "search n suppliers, and accept the minimum price offer received,"

it would seem more sensible to substitute the following strategy :

- "search at most n suppliers, and stop as soon as the minimum price offer is received. Otherwise, accept the lowest offer located among the n suppliers."

This second strategy too, though, has its limitations. It relies on a searcher not only knowing the minimum price for which a product will be sold, but also knowing the full distribution of all prices. This will not always, if ever, be the case. An alternative approach to these essentially <u>fixed sample size</u> search strategies, is to adopt a <u>sequential</u> search process; that is, one in which each price offer is considered on its own merits as it is observed in the random sequence. This can be achieved by comparing each offer with a standard <u>reservation price</u>, so that the search strategy becomes :

- "select a reservation price, R, and accept the first offer received that is no greater than R."

Such a rule takes advantage of any opportunities afforded by early, fortuitous observations of low prices. The main difficulty with this sequential model, though, is concerned with calculating the critical parameter, R. One method can be demonstrated by extending the simple example introduced earlier :

Let, R be the reservation price (which must be one of £60, £70 or £80, since no other prices are possible),

$V(R)$ be the total expected net expenditure resulting from one more search,

x be the next price offer received, and

c be the (fixed) unit search cost.

Further, the new price offer, x, could be

$\leq R$ with probability p, in which case stop, or

$> R$ with probability q (=1-p), in which case continue searching.

Then, $$V(R) = \text{Exp}\ (x : x \leq R).p + V(R).q + c \qquad [3:1]$$

and so, substituting for q,

$$V(R) = \text{Exp}\ (x : x \leq R) + \frac{c}{p} \qquad [3:2]$$

Now consider Exp [n(R)], the expected number of searches before finding a price less than or equal to the reservation price. Then, clearly,

$$\text{Exp } [n(R)] = \sum_{j=1} jp_j$$

where p_j is the probability that the reservation price or lower is first encountered on the j^{th} search. It follows that :

$$\begin{aligned} \text{Exp } [n(R)] &= \sum_{j=1} jpq^{j-1} \\ &= p\sum_{j=1} jq^{j-1} \\ &= p\ (1 + 2q + 3q^2 + 4q^3 + \ldots\ldots..) \\ &= p\ (1-q)^{-2} \end{aligned}$$

$$\underline{\text{Exp } [n(R)] = \frac{1}{p}} \qquad [3:3]$$

Thus, returning to equation [3:2], the first term on the right-hand side is the expected benefit from search, while the second term is the expected cost; that is, the product of the unit search cost and the expected number of searches. Applying the result in equation [3:2] to the numerical example above, and remembering that R can only take one of three values, then it can easily be verified that :

$$V(60) = 60 + 4c$$
$$V(70) = 66.67 + 1.33c$$
$$V(80) = 70 + c$$

Given the search cost, c, the reservation price is chosen to produce the most favourable value of V(R), which in this context is that representing the lowest overall expenditure. If, as before, the individual's unit search cost is £1.50, then :

$$V(60) = 66$$
$$V(70) = 68.67$$
$$V(80) = 71.5$$

Therefore, the reservation price would be set at £60, and search would continue until such an offer is received. The expected number of searches for this to happen is four (from equation [3:3]). Indeed, simple algebra reveals that for any search cost up to £2.50, £60 is the optimal reservation price, increasing to £70 for search costs up to £10, and to £80 thereafter, the latter case reducing the situation to accepting the first price quote received. This demonstrates another important result within search theory, that :

- reservation prices <u>rise</u> as the unit search cost <u>increases</u>.

The fixed sample size and sequential search models discussed here lend useful insights to search theory. A more complex model is needed, however, to prescribe behaviour in situations where there are more general, and less artificial, underlying price distributions than in the simplified example in the illustration. Such a model is derived in the next section.

A GENERALISED SEARCH MODEL

Over the last 20 years several authors have derived models of individual search behaviour. For example, Telser (1973), Rothschild (1974), and Landsberger and Peled (1977) in the context of searching for the lowest priced good; Salop (1973), Lippman and McCall (1976), and Seater (1979) in the context of searching for the highest paid job; while Kohn and Shavell (1974), Karni and Schwartz (1977) and McKenna (1987) derived general models applicable in either context. While no two of these models are identical, they are broadly similar subject to certain changes in emphasis and underlying assumptions, and differing terminology and notation.

The model derived here is based on Hey (1981, pp 49-50) and concerns a situation where an individual is searching for the lowest price of a good, with full knowledge of the price distribution and with the facility of full recall; that is, past offers can be retrieved at any future time. The impact of relaxing these constraints is considered later in this chapter.

In formulating the model, let :

- $F(x)$ represent the cumulative price distribution function (this is equivalent to $\int_{-\infty}^{x} f(z)\,dz$ where $f(z)$ is the probability density function of the price distribution),
- m represent the minimum price so far encountered ,
- $V(m)$ represent the expected value of the objective function starting from a lowest price of m ,
- y represent the next price offer received, and
- c represent the unit search cost, which is kept constant throughout.

The individual wishes to maximise her overall expenditure, and so is seeking to minimise the value of $V(m)$, the objective function. At a given stage in the process, she can accept the best offer so far received, m, or search again at a cost, c.

Thus, $V(m) = \min\{ m , V(m,y)\}$

$$= \min\{ m , c + \int_{-\infty}^{m} V(y)\,dF(y) + \int_{m}^{\infty} V(m)\,dF(y) \}$$

since if the new price received is greater than m, it will be discarded, while if it is smaller than m it becomes the new best offer.

Hence, $$V(m) = \min\{ m , c + \int_{-\infty}^{m} V(y)\,dF(y) + V(m).\{1 - F(m)\} \} \qquad [3:4]$$

Integrating by parts, it follows that :

$$\int_{-\infty}^{m} V(y)\,dF(y) = [\, V(y).F(y)\,]_{-\infty}^{m} - \int_{-\infty}^{m} V'(y)F(y)\,dy$$

$$= V(m).F(m) - \int_{-\infty}^{m} V'(y)F(y)\,dy \qquad [3:5]$$

Substituting [3:5] into [3:4], gives :

$$V(m) = \min\{ m , c + V(m) - \int_{-\infty}^{m} V'(y)F(y)\,dy \} \qquad [3:6]$$

Consider those m for which <u>V(m) < m</u>. Then, from [3:6], it follows that :

$$V(m) = c + V(m) - \int_{-\infty}^{m} V'(y)F(y)\,dy \text{ ,} \qquad \text{and so}$$

$$\int_{-\infty}^{m} V'(y)F(y)\,dy = c \qquad [3:7]$$

Now, by definition, V(y) and F(y) are non-decreasing functions of y, and thus, $V'(y) \geq 0$ for all y, and $F(y) \geq 0$ for all y. The integrand, then, is non-negative. Therefore, there must exist some unique value of m, say R, such that :

$$\int_{-\infty}^{R} V'(y)F(y)\,dy = c \qquad [3:8]$$

<u>and</u>, $V'(y) = 0$ for all $y \geq R$

V(m), then, is a constant, say k, for all values of m greater than R. Now consider those values of m less than R. Then, it must be that :

$$\int_{-\infty}^{m} V'(y)F(y)\,dy < \int_{-\infty}^{R} V'(y)F(y)\,dy \qquad [3:9]$$

Returning to equation [3:6], and using the results in equations [3:8] and [3:9], the second term on the right-hand side,

$$
\begin{aligned}
c + V(m) - \int_{-\infty}^{m} V'(y)F(y)\,dy &= V(m) + \int_{-\infty}^{R} V'(y)F(y)\,dy \\
&\qquad - \int_{-\infty}^{m} V'(y)F(y)\,dy \\
&> V(m)
\end{aligned}
$$

Therefore, by definition from [3:6], within this range

$$V(m) = m$$

Summarising these results,

$$
\begin{aligned}
V(m) &= k \qquad \text{for } m > R \\
V(m) &= m \qquad \text{for } m \le R
\end{aligned}
\qquad [3:10]
$$

For V to be a continuous function, the two must be equivalent when $m = R$, and so the constant k must equal R.

The relationship is presented graphically in Figure 3:1 below.

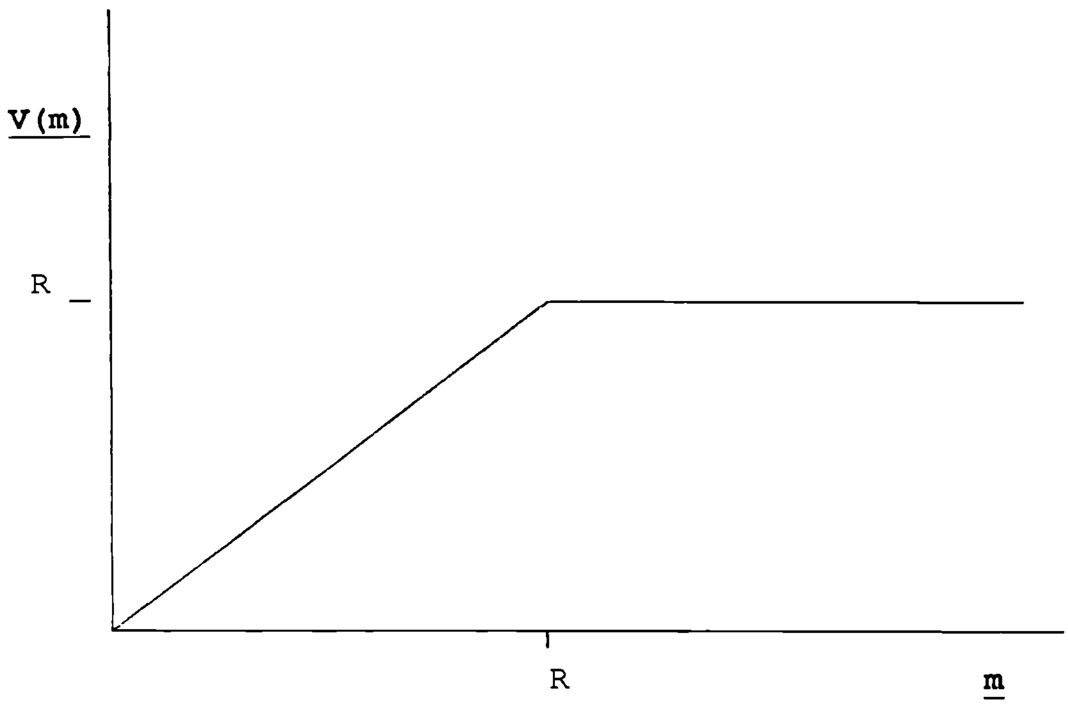

Figure 3:1 ...The expected value of the objective function for different minimum price offers

Thus, from [3:6], if $V(m) = m$, search should be ceased while if $V(m) < m$, it is worth continuing. From Figure 3:1, this can be seen to reduce to searching until the first price is located less than or equal to the reservation price, R. The reservation price can be calculated using the expression derived from substituting for $V'(y)$ from [3:10] in [3:8], so that :

$$\int_{-\infty}^{R} F(y)\, dy = c \qquad [3:11]$$

The above result is an important one in search theory, being the simplest generalised expression for the reservation price. Thus, an individual with complete prior knowledge of the distribution of prices, and, therefore, the cumulative price distribution function F(.), should first calculate a reservation price, R, using the equation above, as well as the value of her unit search cost, c (assumed to be constant). Having calculated this, the individual should then search until a price is located less than or equal to this reservation price, and accept the first such price encountered.

Although this would seem a clear and concise solution to the search problem, except in instances where the price distribution is relatively straightforward, the evaluation of the above integral, and so the reservation price, is non-trivial and will often require an iterative computer process. Heuristic solutions to the search problem requiring less computational effort are introduced and discussed in Chapters 4, 5 and 6.

Where the price distribution is normal, with mean, μ, and standard deviation, σ, an alternative derivation of the same result lends itself to a solution that can be looked-up in statistical tables. The reservation price, R, is given by the expression below (as derived in Appendix 3:1):

$$\frac{R - \mu}{\sigma} + \frac{SL(R)}{\sigma} = \frac{c}{\sigma} \qquad [3:12]$$

where $SL(m) \; \{ = \int_m^\infty (y - m)f(y)dy \}$ is the standardised, normal loss integral (see, for example, Hughes and Grawoig, 1971, p459). So, for illustration, suppose the price distribution has parameters $\mu = 86$, $\sigma = 10$, and that the unit search cost is 4. Then the solution for R given by [3:12] is derived from:

$$\frac{R - 86}{10} + \frac{SL(R)}{10} = \frac{4}{10}$$

Using the Unit Normal Loss Integral Tables reproduced as Appendix 3:2, it can be seen that this is uniquely satisfied where (to two decimal places) :

the standardised function, $\frac{R - 86}{10} = 0.01$, and

the loss function, $\frac{SL(R)}{10} = 0.39$

Solving the first of these gives a reservation price of 86.10, which corresponds to the value calculated numerically in the experimental work that follows in Chapters 4, 5 and 6. In addition, this second derivation indicates the importance of the ratio between the search cost and the standard deviation of the price distribution, that is, c/σ. One particularly useful result concerning this variable, derived in Appendix 3:3, is that:

- the expected number of searches before encountering the reservation price or lower, is a decreasing function of c/σ (and, hence, independent of μ).

This result is used further in some of the new search rules introduced in Chapters 5 and 6 (for example, see Rule K).

MODEL EXTENSIONS

The basic search model developed above has two important, underlying assumptions. First, the searcher has full knowledge of the price distribution, in the sense of knowing, or at least being able to calculate, the exact probability of obtaining any given price offer. Second, there is a full recall facility. Recall relates not just to memory but to memory and availability; thus a recall facility enables any past offer to be retrieved later. In this section, the effect on the model of partially relaxing these assumptions, as well as certain other constraints, is investigated. Specific findings are discussed and referenced, though formal proofs are not reproduced.

I) - Knowledge of the Price Distribution

Given the complex nature of product and service price distributions, it would be unreasonable to assume that, in general, searchers have complete knowledge about a particular distribution. If their knowledge is imperfect, however, use of an optimal reservation price model may compound any initial specification errors and lead to decisions that are substantially sub-optimal. Gastwirth (1971) explored the robustness of search models in this context, and found that modest specification errors could, in some circumstances, result in dramatic increases in the total expected cost, as well as in the total expected number of searches. For example, a searcher assuming that prices were distributed evenly on the unit interval, $F(x) = x$, when in reality they were distributed on the same interval, but in accordance with a right-triangular distribution, $F(x) = x^2$, would on average incur approximately double the total cost and search five times as much as she would had she been correctly informed.

In other cases, a searcher's knowledge of the price distribution may be too limited to enable any prior specification. As such, use of a reservation price model would be more difficult. In these circumstances, each offer received is not only a potential purchase or employment opportunity, but also provides a piece of information that can be used to update and revise prior beliefs about the distribution.

Two cases can be distinguished. First, the searcher receives an offer, uses it to recalculate her reservation price, and then decides whether or not to accept it. Kohn and Shavell (1974) have shown that in this "adaptive" search paradigm, the reservation price is no greater than the reservation price in the "static" search paradigm (where prior knowledge of the distribution is complete).

In, the second case, the offer is accepted or rejected before the distribution is updated, and so, before the reservation price is recalculated. Rothschild (1974, p701) provides a counter-example demonstrating that the reservation price property (that there exists a unique price below which an offer should be accepted and above which an offer should be rejected) does not always hold here.

> "Suppose there are three prices, $1.00, $2.00, and $3.00, and that the cost of search is $0.01. Prior beliefs admit the possibility of only two distributions of prices. Either all prices are $3.00 or they are distributed between $1.00 and $2.00 in the proportion 99 to 1. A man with these beliefs should accept a price of $3.00 (as this is a signal that no lower prices are to be had) and reject a price of $2.00 (which indicates that the likelihood that a much better price will be obtained on another draw is high)."

Existing experimental evidence concerning the effect on search processes of having either full prior knowledge or no prior knowledge about the price distribution is discussed in Chapter 4, while new experimental work in the area is presented and analysed in Chapter 5. In addition, Chapter 6 reports further, new experimental work in the situation where a searcher has partial prior knowledge of the distribution, though using a less pathological and more realistic setting than that conveyed by Rothschild's illustration above.

II) - **Recall**

The search model derived in this chapter carries the underlying assumption that any past offer may be selected at any time. Such a regime is known as "search with recall" and might apply to homogeneous good markets where the total search term is low. In many other situations, previously rejected offers cannot later be retrieved. This type of regime is termed "search without recall", and in the context of labour markets might be a reasonable representation of the real-world situation where there is a high unemployment rate, and where job vacancies are filled quickly. In consumer product markets, examples might include rare or specialist cars, or segments of the property market, though clearly the requirement for homogeneity may be more difficult to satisfy.

A generally more realistic model of search would be "search with uncertain (or partial) recall" ; that is, the probability of a past offer being retrievable is greater than zero (search without recall), but less than one (search with recall). The probability is likely to be linked to the price of the good, in that more favourably priced goods are likely to be sold more quickly.

In situations where the searcher has complete knowledge of the distribution and where search costs are constant, any price offer received should be assessable on its own merits against the optimal reservation price for that distribution. An accept or reject decision can be made immediately, and will not alter over time. The extra facility of recall, whether full or partial, will not have any effect on the overall decision strategy which remains as accepting the first price offer received no greater than the reservation price.

Where knowledge is incomplete, or where search costs vary over time, this may not be the case. Karni and Schwartz (1977) derived a model incorporating uncertain recall based on the following four assumptions (pp 41-42) :

- The expected benefit of search has a finite mean and variance over time.
- The probability that a past offer is currently available decreases over time.
- The marginal cost of search (measured in utiles) increases with the number of searches.
- The marginal cost of the j^{th} search is the same whether the search is a new draw or a backward solicitation of any of the past observations.

The second of these assumptions is a little uncomfortable. As stated above, intuitively, one would expect lower price offers to be more likely to become unavailable than higher price offers, as they are more likely to be seen as bargains and, therefore, accepted. An improved assumption would allow the probability that a past offer is currently available to be a function of both time <u>and</u> its relative magnitude.

Karni and Schwartz (1977, p 48) show that in such circumstances :

- the reservation utility in the case of search with uncertain recall is bounded above by the reservation utility of search with recall, and from below by the reservation utility of search without recall.

The experiments that follow in later chapters are attempting to understand individual search behaviour further, though in most cases (and in all the new experimental work) the facility of full recall is always kept available.

III) - **<u>Other Factors</u>**

Some further factors that may influence the behaviour of the generalised search model include the level of search costs, a searcher's risk attitude, her current wealth position, time, and the concept of diminishing returns to search. While these factors are not developed further in the experimental work of Chapter 5 and Chapter 6, they are discussed here briefly in the interests of completeness. Note that although some results are presented in the context of job search, the findings are equally applicable in the contexts of product or service search that is the central focus of this thesis.

- Search Costs

Most sequential models assume (in the interests of simplicity) that search costs remain constant through time. Given a constant search cost, though, it follows directly from the formula defining the reservation price (equation [3:11]), that as search costs increase, searchers will tend to set higher reservation prices. Further, from the earlier result that the expected number of searches is a decreasing function of c/σ, a higher search cost will result in a fall in the amount of search.

Interesting empirical support for this is presented by Barron and Mellow (1979) in the context of job search. They developed a theory of the unemployed individual's choice of how much "effort" to devote to search, where the term "effort" involves both the monetary cost of search and the time taken. They tested the theory using data from a supplement to the May 1976 Current Population

Survey in the USA. One particular finding supported their prediction that an increase in the mean of the wage offer distribution would increase the search effort input. An increase of one dollar (from $4 to $5) in the expected wage increased search time by 9%. Thus, a higher reservation wage (lower reservation price) will tend to encourage more search effort.

- Risk Attitude

Individuals searching in the paradigm above are assumed to be risk neutral with a linear utility function. Nachman (1972) has shown that, other things being equal, risk averse individuals searching in the basic search paradigm, with or without recall, will search less and settle for lower wages (higher prices) than will risk neutral individuals.

Other interesting results have been found by considering the effect on the reservation price of changing the characteristics of the distribution, and, in particular, its associated risk. Two types of such change in risk of a distribution have been defined in the economics literature. The Rothschild-Stiglitz (1970) mean-preserving change in risk may be attractive to a risk averter despite its consequent reduction in utility. This is because it increases the probability of extremely favourable observations which, coupled with an individual's ability to sample several times, may make it worthwhile to continue search. Kohn and Shavell (1974) remark that this type of change in risk may either raise or lower the reservation wage depending on the specific circumstances. If, however, the job searcher is risk neutral, the mean-preserving increase in risk can only raise her reservation wage.

The second type of change in risk is the Diamond-Stiglitz (1974) mean-utility-preserving increase in risk. Such an increase in risk will raise the reservation wage of a job searcher (Kohn and Shavell, 1974).

Chalkley (1984) introduced to the literature a job search model that allowed null employment offers to be made. If knowledge of the distribution is incomplete in the sense that the probability, q , of receiving a positive wage offer is not known with certainty, Chalkley found that, in general, a more diffuse prior (a greater variance on q) tends to reduce the reservation wage, implying that supposedly risk neutral individuals may, when searching, dislike risk.

- <u>Wealth Position</u>

A further potential influence on the search behaviour of an individual is her current wealth position. As her wealth decreases, a job searcher may be more willing to accept a lower paid employment ("beggars can't be choosers"). Hence, the reservation wage would be expected to fall. Danforth (1974) confirmed this with respect to asset holdings for an expected utility maximiser in both the finite and infinite time horizon. Lippman and McCall (1976) have applied the search model to the bankruptcy problem, and concluded similarly. The special problem here is that at a certain, very low asset value, no re-investment is permitted, and so no further search is possible (search costs being taken to represent general living expenses etc.).

- <u>Time</u>

In the search paradigm described above there is an infinite time horizon, and reservation values are constant through time. If, however, this assumption on time is lifted (that is, a searcher has only a finite amount of time to purchase a product or find employment), then this property of reservation values ceases to hold. McCall (1974) shows that in the basic search paradigm with a finite time horizon, the reservation wage (price) will fall (rise) over time.

Further, Benhabib and Bull (1983) have shown that the expected return to search with t periods remaining is less than the expected return with t + 1 periods remaining, for all t. This leads searchers to increase the likelihood of terminating search by extending the sample size within a period.

- Diminishing Marginal Returns

There has been some discussion in the literature on the assumption of diminishing returns to job search. Apart from being an important property in itself, such an assumption may go some way towards explaining the apparent paradox of a 35 to 40 hour working week compared with Barron and Mellow's empirically observed mean search time of approximately 7 hours per week (1979, p396).

The hypothesis of diminishing returns to search has itself been empirically tested by Chirinko (1982) using two samples drawn from a special survey of unemployed individuals in the May 1976 USA Current Population Survey.

A spatial explanation for this phenomenon has been offered by Seater (1979). His explanation is based on an assumption that a job-seeking individual will conduct a search for vacancies by contacting first those prospective employers closest to home in preference to those further away. Thus, as time passes, and the nearby vacancies have all been contacted, subsequent search will necessitate travelling a greater distance, thereby incorporating greater search costs in terms of time and money, and, therefore, yielding diminishing marginal returns. Search may therefore be terminated earlier.

SUMMARY

This chapter has developed a formal search model set in the context of an individual searching for a consumer product or service at a suitably low price. In addition, relevant extensions to the model described within the research literature have been reviewed.

The key result is that given a cumulative price distribution, F , and a constant unit search cost, c , an individual should set a reservation price, R , and keep searching until she receives a price quote less than or equal to R. The optimal reservation price is given by the expression :

$$\int_{-\infty}^{R} F(x)\ dx \quad = \quad c$$

Solving the expression is non-trivial. A new derivation, however, that utilises normal loss integrals, enables a tabular solution where the price distribution is normal.

Further, where a distribution is normal with standard deviation, σ , it has been shown that the expected number of searches is a decreasing function of c/σ.

The next chapter reviews the existing experimental evidence concerning the apparent use (or non-use) of the theoretically optimal search model.

APPENDIX 3:1

This appendix provides an alternative derivation of the reservation price formula that utilises standard normal loss integrals and enables a tabular solution.

Using similar notation to before, let :

- f represent the probability density function of the price distribution ,
- F represent the cumulative price distribution ,
- m represent the minimum price received so far ,
- y represent the next price offer received , and
- c represent the fixed unit search cost.

The expected gain from searching once more is $m - y$ with probability $f(y)$ for all $y \leq m$, and 0 with probability $f(y)$ for all $y > m$. In either case there is also a loss of c. Thus, the net expected gain, E, is given by :

$$E = \int_{-\infty}^{m} (m - y).f(y)\, dy \quad - \quad c \qquad [A31:1]$$

$$= \int_{-\infty}^{\infty} mf(y)dy \; - \; \int_{-\infty}^{\infty} yf(y)dy \; + \; \int_{m}^{\infty} (y - m)f(y)dy \; - \; c$$

$$= m \; - \; \mu \; + \; SL(m) \; - \; c$$

where $SL(m)$ $\{ = \int_m^\infty (y - m)f(y)dy \}$ is the standardised, normal loss integral. Re-writing,

$$E = \sigma \{ \frac{m - \mu}{\sigma} + \frac{SL(m)}{\sigma} - \frac{c}{\sigma} \}$$

and so, the individual should continue searching if the expected gain, E, is positive. That is, if

$$\frac{m - \mu}{\sigma} + \frac{SL(m)}{\sigma} > \frac{c}{\sigma}$$

But, trivially, from [A31:1], $\frac{m - \mu}{\sigma} + \frac{SL(m)}{\sigma}$ is an increasing function of m. Thus, there exists some R such that :

$$\frac{R - \mu}{\sigma} + \frac{SL(R)}{\sigma} = \frac{c}{\sigma} \qquad [3:12]$$

where once again, the decision rule is to continue searching if $y > R$, and stop if $y \leq R$. R itself is found by integrating [A31:1] by parts. Hence,

$$[(R - y)F(y)]_{-\infty}^{R} - \int_{-\infty}^{R} (-1)F(y)dy = c$$

so,

$$\int_{-\infty}^{R} F(y)dy = c \quad \text{(as per 3:11)}$$

APPENDIX 3:2

This appendix reproduces values of the unit normal loss integral for use in calculating reservation prices in accordance with equation [3:12].

The values in the body of the table are expected opportunity losses for linear loss functions and a normal distribution with a mean of zero and a standard deviation of unity. The value represents the standardised deviation of the break-even value from μ.

Unit Normal Loss Integral

$$L_{N^*}(u) = P'_{N^*}(u) - u\,P_{N^*}(\tilde{u} > u)$$

u	.00	.01	.02	.03	.04	.05	.06	.07	.08	.09
.0	.3989	.3940	.3890	.3841	.3793	.3744	.3697	.3649	.3602	.3556
.1	.3509	.3464	.3418	.3373	.3328	.3284	.3240	.3197	.3154	.3111
.2	.3069	.3027	.2986	.2944	.2904	.2863	.2824	.2784	.2745	.2706
.3	.2668	.2630	.2592	.2555	.2518	.2481	.2445	.2409	.2374	.2339
.4	.2304	.2270	.2236	.2203	.2169	.2137	.2104	.2072	.2040	.2009
.5	.1978	.1947	.1917	.1887	.1857	.1828	.1799	.1771	.1742	.1714
.6	.1687	.1659	.1633	.1606	.1580	.1554	.1528	.1503	.1478	.1453
.7	.1429	.1405	.1381	.1358	.1334	.1312	.1289	.1267	.1245	.1223
.8	.1202	.1181	.1160	.1140	.1120	.1100	.1080	.1061	.1042	.1023
.9	.1004	.09860	.09680	.09503	.09328	.09156	.08986	.08819	.08654	.08491
1.0	.08332	.08174	.08019	.07866	.07716	.07568	.07422	.07279	.07138	.06999
1.1	.06862	.06727	.06595	.06465	.06336	.06210	.06086	.05964	.05844	.05726
1.2	.05610	.05496	.05384	.05274	.05165	.05059	.04954	.04851	.04750	.04650
1.3	.04553	.04457	.04363	.04270	.04179	.04090	.04002	.03916	.03831	.03748
1.4	.03667	.03587	.03508	.03431	.03356	.03281	.03208	.03137	.03067	.02998
1.5	.02931	.02865	.02800	.02736	.02674	.02612	.02552	.02494	.02436	.02380
1.6	.02324	.02270	.02217	.02165	.02114	.02064	.02015	.01967	.01920	.01874
1.7	.01829	.01785	.01742	.01699	.01658	.01617	.01578	.01539	.01501	.01464
1.8	.01428	.01392	.01357	.01323	.01290	.01257	.01226	.01195	.01164	.01134
1.9	.01105	.01077	.01049	.01022	$.0^{2}9957$	$.0^{2}9698$	$.0^{2}9445$	$.0^{2}9198$	$.0^{2}8957$	$.0^{2}8721$
2.0	$.0^{2}8491$	$.0^{2}8266$	$.0^{2}8046$	$.0^{2}7832$	$.0^{2}7623$	$.0^{2}7418$	$.0^{2}7219$	$.0^{2}7024$	$.0^{2}6835$	$.0^{2}6649$
2.1	$.0^{2}6468$	$.0^{2}6292$	$.0^{2}6120$	$.0^{2}5952$	$.0^{2}5788$	$.0^{2}5628$	$.0^{2}5472$	$.0^{2}5320$	$.0^{2}5172$	$.0^{2}5028$
2.2	$.0^{2}4887$	$.0^{2}4750$	$.0^{2}4616$	$.0^{2}4486$	$.0^{2}4358$	$.0^{2}4235$	$.0^{2}4114$	$.0^{2}3996$	$.0^{2}3882$	$.0^{2}3770$
2.3	$.0^{2}3662$	$.0^{2}3556$	$.0^{2}3453$	$.0^{2}3352$	$.0^{2}3255$	$.0^{2}3159$	$.0^{2}3067$	$.0^{2}2977$	$.0^{2}2889$	$.0^{2}2804$
2.4	$.0^{2}2720$	$.0^{2}2640$	$.0^{2}2561$	$.0^{2}2484$	$.0^{2}2410$	$.0^{2}2337$	$.0^{2}2267$	$.0^{2}2199$	$.0^{2}2132$	$.0^{2}2067$

APPENDIX 3:3

This appendix provides a proof that the expected number of searches before encountering the reservation price or lower, is a decreasing function of c/σ.

Again, using similar notation to before, from [3:11],

$$c = \int_{-\infty}^{R} \int_{-\infty}^{x} f(y)\ dydx$$

where $R = R(c,\mu,\sigma)$. Changing the variable y using the transformation, $z = (y - \mu)/\sigma$, leads to :

$$c = \int_{-\infty}^{R} \int_{-\infty}^{(x-\mu)/\sigma} f_{0,1}(z)\ dzdx \qquad [A33:1]$$

with $f_{0,1}(z)$ being the probability density function of the normal distribution with zero mean and unit standard deviation, and therefore, independent of both μ and σ. Again, changing the variable x in [A33:1] using the transformation, $t = (x - \mu)/\sigma$, gives :

$$c = \sigma \int_{-\infty}^{(R-\mu)/\sigma} \int_{-\infty}^{t} f_{0,1}(z)\ dzdt \qquad [A33:2]$$

If, $c = k$, $\mu = 0$, and $\sigma = 1$, then this becomes :

$$k = \int_{-\infty}^{R(k)} \int_{-\infty}^{t} f_{0,1}(z)\ dzdt \qquad [A33:3]$$

Now, $R(k)$ is independent of μ and σ, and is an increasing function of k. Replacing k by c/σ in [A33:3]:

$$\frac{c}{\sigma} = \int_{-\infty}^{R(c/\sigma)} \int_{-\infty}^{t} f_{0,1}(z)\ dzdt \qquad [A33:4]$$

and by identifying [A33:4] with [A33:2] ,

$$R(c/\sigma) = \frac{R(c,\mu,\sigma) - \mu}{\sigma} \qquad [A33:5]$$

It has already been shown that the expected number of searches before finding the reservation price or lower, $E\ [n(R)]$, is equivalent to $\frac{1}{p}$ (see [3:3]). But, by definition,

$$p = \int_{-\infty}^{R} f(y)\ dy$$

Changing the variable y above using the transformation $z = (y - \mu)/\sigma$, gives :

$$p = \int_{-\infty}^{(R-\mu)/\sigma} f_{0,1}(z)\, dz \qquad [A33:6]$$

Substituting [A33:5] into [A33:6] :

$$p = \int_{-\infty}^{R(c/\sigma)} f_{0,1}(z)\, dz$$

Therefore, p is an increasing function of $R(c/\sigma)$, which in turn is an increasing function of c/σ. Thus, it follows that $E\,[n(R)]$, the expected number of searches, is a decreasing function of c/σ , as required.

CHAPTER

FOUR

CHAPTER FOUR

EXPERIMENTAL STUDIES

INTRODUCTION

The previous chapter developed a formal search model that can be used to dictate search strategy where an individual can sample offers from a large distribution of offers, at a constant unit search cost. Specifically, the individual should set a reservation price at the outset, and then accept the first offer received no greater than that reservation price.

This chapter reviews the experimental studies published in this area that seek to investigate, in particular, the extent to which individuals actually do adopt reservation price search strategies. To date, there have been only a limited number of experimental studies concerning single variable search, some of which are set in the context of searching for the lowest price of a good, while others relate to the search for the highest paid job. As discussed before, however, the characteristics of the alternative settings are otherwise identical. The two major research contributions in this area have been made by Schotter and Braunstein (1981), and by Hey (1981, 1982 and 1987). Schotter and Braunstein's study tested a total of 11 hypotheses investigating a wide variety of theoretical search results, such as the use of reservation wages, and the effects of risk. Analysis was carried out at an aggregate level to discover whether at this small market level actual search behaviour complied with the predictions of the theoretical models.

In contrast, Hey's studies adopted a behavioural approach, with a focus at the individual level rather than at the aggregate level. He attempted to uncover reasonable rules-of-thumb that individuals might actually be using in making search or buy decisions. Ideally, such rules would be characterised by their greater simplicitly than the optimal search model, but with only a small loss in performance.

A review of the Human Information Processing literature relevant to accounting and decision making (in which framework Hey's studies are embedded) is provided in chapter 7 of this thesis. It is included there, rather than in the current chapter, in the interests of continuity and coherence, as it provides an important link between the price search studies of chapters 5 and 6, and the study of a behavioural phenomenon - functional fixation - in chapter 8.

Most of this chapter, then, is devoted to a description and evaluation of the two major works above. First, though, the results from three earlier studies are briefly reported.

EARLY WORK

Rapoport and Tversky (1966) conducted a computer controlled experiment where the subjects were required to search for the "highest" offer from a distribution function of observations that was assumed to be known. Subjects were split into two groups; group L searching without and group H searching with the facility of recall. The authors concluded tentatively that search with recall resulted in more offers being sampled than in the case without recall, and that, in both conditions, the amount of search decreased as the cost of search increased. It was not clear, however, whether the subjects were actually utilising optimal search rules.

Kahan, Rapoport and Jones (1967) conducted an experiment into search without recall (ie. once an offer is passed, it is no longer available) where, this time, the distribution of observations was unknown, there was a zero search cost, and an upper limit - 200 - to the number of searches that could be undertaken. Again, subjects were required to discover as high an offer as possible. Clearly, an optimal reservation price cannot be calculated as the distribution is unknown. The authors, though, derived an optimal strategy by linking the experiment to the literature on "optional stopping" rules. A subject following an optional stopping strategy would sample n observations in order to gain a view of the overall distribution, and then stop at the first subsequent price that is higher or lower than all previous prices, depending on the particular experimental context. In the Kahan, Rapoport and Jones experiment, the optimal, optional stopping strategy was computed as being to pass the first 74 offers received, and then accept the first subsequent offer greater than the highest of the first 74. Sixty percent of subjects behaved consistently with such a strategy, though it seems extremely unlikely that many subjects, if any, were actually using so specific a decision rule. (Note that the added facility of recall would render the experiment trivial, as the zero search cost would imply a searcher could not lose by searching the maximum 200 times.)

A weakness of the earlier Rapoport and Tversky (1966) study was that in reality subjects had received minimal prior information about the distribution function, and had sampled only a relatively small number of offers during the experiment. Thus, although the distribution function was assumed to be known, in terms of its underlying parameters, there was considerable doubt as to whether subjects had learned its shape sufficiently well. Rapoport and Tversky (1970) rectified this by conducting another experiment where the seven participants were allowed a total of 60 hours each to become thoroughly familiar with the two distributions used in the experiment (A and B), by means of repeated sampling. Each distribution consisted of four-digit numbers, A being approximately normal with mean 1630 and standard deviation 167, while B was again approximately normal with the same standard deviation but a higher mean of 1797. The experiment itself followed this learning period, the specific design being as summarised in Table 4:1.

TABLE 4:1

RAPOPORT AND TVERSKY (1970) - EXPERIMENTAL DESIGN

Session	Dist'n	N	Recall	No. of Trials	Unit Search Cost
1	A	24	No	24	0,5,10,20
2	B	24	No	24	0,5,10,20
3	A	24	Yes	18	5,10,20
4	A	8	No	20	0,5,10,20
5	B	24	Yes	18	5,10,20
6	B	8	No	20	0.5,10,20

Thus, for example, in session 3 subjects searched with full knowledge and full recall from a normal distribution with mean 1630 and standard deviation 167; and undertook six separate trials for each of three search cost conditions (c = 5,10,20), there being a maximum number of observations permitted within each trial (N = 24). As there was no significant difference between results from the two distributions, they were combined in the analysis. The authors' main finding was that in the no-recall condition 65.2% of problems were solved optimally where search was restricted to 24 observations, and 71.1% where the limit was 8 observations. This compared to 61.8% of problems where there was the extra facility of recall. They concluded (1970, p 119) that :

> "...the results of the present study suggest that the optimal model provides a reasonably good account of the behaviour of the subjects."

It should be remembered, though, that the seven subjects who participated in the experiment were thoroughly familiar with the distributions; they could be considered experts. As such, the proportion of problems solved optimally is, perhaps, surprisingly low. In any event, given the experimental design, it is doubtful that the findings can be generalised to more realistic settings regarding the distribution familiarity.

Over the next decade, there were many advances in the theoretical literature concerning search model derivations and extensions. It was not until 1981, however, that a large-scale experimental study was undertaken to investigate the practical robustness of these advances.

SCHOTTER AND BRAUNSTEIN (1981)

Schotter and Braunstein (1981) published the results of an extensive experimental investigation into individual search behaviour. They tested a total of 11 hypotheses, the first of which, particularly relevant to the new experimental work that follows in later chapters, is reproduced below for illustration:

H1 - The Reservation Wage Hypothesis

> People actually search according to the reservation wage rule and on average tend to set the optimal reservation wage.

The remaining ten hypotheses are not reproduced here as, mostly, they are less directly relevant to the new experimental work that follows in later chapters. Briefly, however, H2 and H3 are concerned with the effects of risk aversion with and without recall, H4 with the effect of changing search costs, H5 with the effects of increases in risk-mean-preserving spreads, H6 with uncertain recall, H7 with no recall, H8 with the constancy of reservation wages over time, H9 with a finite time horizon, and H10 and H11 with searching from unknown or mis-specified price distributions.

The "basic search paradigm" mentioned in several of the hypotheses, refers to the following formally defined scenario (1981, p 3) :

> "An individual, referred to as the searcher, is seeking employment. Each and every day (until he accepts a job), he ventures out to find a job, and each day he generates exactly one job offer (he is not allowed to vary the intensity of his search efforts), offered to him from a stationary distribution of wages known to him. The cost of generating each offer is a constant c, and there is no limit on the number of offers the searcher can obtain. In addition, once a searcher is offered a job, that offer is always available to him to accept (there is a perfect recall of job offers). Finally, the searcher has a utility function which is linear in income (the searcher is risk neutral)."

The 56 undergraduates participating in the experiment were assigned randomly to one of three groups; Group I (the Risk Neutral group), Group II (the Risk Averse group), and Group III (the Uncertainty group). Subjects in Group I searched in the basic search paradigm and performed a total of 12 experimental trials. Those trials relevant to the hypothesis specified above are highlighted below :

Trial 1 - search was from a symmetric triangular wage distribution, $p(w)$, given by :

$$p(w) = \begin{cases} \dfrac{w}{10{,}000} & \text{for} \quad 0 \leq w \leq 100 \\[2ex] \dfrac{100 + (100 - w)}{10{,}000} & \text{for } 100 \leq w \leq 200 \end{cases}$$

There was no limit to the number of searches permitted, though each one cost five "points".

Trial 2 - this was identical to trial 1 as far as the subjects were concerned, but in reality the sequence of wages was pre-selected. The first five numbers were 80.29, 78.66, 115.64, 110.75 and 146.35, thereby presenting the searcher with four wages below the theoretically optimal reservation wage of 133.00.

Trial 3 - as trial 1, but search was from a rectangular distribution in which all wages were equally likely. That is,

$$p(w) = \frac{1}{200}$$

Trial 12 - similar to trial 2, the pre-selected sequence this time being such that a subject had to search six times before receiving an offer higher than the optimal reservation wage (93.95, 43.58, 65.86, 82.87, 74.88, 147.76).

If a searcher searched n times, and accepted a wage w, the payoff would be $w - nc$ points. Subjects in Group I were paid one penny per point as incentive. Group II subjects performed exactly the same trials, but their payoff conversion function was set in such a way as to simulate an Arrow-Pratt measure of risk aversion (see, for example, Pratt, 1964).

Group III subjects were risk neutral, but performed only eight trials. These were designed to enable comparison with Group I subjects regarding the effects of searching from unknown distributions, or from distributions about which they were deliberately mis-informed.

Results

H1 - The Reservation Wage Hypothesis

The reservation wage hypothesis was tested by considering three parameters across trials 1, 2, 3 and 12 for Groups I and II. The three parameters were the reported reservation wage used - discovered by asking subjects for the minimum bribe they would be willing to accept rather than searching again - the highest rejected wage, and the actual accepted wage. The results are summarised an Table 4:2.

TABLE 4:2

TESTS OF THE RESERVATION WAGE HYPOTHESIS

	Group I : Risk Neutral		Group II : Risk Neutral	
Trial	Optimal R.W.	Mean of Reported R.W.	Optimal R.W.	Mean of Reported R.W.
1	133	134.50 *	130	109.72 *
2	133	135.75 *	130	107.95 *
3	155	156.75 *	152	136.24 *
12	133	136.00 *	130	107.24 *
Trial	Optimal R.W.	Average Highest Rejected Wage	Optimal R.W.	Average Highest Rejected Wage
1	133	123.17 *	130	107.27 *
2	133	114.97 *	130	106.34 *
3	155	125.57 *	152	128.72 *
12	133	102.02 *	130	99.07 *
Trial	Expected Accepted Wage Given Reported R.W.	Actual Accepted Wage	Expected Accepted Wage Given Reported R.W.	Actual Accepted Wage
1	155	146.45 *	136	141.40 *
2	155	139.15 *	136	123.75 *
3	170	170.38 *	157	168.72 *
12	155	134.37 *	136	124.70 *

* significant at the 95% level

As can be seen, in all cases results were significant at the 95% level. That is, in no case were the actual results significantly different from the optimal or expected results. Thus, for example on trial 3, the Group I subjects reported an average acceptance bribe of 156.75 which compares closely with the optimal 155.00.

AN EVALUATION OF SCHOTTER AND BRAUNSTEIN'S WORK

Overall, the results of Schotter and Braunstein's extensive experiment broadly comply with the behaviour that is predicted by theoretical search models. In particular, it appears that the reservation wage hypothesis holds in practice. There are, however, two important riders to this conclusion.

First, the reported results are all based on the average of many subjects' behaviour. They describe behaviour at a small market aggregate level, rather than at an individual level. Second, the results can conclude only that subjects behaved (on aggregate) as though they were using an optimal reservation rule. The experiment does not seek to investigate whether they actually were using such a rule.

The optimal search model derived in Chapter 3 requires a searcher to set a reservation price, R , given by :

$$\int_{-\infty}^{R} F(x)\, dx \quad = \quad c$$

and accept the first offer no greater than this reservation price. The practical application of the exact model, however, is characterised by three main shortcomings, that stem mostly from the real-life constraint of bounded rationality as discussed earlier in Chapter 1.

First, where an individual is searching from an unknown environment, a picture of the distribution function can only be built-up over time. Where, in addition, only a limited number of observations are sampled, it is inevitable that this picture of the distribution may be at best incomplete, and at worst totally wrong. Any mis-specification of the model will lead potentially to errors in the reservation price that is set. Indeed, as Schotter and Braunstein discovered, mis-information can result in substantially sub-optimal behaviour.

Second, even where the distribution function is known with some accuracy, the subsequent evaluation of the reservation price, R, is non-trivial. It requires substantial computational power. The cost of computation, therefore, is not sufficiently small to be ignorable.

Third, and following on from the criticism above, the evaluation obtained in any case is necessarily an approximation, and it is not clear that any approximating error is small.

The additional criticism that the model requires a searcher to know her search costs and economic utility functions, while valid, would apply whatever search model was being used.

Thus, it seems unlikely that participants in Schotter and Braunstein's experiment were genuinely behaving in accordance with the predictions of formal search models, at least not at the individual level. A consequent research issue is to discover what kinds of search rules or heuristics individuals use as substitutes. This was addressed, to an initial extent, by the work of Hey (1981, 1982, 1987).

HEY (1981, 1982, 1987) - REASONABLE RULES OF THUMB

In trying to understand the impact of the practical limitations of formal search models, Hey (1981) suggested two alternative frameworks. Either searchers simplify the problem first and then behave optimally with respect to the simplification ("sub-optimal search"), or they adopt some simple, reasonable rules of thumb. In comparing these two, Hey suggests (1981, p 69) that :

> "while the former may simply be an attempt at the latter, (or vice-versa), it is by no means clear that the "optimal" in "sub-optimal" will dominate the "sub". Taken in conjunction with the empirical observation that, in practice, the expected number of searches following even the optimal strategy (with respect to the true distribution) is likely to be small, the paper suggests that the scope of learning may well be limited; thus, particularly in the presence of computation cost, reasonable rules of thumb may well be preferable. Since minimal requirements for "reasonableness" lead to sensible aggregate predictions, this is not particularly damaging to search theory."

Hey (1982) provided an experimental follow-up to these ideas, being concerned with attempting to discover specific "reasonable rules of thumb" that searchers adopt. 31 subjects participated in four different cases where a consumer durable item had to be purchased from one of an infinite number of suppliers. Subjects were told the maximum amount that they should be willing to spend on the item (inclusive of search costs) as well as the unit cost of search. They were unaware of the underlying shape and parameters of the price distributions used. The four cases were as shown in Table 4:3, each distribution being normal.

TABLE 4:3

HEY (1982) - PRICE DISTRIBUTIONS USED

Case	Budget	Mean	Standard Deviation	Search Cost	Reservation Price
	£	£	£	£	£
1	250	215	25	2.5	192.50
2	100	86	10	2	81.10
3	250	215	25	5	202.75
4	100	86	10	4	86.10

Using an explicit record of price sequences and subjects' decisions, together with tha analysis of verbal protocols recorded at the time of the experiment, Hey derived the following reasonable rules of thumb (1982, pp 72-74) :

Rule A (reservation rule)

Stop searching if a price quote is received that is sufficiently low.

Rule A* (optimal reservation rule)

Stop searching if a price quote is received less than the optimal (with respect to the true distribution) reservation value.

Rule B (one bounce rule)

Have at least two searches; stop if a price quote is received larger than the previous quote.

Rule C (two bounce rule)

Have at least three searches; stop if both the last quote and the next to last are larger than the second to last.

Rule D (modified one bounce rule)

Have at least two searches; stop if a price quote is received larger than the previous quote less the search cost.

Rule E (modified two bounce rule)

Have at least three searches; stop if both the last quote exceeds the second to last less twice the search cost and the next to last exceeds the second to last less the search cost.

Note that as subjects did not know the true distribution, then at most their behaviour could be as though they were using Rule A^*. As an illustration of the underlying evidence for these rules, consider the following extract from the protocol of subject 25 case 3 :

"[214.05 , 207.86] ... so I'm doing a little better, but I think we should search further ... [226.73] ... no, I don't like that quote ... I'll search once more and see what happens to that ... [209.23] ... OK, I've spent some money on search procedures, but I now believe that £207.86 for the cost of this item is quite good ... I will buy."

The subject's behaviour is consistent with both Rule C and Rule E, though it is not possible to ascertain which of the two rules was being used, if either.

Appendix 4:1 (a,b,c and d), included at the end of this chapter, presents a complete record of the price sequences obtained by the 31 subjects across the four cases, and, for each sequence, indicates the rules with which individuals' behaviour was consistent. Note that in two cases a subject was permitted to give up without buying (subject 13 case 4, subject 19 case 4) as they had exhausted their budget, and so their price sequences have been excluded. Table 4:4 summarises the frequency with which rules were apparently adopted; that is, the number of sequences for which they were consistent with observed behaviour. As mentioned above, the same observed sequence may well match with more than one rule, or no rules. In addition, the results for Rule A are recorded exclusive of results for Rule A* which is a special case of it.

TABLE 4:4

HEY (1982) - OCCURRENCE OF SEARCH RULES

		Occurrence of Search Rule					
Case	n	A	A*	B	C	D	E
1	31	8	3	6	9	6	8
2	31	4	7	10	7	11	8
3	31	4	12	6	3	8	3
4	29	5	9	8	2	11	3
	122	21	31	30	21	36	22

The relatively low proportion of subjects (25%) whose behaviour was consistent with the optimal reservation price strategy (A^*) is at variance with the results of Rapoport and Tversky (1970) and Schotter and Braunstein (1981) discussed earlier, where subjects mostly behaved optimally. The two likeliest contributory factors to this are that Hey's subjects had no initial information about the price distribution, and no pecuniary incentives to perform. These possible explanations were both addressed in the Hey (1987) study.

Four experimental conditions were identified depending on the level of information about the distribution, and whether there was a recall facility. The grouping is shown in Table 4:5. 32 subjects participated in the experiment, eight being assigned to each group, and each subject performed five trials.

TABLE 4:5

HEY (1987) - EXPERIMENTAL DESIGN

	Recall Permitted	No Recall Permitted
Full information about distribution	Group α	Group β
No information about distribution	Group Ω	Group δ

An incentive scheme was incorporated, subjects receiving a fixed amount of £1 plus a bonus proportional to the outcome of their performance in one of the five trials, selected randomly.

Appendix 4:2 at the end of this chapter presents detailed results of the experiment. Subjects were allowed any number of trial runs to familiarise themselves with the technology, though not with the distributions used in the formal experiment. A summary of the results is presented as Table 4:6.

TABLE 4:6

HEY (1987) - OCCURRENCE OF SEARCH RULES

		Occurrence of Search Rule					
Case	n	A	A*	B	C	D	E
α	40	9	23	3	-	2	-
β	40	12	26	-	-	-	2
Ω	40	3	13	10	5	7	5
δ	40	11	21	-	3	-	2
	160	35	83	13	8	9	9

Case Ω, corresponding to no initial information and full recall, is a straightforward replication of Hey's 1982 experiment, though with an added financial incentive and different price distributions. Its reported results are broadly similar. In terms of adopting the optimal A^* strategy, it is notable that subjects with full knowledge outperform those without (61% against 43%) which is not surprising. Further, subjects with no recall facility outperform those for whom past offers are always available, by 65% to 58% in the full knowledge condition and by 53% to 33% in the no knowledge condition. This does appear surprising, though it may be that the absence of a recall facility requires subjects to place much greater emphasis on the relative merits of each offer as it appears.

Although the outcome of Hey's experiments suggest that the reasonable rules of thumb account for a high proportion of observed behaviour, and, while not optimal, appear fairly robust, several criticisms apply. These are discussed below.

AN EVALUATION OF HEY'S WORK

First, considering the complete set of rules, apart from the difficulty in distinguishing them in certain circumstances (as mentioned above), it is also apparent that Rules B and C fail to take into account the search cost - which is surprising. Further, all four "bounce" rules attach some importance to the order in which the price quotes are received. Hey, himself, expresses dissatisfaction with the logic of this (1982, p 73) :

> "(Rule B) appears rather strange ... mainly in that it endows the order of the price quotes with some significance. For example, a person using this rule would stop after receiving £230, £190, £210 in that order, but would continue after receiving £230, £210, £190 in that order. We fail to see the rationale behind this phenomenon."

The explanation seems psychological rather than logical. In the former case, the two previous decisions to continue searching both paid off, and with at most one search cost to lose, a further attempt might seem a gamble worth taking. Hence, a subject will keep playing "winning streaks". This may, in part, be due to some framing effect (see, for example, Tversky and Kahneman, 1981; McNeil et al, 1982) in that the way in which the problem is presented may seem to endow the order with some importance.

Second, no distinction is made between rules appropriate in situations where subjects have no knowledge of the underlying price distribution and situations where they have full knowledge. Table 4:7 compares the frequency with which rules matched observed behaviour for groups α (full knowledge) and Ω (no knowledge) in Hey's (1987) "Still Searching" experiment. Both groups were permitted full recall of past offers. It is clear that the two groups demonstrate a very different pattern of behaviour.

The use of the four "bounce" rules is virtually negligible where subjects have full knowledge. This is understandable, as given their knowledge, subjects are able to judge each price quote received on its own merits, and not on the basis of the last or next quote. For this reason, separate consideration should be given to the reasonableness of the rules depending on the subjects' knowledge level about the distribution.

TABLE 4:7

"STILL SEARCHING" - A SUMMARY OF RULES USED

	Full Knowledge (n=40)	No Knowledge (n=40)
Occurrence of Rules		
A or A*	32	16
B, C, D or E	3	16

The third set of criticisms apply to decision situations where subjects have no knowledge of the distribution. Clearly, Rule A* can only be observed to occur by coincidence, as subjects are not able to calculate the optimal reservation price (due to the lack of information). Further, while searching until a sufficiently low price quote is received is a plausible strategy, Rule A conveys no clue as to how "sufficiently low" is defined. Even if a subject was known to be using Rule A, an outside observer would be unable to predict accurately when the subject would stop searching. This is not the case with Rules B, C, D or E. As it stands, Rule A is considered, therefore, to be insufficiently precise.

In addition, it is noted that in Hey's experiments, out of a total of 162 separate trials where subjects had no knowledge bul full recall, in as many as 16 cases (10%), subjects accepted the first offer received. Only four explanations could account for such behaviour. First, the cost of search might be extremely high compared with the offer just received. In the "Search for Rules for Search" experiment (122 trials, 10 first offer acceptances), however, the highest such ratio was only 5.1% which is not excessive. Second, subjects may have learned the distribution already, possibly from the preliminary trials. Third, the subjects had insufficient incentive to act rationally. Fourth, and probably the most likely explanation, is that subjects used the given budget figure as an anchor with which to compare the price quotes received. These possibilities are excluded in the design of the new experimental work that follows in Chapter 5 and Chapter 6.

The fourth criticism concerns situations where subjects have full knowledge of the distribution. As discussed above, Rules B, C, D and E do not seem appropriate. Moreover, given the computational complexity of calculating the optimal reservation price, it is highly unlikely that subjects are actually using Rule A^*. Rather, they may be adopting some heuristic, albeit a heuristic that performs well in comparison with A^*. The interesting issue is to discover the properties of such heuristics and to identify any common threads. Merely matching observed behaviour with Rules A or A^* does not explore this issue.

SUMMARY

This chapter has examined the experimental evidence published in the existing research literature regarding the behaviour of individuals when searching for the most favourable price of an otherwise homogeneous consumer product or service, or an employment contract.

It is evident that observed behaviour changes substantially from situations where a searcher has full initial information about the underlying price distribution, to situations where the searcher has no initial information. The apparent use of the optimal reservation price strategy is far greater in the former case than the latter, but even so, there is still <u>no</u> evidence to suggest that subjects actually were utilising such a search rule, given its computational complexity. It is possible, perhaps probable, that subjects whose behaviour was consistent with Rule A^* are, in fact, adopting some high performing heuristic.

The new experimental work that follows, particularly that presented in Chapter 5, seeks to uncover such heuristics which, either in the no knowledge situation or the full knowledge situation, describe individuals' search behaviour more fully and more accurately than Hey's reasonable rules of thumb. These new rules - especially in the no knowledge situation - may also perform more closely to the optimal.

APPENDIX 4:1 (a)

This appendix, together with Appendices 4:1 (b), 4:1 (c) and 4:1 (d), reproduce the raw data for the four cases in the Hey (1982) "Search for Rules for Search" experiment.

Raw data of Case 1.

Parameters: $x = 250$, $c = 2.5$, $\mu = 215.0$, $\sigma = 25.0$.

s no.	Price quotes obtained in chronological order							Consistent with rule(s)[a, b]	
(1)	224.49	207.06	222.84	211.29				C	E
(2)	184.48							A*	
(3)	213.13	251.84	255.34	197.25				A	
(4)	232.73	185.98	280.54	223.91				C	E
(5)	240.16	236.52						A	
(6)	191.55	185.91	183.70	194.33	224.52			C	
(7)	184.46	275.88	243.10					C	E
(8)	250.85	198.13	175.32					A*	
(9)	228.41	274.91	175.30	248.00	229.19	201.49	245.67		
(10)	209.05	225.40	207.19	225.10				(1)	
(11)	232.10	220.42						A	
(12)	203.28	187.43	191.27					B	D
(13)	237.55	235.12	213.80					A	
(14)	177.82	234.08	226.17	252.13	246.65	229.95	189.70		
(15)	212.63	197.47	185.97	224.58				B	D
(16)	235.15	246.50	189.57					A*	
(17)	228.01	215.19	226.14					B	D
(18)	191.30	202.66	148.53					A	
(19)	176.42	199.27	236.25					C	E
(20)	241.50	227.76						A	
(21)	217.90	198.55						A	
(22)	222.26	202.64	217.39					B	D
(23)	244.18	174.78	207.65	237.05				C	E
(24)	195.76							A	
(25)	240.17	211.66	222.47	197.22	221.12				
(26)	219.85	176.59	204.99					B	D
(27)	243.58	219.14	213.71	205.74	221.29	229.38		C	E
(28)	161.82	200.80	190.89					C	E
(29)	199.83	249.53	246.91	243.57					
(30)	192.14	236.50	207.48					C	E
(31)	218.28	215.34	185.77	231.84				B	D

[a](1) consistent with mixture of B and C (or of D and E)

[b](a) number consistent with either A or B or C: 27 (out of 31) (1 borderline), (b) number consistent with either A or D or E: 27 (out of 31) (1 borderline), (c) subjects consistent with none of rules (nor mixture): 9, 14 and 29.

APPENDIX 4:1 (b)

Raw data of Case 2.

Parameters: $x = 100$, $c = 2.0$, $\mu = 86.0$, $\sigma = 10.0$.

S no.	Price quotes obtained in chronological order							Consistent with rule(s)[a, b]	
(1)	84.25	80.74	71.37	111.78				B	D
(2)	108.34	71.74						A*	
(3)	88.64	91.76	97.96	101.82	100.65	67.11		A*	
(4)	94.35	70.20	76.18					B	D
(5)	87.41	101.40						B	D
(6)	84.57	103.38	106.10					C	E
(7)	82.33	103.63						B	D
(8)	79.37	99.00						B	D
(9)	68.63	93.69	82.05					C	E
(10)	101.92	74.79	35.51	102.95				C	E
(11)	88.25	69.20	90.86	84.42	71.05				
(12)	82.63	92.52	72.87					A*	
(13)	93.97	90.91	87.84	85.74	81.02			A*	
(14)	94.30	80.05						A*	
(15)	100.98	67.07	91.08					B	D
(16)	106.32	85.62	78.50	86.34				B	D
(17)	106.71	82.33	96.86	90.97				C	E
(18)	72.53	82.29	85.93	70.14				A	
(19)	87.41	74.71						A*	
(20)	79.18	86.51						B	D
(21)	79.09	90.98	71.14					A	
(22)	92.41	85.02	88.18	89.57				C	E
(23)	86.71	68.84	94.60	73.25	83.76	82.04	92.75		
(24)	116.08	68.50						A*	
(25)	94.25	98.17	80.08	85.08				(1)	
(26)	67.45	80.18	91.80					C	E
(27)	84.82	84.82						D	
(28)	64.82	91.13						B	D
(29)	86.07	76.11	88.58					B	D
(30)	85.90	89.31	88.71					C	E
(31)	90.18	91.52	89.48					A	E

[a](1) consistent with mixture of B and C (or of D and E).
[b](a) number consistent with either A or B or C: 27 (out of 31), (b) number consistent with either A or D or E: 28 (out of 31), (c) subjects consistent with none of rules (nor mixture): 11 and 23.

APPENDIX 4:1 (c)

Raw data of Case 3.

Parameters: $x = 250$, $c = 5.0$, $\mu = 215.0$, $\sigma = 25.0$.

S no.	Price quotes obtained in chronological order						Consistent with rule(s)[a,b]	
(1)	229.47	223.55	214.71	201.22	181.88	209.59	B	D
(2)	215.23	255.46	237.34				C	E
(3)	227.63	185.85					A*	
(4)	200.89	176.29	225.05				B	D
(5)	184.34						A*	
(6)	253.66	198.83	231.18	204.63	203.88			
(7)	190.79						A*	
(8)	178.24	237.35	226.66	222.04				
(9)	173.77						A*	
(10)	206.42	209.99	263.45				C	E
(11)	235.12	223.07	241.57				B	D
(12)	197.09	234.15	240.25	255.31				
(13)	259.63	206.11	211.79	230.54	218.58	176.70	A*	
(14)	206.13	210.27	208.84	225.83	202.87		A*	
(15)	224.13	236.72	205.45	212.49			(1)	
(16)	233.51	248.66	227.32	187.48	256.95		(1)	
(17)	245.88	188.54					A*	
(18)	213.04	196.02					A*	
(19)	228.62	200.62					A*	
(20)	220.11	201.33					A*	
(21)	199.34	203.15	177.85				A	
(22)	228.97	222.90	203.77	206.01	181.56		A*	
(23)	178.37	189.35	289.36	214.38	226.34			
(24)	225.62	209.54	204.65				A	D
(25)	214.05	207.86	226.73	209.23			C	E
(26)	217.87	181.25	217.05				B	D
(27)	229.46	214.09					A	
(28)	225.75	248.15					B	D
(29)	230.34	229.01					A	D
(30)	200.59						A*	
(31)	223.25	241.88					B	D

[a](1) consistent with mixture of B and C (or of D and E).

[b](a) number consistent with either A or B or C: 25 (out of 31), (b) number consistent with either A or D or E: 25 (out of 31), (c) subjects consistent with none of rules (nor mixture): 6, 8, 12 and 23.

APPENDIX 4:1 (d)

Raw data of Case 4.

Parameters: $x = 100$, $c = 4.0$, $\mu = 86.0$, $\sigma = 10.0$.

s no.	Price quotes obtained in chronological order						Consistent with rule(s)[a, b]
(1)	78.02	85.66	79.04				C E
(2)	78.56	79.90	76.20	77.06			(1)
(3)	81.00	74.57	72.36				A D
(4)	91.14	74.57	78.69				B D
(5)	93.36						A
(6)	74.36	84.41	72.90	96.89	96.83	93.70	
(7)	93.23	81.32					A*
(8)	78.99	87.34	75.81				A E
(9)	85.20	80.43	77.94				A D
(10)	78.05	85.35					B D
(11)	87.93	75.82	76.59	77.73	77.26		
(12)	83.46	89.80					B D
(14)	91.33	71.73					A*
(15)	73.39	88.40	86.31	83.72			
(16)	75.99	81.76					B D
(17)	85.46	86.34	82.89	87.05			(1)
(18)	91.67	79.79					A*
(20)	85.09	94.89					B D
(21)	88.19	77.83					A*
(22)	84.05	97.30					B D
(23)	82.11	89.96					B D
(24)	79.10						A*
(25)	64.51	83.75	87.89				C E
(26)	87.43	95.36					B D
(27)	88.52	83.58					A*
(28)	79.70	72.32	70.81				A D
(29)	82.31						A*
(30)	79.00						A*
(31)	99.92	84.83					A*

[a](1) consistent with mixture of B and C.

[b](a) number consistent with either A or B or C: 24 (out of 29), (b) number consistent with either A or D or E: 24 (out of 29), (c) subjects consistent with none of rules (nor mixture): 6, 11 and 15.

APPENDIX 4:2

This appendix summarises the results obtained in the "Still Searching" experiment, Hey (1987).

Expt/ subject	Trials	Number of offers in round					Rules with which behaviour consistent in round				
		1	2	3	4	5	1	2	3	4	5
α1	3	2	1	4	1	2	A*	A*	A*	A*	A*
α2	4	1	10	2	1	2	A*		A*	A	A
α3	2	1	10	2	4	9	A*	A*	BD	A*	A*
α4	10	4	2	5	3	2	A*	A		A	A*
α5	7	1	1	2	1	2	A*	A*	A*	A	A*
α6	4	2	1	10	5	2	B	A		A	A*
α7	15	1	2	7	5	2	A*	A			BD
α8	5	1	2	2	1	1	A*	A	A*	A*	A*
β1	4	1	3	3	7	2	A*	A*	AE	A	A*
β2	3	2	3	5	1	2	A	A		A*	A*
β3	2	1	2	2	1	1	A*	A*	A*	A*	A*
β4	5	1	4	5	2	7	A*	A	A*	A*	A*
β5	8	1	2	3	6	1	A*	A*	A		A
β6	15	3	1	4	1	3	A*	A*	A*	A*	A*
β7	5	2	3	6	2	1	A*	AE	A	A	A*
β8	3	5	1	1	5	1	A*	A	A*	A	A*
γ1	7	2	3	8	7	3	B	B			CE
γ2	3	2	4	6	3	2	A*			BD	BD
γ3	10	1	4	8	6	2	A*			A*	A*
γ4	8	1	4	11	15	3	A*	A			A
γ5	2	1	3	4	2	2	A*	CE	CE	BD	BD
γ6	7	2	2	4	6	1	B	AD	CE	A*	A*
γ7	2	2	3	5	3	3	A*	BE	CE	BD	BD
γ8	2	1	3	5	3	1	A*	A*		A*	A*
δ1	15	2	1	3	1	1	A	A	CE	A	A*
δ2	1	1	2	4	5	3	A*	A*	CE		A*
δ3	11	2	1	1	1	4	A	A*	A*	A*	
δ4	6	1	5	7	5	8	A*	A*	A*	A	A*
δ5	5	1	3	10	4	1	A*	A*		A*	A*
δ6	9	1	13	4	1	2	A*		A	A*	A*
δ7	6	3	4	6	5	2	A	A		A*	A*
δ8	6	3	1	1	2	3	C	A	A	A	A*

CHAPTER

FIVE

CHAPTER FIVE

BETTER HEURISTICS FOR ECONOMIC SEARCH - EXPERIMENTAL AND SIMULATION EVIDENCE

INTRODUCTION

This chapter extends the experimental work reported in the previous chapter using a partial replication and extension of the Hey (1982) study. It is concerned with two important issues. What rules do individuals actually use to govern their search for a sufficiently low price, and how well do these search rules perform when compared with an optimal reservation price model.

The first part of the chapter, then, describes a new experiment aiming to assess the extent to which Hey's "reasonable rules of thumb" correspond to observed behaviour, and to determine any other rules of thumb that match this behaviour better. By analysing the price quotations received by subjects in conjunction with verbal protocols recorded at the time of the experiment, several such rules are derived, both in the "no knowledge" and "full knowledge" conditions.

The second part of the chapter describes a series of simulations aiming to discover how well these search rules perform over a very large number of trials. That is, how little extra expenditure could be incurred, on average, as a result of adopting one of these rules of thumb instead of the optimal reservation price rule. The simulation process also fine-tunes the proposed rules to produce the variations on each rule that either match observed behaviour best, or perform most closely to the optimal. Thus, some heuristics are developed that, when compared with the reservation price rule, are easier to understand and easier to use, with only a small loss in performance.

THE EXPERIMENT

Task

Subjects were required to purchase unspecified, common items. In each case there was some variation in the price quotes that could be received, and so a potential benefit from "shopping around". There was, however, a constant, non-zero search cost. Thus, subjects needed to balance the expected costs and benefits in determining their decision strategy. Price quotes received were always available for the duration of the experiment, that is, there was full recall, and, within each purchase, were from the same distribution. Prices were generated, displayed and selected by means of an easy-to-use interactive computer program.

Procedure

Subjects were randomly allocated to one of four groups. For each subject, the experiment consisted of an initial, single trial with non-random prices, to enable familiarisation with the program, followed by three phases. Phase 1 (groups A and C only) comprised four trial runs from different price distributions, group C having no knowledge of the distributions, group A having full knowledge in the sense of knowing them to be normal with specified means and standard deviations. In phase 2, the rewarded part of the experiment, four further purchases were made using the same four normal distributions as used by Hey (1982). These are summarised in Table 5:1. Only groups A and B had full knowledge of the distribution in phase 2.

TABLE 5:1

PRICE DISTRIBUTIONS WITHIN PHASE 2

Number	Mean	Standard Dev'n (σ)	Search Cost (c)	Reservation Price	σ/c
	$	$	$	$	
1	215	25	2.5	192.50	10
2	86	10	2	81.10	5
3	215	25	5	202.75	5
4	86	10	4	86.10	2.5

In phase 3, the availability of knowledge was reversed, the distributions used being simple multiples of the ones in phase 2. Designing the experiment in this way not only enabled a sufficient volume of data to be obtained from which to gain insights into search behaviour, but also allowed some investigation into any "learning" effects arising from the initial trials or from changes of knowledge levels. Table 5:2 summarises the difference between the four groups.

TABLE 5:2

EXPERIMENTAL DESIGN SUMMARY BY GROUP

Level of Knowledge about the Distribution in :		Number of Trial Runs in Phase 1	
Phase 2	Phase 3	4	0
Full	No	A	B
No	Full	C	D

The subjects performed the experiment in separate 15 minute sessions in the presence of the author to avoid any misunderstandings or problems. They were encouraged to think aloud, their verbal protocols being recorded on tape.

Subjects

24 subjects participated in the experiment (6 in each group), all being second or third year undergraduate students from the Warwick Business School, with no previous exposure to search theory. As an incentive, subjects were paid a fixed fee of £1 plus a bonus

proportional to their performance in phase 2. Performance was calculated by comparing the amount spent by the subject with the amount that a computer would have spent using an optimal, full knowledge, reservation model. Where there was no difference, the incentive bonus was 50p., reducing linearly to zero where the subjects' overall performance was 25% or more worse than the optimum. A "lucky" student could earn a bonus more than 50p.

A subject's pay-off might be linked to "ability". That is, participants who are more intelligent, more numerate, or more used to making consumer purchasing decisions, might perform better (and, therefore, earn more money) than other participants. No explicit tests were undertaken, however, to measure this variable either in the current experiment, or in the price search with partial prior knowledge experiment described in Chapter 6. This is for the following reasons. First, the objective of the experiment was to discover <u>general</u> search heuristics, and not to explore explicitly any links between the types of rules adopted by subjects and their individual level of competence. Second, each subject made only a small number of purchase decisions that could be used in the formal analysis - four in Phase 2 and four in Phase 3. Given that each purchase involves the search for, on average, only two or three prices, this represents too small a sample to enable ability to be tested in a way that will allow meaningful results.

Further work in the future, however, will investigate in more depth the whole issue of subjects' learning behaviour over a large number of trials. Some measure of "ability" will be an important component of the analysis of such learning processes.

RESULTS AND ANALYSIS OF EXPERIMENT

As stated above, a reward scheme linked to performance in phase 2 of the experiment was incorporated as an incentive to participants. The mean pay-offs per subject were : group A £1.42 ($\sigma = 0.07$), group B £1.49 ($\sigma = 0.07$), group C £1.43 ($\sigma = 0.12$), and group D £1.45 ($\sigma = 0.10$). It is surprising that subjects in groups B and D, without the benefit of the four initial trials, out-performed subjects in groups A and C. The difference in pay-offs, however, is not significant at the 10% level ($t_{10} = 1.22$). Further, although on average, subjects with full knowledge (groups A and B) out-performed those with no knowledge, again the difference in pay-offs was not significant at the 10% level ($t_{10} = 0.24$). As might be expected, however, the no knowledge groups exhibited a wider range of performance.

Appendix 5:1 contains details of the sequences of price quotes received in phases 2 and 3. Careful analysis of these sequences, together with the verbal protocols taken at the time of the experiment, led to the formulation of several new search rules. These are described and discussed below. Excerpts from the protocols have been reproduced as supporting evidence for these new rules, though these are necessarily restricted due to space limitations. Results from phase 3 have also been included in the analysis despite performance not being formally rewarded. This is justified since comparing the frequency with which different search rules matched observed behaviour between the two phases revealed no significant difference at the 10% level for the no knowledge condition (chi_7^2 = 2.284) or the full knowledge condition (chi_6^2 = 1.638).

No knowledge rules

Four new rules (F, G, H and J) are proposed that describe search behaviour in situations where a decision maker has no knowledge of the distribution. Their relative occurrence is summarised in Table 5:3, and compared with that for Hey's four "no knowledge" rules (B, C, D and E). The overall average occurrence referred to in Table 5:3 represents the percentage of all trials in which observed behaviour matched the given search rule. Note that it is possible for the same search behaviour to correspond to several search rules.

TABLE 5:3

NO KNOWLEDGE OF DISTRIBUTION - SEARCH RULES OCCURRENCE

	Current Experiment				Prior Work		Overall Average Occur.
	Phase 2		Phase 3		*1	*2	
Group	C	D	A	B			
n	24	24	24	24	122	40	
Hey's Rules							
B	5	8	4	7	30	10	25%
C	6	5	7	5	21	5	19%
D	6	9	3	9	35	7	27%
E	6	5	9	7	22	5	21%
New Rules							
F	9	8	7	13	35	-	33%
G	11	9	10	15	36	10	35%
H	11	12	9	16	38	-	39%
J	6	5	7	9	28	-	25%

*1 ... Hey (1982)
*2 ... Hey (1987)
\- ... not available

Rule F

Have two searches, receiving quotes p_1 and p_2.
If $|p_1 - p_2| \leq 2c$, where c is the search cost, stop.
Otherwise search once more.

The form of this rule was partly suggested by Hey (1981, p 62). The idea behind the rule is that where $|p_1 - p_2|$ is small, it is likely that the standard deviation of the price distribution is small, and so, therefore, are the expected benefits from further search. An illustration of the adoption of rule F is provided by subject D3, run 2 :

> "[81]... price given 81, cost of search 2 ... [90] ... price difference there is 9 dollars more expensive, 2 dollars cost of search ... so it's probably worth doing one more, and if it's higher I'll accept the first quote ... [87] ... it is ... so the distribution there seems to be fairly close, within 10 ... and, furthermore, five costs of search would totally eradicate any savings I have by a lower quote ... I'll go for the first quote."

On average, the behaviour of just over one-third of subjects with no knowledge in the current experiment was consistent with the adoption of rule F. From Table 5:3, 35 of 122 subjects in Hey's "Search for Rules for Search" experiment behaved in accordance with rule F. In this sense, it was not out-performed by any of Hey's six search rules.

Rule G

Have three searches.

This is the simplest rule, its rationale being that three quotes is enough to be confident about the nature of the distribution. As an example, consider subject C3, run 2 :

> "[89] ... this one's only 2 dollars (the cost of search), so I wouldn't be too worried about spending that much having a look ... [84] ... and that one's cheaper ... [99] ... I think I'll probably buy there."

Despite its simplicity, rule G is consistent with the behaviour of subjects in 35% of all the trials in the current experiment and in Hey's two experiments. Obviously, though, such a fixed sample size strategy would not be appropriate where subjects had full knowledge of the price distribution.

Rule H

Have two searches, receiving quotes p_1 and p_2. If search cost, c, > 10% min $\{p_1,p_2\}$, stop. Otherwise search again receiving quote p_3. Stop searching unless $p_2 \le p_1 - c$, and $p_3 \le p_2 - c$, in which case keep searching until the first "modified bounce".

This rule is a variation on rule G, as in most cases it will result in three searches. There are, however, two exceptions. First, a subject would search only twice where the cost of search was prohibitive. Second, a subject will keep playing "winning streaks", as in Hey's modified bounce rules (D and E). As an illustration of rule H consider the following protocol extract from subject C3, run 1 :

> "[223] ... well this is just two and a half dollars (search cost) and the price is 223 dollars, so it's hardly anything for cost, so I'd have a good look at the other prices ... [218] ... so that one's actually cheaper ... I'll have a look at another one 'cos it's not going to cost very much ... [189] ... and that one's even cheaper ... and I think I'd look at another one 'cos for two and a half dollars it's probably worth it ... [159] ... it's getting cheaper, which means I'm more tempted to have a look at another one ... [194] ... yes, and I think I'd buy ... because that's got more expensive."

Rule H explains subjects' behaviour in 48 of the 96 trials in the current experiment, and as Table 9:3 shows, it has an overall average occurrence of 39%, the highest of all the no knowledge rules.

<u>Rule J</u>

> Keep searching until the total search cost, nc, is such that $nc > 7.5\% \min p_i$, where n is the number of searches so far.

Rule J, then, focuses solely on the total amount spent on search as a function of the most favourable price so far received. The following example from subject D2, run 3 demonstrates the use of total search cost as a deciding factor :

> "[239] ... let's see what you get next time ... [168] ... the price is a lot lower ... it might well be worth searching further and seeing if you're likely to get a lower price still or if you get a much higher quote ... [202] ... now, the third price is just somewhere in-between the first two ... but, they are quite expensive search costs ... it's costing me 5 dollars each time ... so judging from the prices you're given, if you search further, even if you get a lower price, it would just be outweighed by at least 20 dollars searching costs you'd be getting, so I'll take the second price."

Although rule J matched observed behaviour less frequently than the three other new rules, only rule D of the four Hey rules did better than its 25% overall average occurrence. The performance of all the new no knowledge rules is discussed further in the simulation section of this chapter.

In addition to the no knowledge rules described above, several alternative search rules derive from the literature on "optional stopping" (see, for example, Rapoport and Tversky, 1966, 1970, as discussed in Chapter 4). Thus, a subject would sample n prices and then stop at the first subsequent price that is lower than all previous prices. In the 96 no knowledge trials in the current experiment, the overall frequency of matches between observed behaviour and the behaviour that would be predicted from use of an optional stopping model was 17% for n = 1, 23% for n = 2, and 7% or less for any other value of n. Optional stopping rules, then, do not seem to describe observed behaviour as well as any of the new rules developed, nor did any subject's protocol suggest their use. They may be more appropriate in a "no-recall" setting, but are not pursued further here.

Full knowledge rules

Three new rules (K, K^* and L) are proposed that describe search behaviour in situations where a decision maker has full knowledge of the distribution. Their relative occurrence is summarised in Table 9:4 and compared with the corresponding results for rules A and A^*, Hey's "full knowledge" rules. Although A^* is a special case of A, its overall average occurrence is separated from A for purposes of exposition.

Rule K

> Keep searching until a price is found at least one standard deviation below the mean, up to a maximum of σ/c searches (rounded).

This rule makes simple use of the distribution parameters available to the subject recognising that once a price has been located at least one standard deviation below the mean, there is little likelihood of bettering it. The constraint on the number of searches takes into account the impact of high search costs, relating the cost of search to the price dispersion. It was shown in Chapter 3 that the expected number of searches is a decreasing function of c/σ (and, therefore, an increasing

TABLE 5:4

FULL KNOWLEDGE OF DISTRIBUTION - SEARCH RULES OCCURRENCE

	Current Experiment				Prior Work Hey (1987)	Overall Average Occur.
	Phase 2		Phase 3			
Group	A	B	C	D		
n	24	24	24	24	40	
Hey's Rules						
A*	14	13	14	13	23	56%
A	5	5	7	6	9	24%
New Rules						
K	10	9	12	9	-	42%
K*	13	12	12	11	-	50%
L	15	16	12	12	-	57%
Expert Rules						
M	12	13	15	13	-	55%
N	12	13	14	12	-	53%

\- ... not available

function of σ/c), thus justifying the use of σ/c as a decision criterion in the current rule. Illustrations of rule K include subject A2, run 1 :

> "The mean is 215, the standard deviation is 25, so to judge it I'll take the standard deviation away from the mean ... which would be 190 ... so the price given [239] is much higher than that and the cost of search is quite small, so I think it's worth some searches ... "

On the fifth search, subject A2 encountered a price of 190, and duly accepted it. Subject A1, run 4 :

> "[100] ... mean of 86, standard deviation of 10, cost of search 4 dollars ... I think I'm going to go ahead and search for one ... [84] ... price of 84 now, cost of 92 ... so if I go ahead and do another search I'll be at least paying 96 ... the chances of me getting something cheaper than about 80 or so to take care of that extra cost of search are ... let's see ... yes, I think I'll try one more ... [89] ... I'm going to stop, just because it's 4 dollars for each search."

Thus, the subject stopped searching after σ/c searches. Rule K reflected the behaviour of subjects in 40 of the 96 trials in phases 2 and 3. However, the one standard deviation requirement is, perhaps, a little too rigid. Rule K^* is a slight modification :

<u>Rule K^*</u>

Keep searching until a price is found at least 0.75 standard deviation below the mean, up to a maximum of σ/c searches (rounded).

That is, to be acceptable a price needs to be nearer to one standard deviation below the mean than half a standard deviation. For example, subject B6, run 3 :

> "Mean 215, standard deviation 25, cost of search 5 ... [230] ... right, well 230 is well above the mean, so I'll search ... [194] ... that's 21, almost one standard deviation, below ... yeah, I'll settle for that one."

Exactly one half of the trials revealed behaviour consistent with rule K^*.

Rule L

> Keep searching until a price, p, is located such that the chance of obtaining a price less than or equal to p - c is less than or equal to 30%.

Essentially, rule L is another modification of rule K where the "reservation" price is $\underline{\mu - 0.53\sigma + c}$ and there is no restriction on the number of searches. Note that the reservation price for rule L is a function of all three given parameters. For example, consider subject B5, run 4 :

> "[78] ... I'm going to stop at that one ... because mean's 86, standard deviation 10, so I'd be lucky if I got anything less than 76 ... I've got quite a high cost of search in comparison to what the average is ... so I shall stop right now."

Overall, 57% of the full knowledge trials in phases 2 and 3 indicated behaviour consistent with rule L. As such, it out-performed all the other rules in this category.

Expert rules

In addition to the full knowledge rules above, two further "expert" rules have been developed. These are less trivial to remember than rules K, K^* and L above, and involve greater computational requirements, though remaining much simpler than rule A^*. Again, the apparent overall average frequency of occurrence of these rules is shown in Table 5:4. It is not suggested, however, that subjects were actually using these expert rules.

Rule M

> Let m represent the minimum price so far encountered. Calculate the probability, p, of receiving a price quote lower than $m - c$, where c is the search cost. Then calculate the probability of receiving a price quote lower than $m - c/p$. If this is $\leq 5\%$ stop, otherwise search again and repeat.

The rationale underlying this rule is that the expected number of searches to achieve a price quote lower than $m - c$ is $1/p$ (see Chapter 3). Thus, to gain over the current minimum requires a price low enough to cover the expected future search cost (c/p). Being a second-order rule, rule M is more complex than rule L above.

Rule N

Continue searching until a price is received less than or equal to a reservation price, R, where $R = \mu + \sigma z$ and $z = 3\sqrt{c/\sigma} - 2$.

This rule is an attempt to approximate the true reservation price using a relatively simple formula derived from straightforward regression analysis of the true reservation price against c/σ using a large set of distributions of μ, σ and c. The formula has a correlation coefficient of 0.98 with the true reservation price using the distributions in Table 5:5.

Clearly, the σ/c parameter is of crucial importance in determining high performance behaviour. Over the small number of purchases that each subject made, however, this factor was very rarely explicitly identified as important. More purchases, probably with feedback, would be necessary before subjects are likely to learn the importance of the σ/c parameter.

Both expert rules exhibit excellent performance when compared with the optimal, but more complex, reservation rule, as discussed in the next section.

THE SIMULATION

Having identified some rules of thumb which are reasonably consistent with observed behaviour, a suite of three additional computer programs was developed to enable further analysis. The programs performed the following tasks :

1) ... test the performance of each rule against very large sets of simulated purchases using prices generated from the same distributions (simulation has the immense advantages of speed and consistency over live subjects!).

2) ... test the matching of the rules with the experimental data (giving the results in Tables 5:3 and 5:4 above).

3) ... a combination of the above two programs generates a set of purchases with random stopping, and tests the rules against this data to discover any underlying fit of the rules which might not be accounted for by intelligent behaviour.

4) ... (and fundamentally) the computer program enabled simulation of the performance and matching of variations in each of the rules. Suitable variations

in the parameters embedded within the rules were simulated systematically in an effort to ascertain both sensitivity to the parameters and the overall "best performing" and "best matching with student behaviour" variant of each rule.

Optimising Performance

"Performance" is defined as the average percentage spend over the theoretical average spend of the optimal rule, A^*. Thus, the expected stopping price (given that it is $\leq R$) is given by :

$$\frac{\int_{-\infty}^{R} y\, f(y)\, dy}{p}$$

where $p = \int_{-\infty}^{R} f(y)\, dy$, the probability of a price less than or equal to R on any given search; and the total expected spend is, therefore,

$$\frac{1}{p} \left(c + \int_{-\infty}^{R} y\, f(y)\, dy \right)$$

using equation [3:3] from Chapter 3. This last expression, when combined with equation [A31:1] and noting that the net expected gain, E, is zero when the minimum price received, m, is equal to R, surprisingly reduces to simply R!

For consistency, this performance measure is applied to both "full knowledge" and "no knowledge" rules. The program generated prices randomly and in turn from five pre-defined Normal distributions as shown in Table 5:5. These distributions are based on Hey's in that three of them (2,3 and 4) are identical to his, and the other two have the same realistic (see Pratt, Wise and Zeckhauser, 1979) mean to standard deviation ratio of 8.6. The extra two distributions have been added with more extreme values of the standard deviation to search cost ratio (σ/c), in order to be able to average performance over a reasonable spread of possible distributions. The rules tested include all the new rules, and all Hey's rules except rule A, since rule A is non-deterministic as previously mentioned.

TABLE 5:5

SIMULATION PRICE DISTRIBUTIONS

Dist	Mean (μ) $	Stan Devn (σ) $	Search Cost (c) $	c/σ	$\frac{R-\mu}{\sigma}$	Resvn Price (R) $
1	86	10	10	1	0.9	95.0
2	86	10	4	0.4	0.01	86.1
3	86	10	2	0.2	- 0.49	81.1
4	215	25	2.5	0.1	- 0.9	192.5
5	215	25	1.25	0.05	- 1.25	183.75

Each run simulated 5,000 purchases for each distribution under the same constraints as the live student experiment, except that up to 20 searches were possible for each purchase. This is a reasonably high number of purchases and is over three times as many as in Hey's simulations. The program generated enough prices for each purchase to test each decision rule. The expenditure for each decision rule was accumulated and then averaged over each distribution and for the run overall.

The simulation for each distribution for each rule took around five minutes. This was small enough to allow many runs to be made, varying parameters for each rule, in the search for the optimum performance for the rule. For example, rule F was tested for the difference between the first and second prices being less than "r" search costs, with "r" varying over a suitable range of values. The results showed the sensitivity of the rule's performance to this parameter, as well as optimising its overall performance. Appropriate parameters for all the rules are presented in Table 5:6. Note that some rules (specifically, A, A^*, B to E, and N) permitted no variations in format; similarly rule K^* is simply a variation of rule K. These rules, therefore, are excluded from Table 5:6 (and Table 5:7).

Some slightly more complex variations were investigated, but eventually discounted since they did not significantly improve performance. The simulation also included a test of the optional stopping rule, and the performance of random stopping, the results of which are discussed in due course.

TABLE 5:6

OPTIMISING PERFORMANCE PARAMETERS

Rule	Parameter (r)	Performance %	Average Occur.	Param. Value (r)
No Knowledge				
F	Stop after 2 searches if $\lvert p_1 - p_2 \rvert < rc$	5.8	35%	3
G	Stop after r searches	6.5	47%	3
H	Stop after 2 searches if c > r% of the lowest price so far	4.7	45%	5%
J	Stop when total search costs > r% of the lowest price so far	2.2	24%	5%
Full Knowledge				
K	Stop when a price is reached $\leq \mu - r\sigma$	1.1	42%	1
L	Stop when probability of finding a price lower than current min less c is ≤ r%	1.0	49%	20%
Expert Rules				
M	Stop when probability of a low enough price is ≤ r%	0.3	55%	0.05

This table shows the results of choosing the parameter value for each rule which gave the best performance in terms of the average % spend above the theoretical minimum, and also shows the % occurrence of the rule with this parameter value for the current experiments only.

Optimising Occurrence

A program was developed as stated above to allow the same rules and variations in them to be matched against the fixed experimental data (that is, the subject behaviour) in order to establish the best match with, and therefore the best possible explanation for, this behaviour. This program generated the basic analysis for Tables 5:3 and 5:4, but, more importantly, the optimisation results which are in Table 5:7. It included matching with the optional stopping rule discussed above.

Identifying Underlying Occurrence of Rules

The third area of analysis was to match simulated totally random stopping behaviour against each rule, in order to gain a feel for the underlying occurrence of rules, independent of the human behaviour.

Random stopping between 1 and n searches (with n varying from the minimum of one to the maximum of 20 searches) was matched against all the optimised rules. The results of this matching for $n = 4$ are shown in Table 5:8.

TABLE 5:7

OPTIMISING OCCURRENCE PARAMETERS

Rules	Performance %	Average Occur.	Param. Value (r)
No Knowledge			
F	6.4	48%	0
G	6.5	47%	3
H	5.3	50%	10%
J	2.2	32%	7%
Full Knowledge			
K	2.5	59%	0.3
L	1.8	57%	30%
Expert Rules			
M	0.7	57%	0.15

This table is similar to Table 5:6 but shows the results of optimising the occurrence data.

Findings

The objective was to discover rules which either performed well, or matched well, with subject behaviour, or both. Ideally, the rule should also be simply expressed; a good match only means that the subject behaves as if she were using the rule, but if the rule is sufficiently simple, the subject is more likely to have been using the rule. Sometimes there had to be a trade-off between these criteria, depending on the particular sensitivities (see, for example, rule J in Tables 5:6, 5:7 and 5:8). The results are summarised in Table 5:8.

Note that rule A^*, the optimal rule, clearly should perform best, which it does, but it is still subject to random "lucky" or "unlucky" prices, as are all the rules, so on some runs it would perform better or worse than the theoretical optimal minimum spend.

In addition, it was found that the optional stopping rule described earlier gave at best ($n = 1$) an average performance 10.9% worse than the theoretical optimal. This is lower than any of the other rules identified, and is another reason for discounting such rules.

In general, in the no knowledge situation, the rules perform better with medium values of σ/c. All the rules perform better than rules B to E, and match as well or better with the current experimental data.

TABLE 5:8

PERFORMANCE OF RULES FOR DIFFERENT DISTRIBUTIONS

Rule	Parameter "r"	Percent spend over theoretical minimum on distributions 1	2	3	4	5	Average Performance	Occurrence	Underlying Occurrence
No Knowledge									
B		11.8	4.4	3.6	5.7	8.4	6.9%	25%	24%
C		27.5	8.9	4.0	3.8	5.3	8.5%	24%	14%
D		8.4	4.3	3.9	5.7	8.4	6.5%	28%	24%
E		16.6	6.9	3.8	4.0	5.6	6.7%	28%	18%
F	2	7.8	4.6	3.6	5.3	7.3	5.9%	39%	25%
G	3	13.5	4.4	3.1	4.7	7.2	6.5%	47%	25%
H	10	6.3	4.7	3.2	4.5	6.9	5.3%	50%	25%
J	7.5	1.5	3.4	2.2	2.6	2.2	2.4%	28%	15%
Full Knowledge									
A*		0.6	0.4	0.1	0.2	0.0	0.2%	56%	19%
K	1	1.5	2.5	1.3	0.6	0.6	1.1%	42%	17%
K*	0.75	1.5	2.0	0.7	0.6	1.9	1.3%	50%	20%
L	30	1.2	0.5	0.2	1.5	3.8	1.8%	57%	22%
Expert Rules									
M	0.05	0.7	0.6	0.2	0.2	0.1	0.3%	55%	18%
N		0.6	0.4	0.3	0.4	0.0	0.3%	53%	

This table shows the varying performance of the final form of each rule over the different simulation distributions. The value of the parameter described in Table 5:6 is shown in the second column. It also reproduces the average performance and experimental occurrence rates, and includes the underlying occurrence of the rule when matched with random stopping.

Rule G (have three searches), the simplest rule of all, was popular in practice, and performs reasonably well compared with rules B to E. Rule F performs slightly better by sometimes stopping after two searches. Rule H performs better still and also coincides well with the experimental behaviour. Rule J, however, is by far the best performer of the no knowledge rules, and its adoption could save substantial amounts of money on the purchase of high value goods. It does not match the subject behaviour as well as other rules, but this could merely confirm that not many students had learned a strategy that used this rule. Rule J's other strength is that its performance does not deteriorate much for extreme values of σ/c; indeed rule J is at its best with low values of this ratio.

There is a clear difference in performance between no knowledge rules and full knowledge rules. Knowledge is required in order to achieve performance within 2% of the optimum. Some of the new full knowledge rules can achieve as little as 1% from the optimum without explicitly having to calculate the reservation price. Students appear to use a form of full knowledge rule quite frequently. Indeed the best match of all with the subject data comes with a variant of rule K where the "reservation price" is given by $R = \mu - 0.3\sigma$; this occurrence was reflected by comments from the protocols, but at the same time demonstrates conservative behaviour since, on average, this variant stops too early. It seems likely, though, that it is a variant of rule K that subjects are actually using when they behave consistently with rule A^*. Rule L also matches experimental data well and could reflect the gambling nature of some of the students. None of the full knowledge rules performs badly with extreme values of σ/c.

The expert rules M and N perform very closely to the optimum rule. They do not require the explicit calculation of the true reservation price, though the former does require tables or computation. Rule N can easily be computed approximately in the head, and therefore, could reasonably be called an "expert rule of thumb". Subjects certainly did not "know" this rule, however. Both these rules perform well because they approximate to rule A^*, and they match well with subject behaviour because they also approximate to rule K.

Comparing the performance and matching of all the rules with their underlying performance and occurrence against a random stopping rule (see Table 5:8), several of them show surprisingly little improvement over random behaviour. (Random stopping after up to 4 searches gave the best underlying performance with which to compare, that is 7.7%). This applies particularly to rules B and D. This would suggest that these rules are not serious candidates as "reasonable" or "high performance" heuristics.

SUMMARY

This chapter has reported an experiment that extends the work on single parameter search, explicitly distinguishing the no knowledge and full knowledge situations. It has shown that knowledge of the parameters of the price distribution is often a highly valuable asset in terms of performance. Some heuristics have been identified that are more soundly based, perform better, and concur with actual behaviour better than previously suggested heuristics, and are more likely to explain the behaviour than the theoretically optimal rule.

In particular, where a consumer wishes to purchase some product or service, the price of which may vary across different suppliers, but where that consumer is unaware of the statistical parameters of the price distribution, a new search rule (rule J) has been found which offers high performance, yielding an average expenditure within 2.4% of the theoretical minimum :

> Keep searching until the total search cost is greater than seven and a half percent of the minimum price received.

Similarly, where the consumer is aware of the price distribution parameters, a simple search rule (rule K^*) has been found that gives high performance, within 1.3%

of the theoretical minimum, and can account for subjects' behaviour in a substantial number (50%) of trials :

> Keep searching until a price is found at least 0.75 standard deviations below the mean, up to a maximum of σ/c searches.

While these are important findings in the context of single parameter search, there are some minor limitations of the current experimental design. First, 24 subjects represented a rather limited sample, and necessitated the results to be analysed by trial instead of by subject. In fact, across the whole experiment, there were five instances (out of a possible 48) where a subject's behaviour was consistent with the same rule during all four trials within the same phase - two full knowledge (rule K and rule L), and three no knowledge (rule B, D or H; rule G or H; and Rule F, G or H). An experiment with a larger pool of subjects and a larger number of trials would provide a more appropriate basis for analysing results at the subject level. In particular, this would enable an examination of learning effects, both within and between search rules, and could incorporate measures of "ability", to test whether more "able" subjects exhibit better performance (earn more money), and learn more quickly than subjects who are less able.

Second, under the incentive structure offered to participants, total payments averaged around £1.45 per student for about 15 minutes work, of which £1 was a fixed fee unrelated to performance. Although all participants were observed to be serious and enthusiastic about the task, a more rewarding incentive structure would help reduce any uncertainty concerning motivation.

The experiment was mainly concerned with developing and testing new search rules both with and without knowledge of the underlying price distribution. In doing this, some analysis was carried out considering the impact of the key variable, σ/c. Indeed, some of the rules are quite sensitive to this ratio. For instance, in the no knowledge condition, a high σ/c ratio will lead to a high, average, optimal number of searches. In such cases, rules F, G and H (as well as B, C, D and E) with their strong likelihood of an early stop, may not perform so well.

The experimental work described here is extended in the next chapter to investigate search behaviour in the situation where searchers have <u>partial</u> prior knowledge of the underlying price distribution. That is, they have a preliminary idea of the anticipated price level, but do not know (in advance) the representativeness of that preliminary idea, nor the location of any specific prices. A wide range of σ/c values are used in both the experiment itself and the subsequent simulation.

APPENDIX 5:1 (a)

This appendix reproduces the experimental data for subjects in the no knowledge condition from experimental group C during phase 2.

Stud. No./	Trial	Price Quotes Received	Consistent with Search Rules							
1	1	226 196 240	B		D		F	G	H	
	2	81 101 75					F	G	H	J
	3	234 182 233 198 211								
	4	74 102 79		C		E	F	G	H	
2	1	184 208 239		C		E	F	G	H	
	2	84 104 88 80 73								
	3	219 195 231 168 234								
	4	81 97	B		D					J
3	1	223 218 189 159 194	B		D				H	J
	2	89 84 99	B		D		F	G	H	
	3	274 158 210 205		C		E				
	4	83 78 84	B		D			G	H	
4	1	219 231 175					F	G	H	
	2	80 75								
	3	248 247 207						G	H	
	4	76 95 90 78 94 90								
5	1	211 245 224 200 203 218 253 214 195								
	2	96 94 75 100 97		C		E				
	3	202 203 168 178 234 218								
	4	97 84 103 97 85								
6	1	197 214 204		C		E	F	G	H	
	2	100 96 79						G		J
	3	180 253 190		C		E	F	G	H	J
	4	89 89			D		F			J
			5	6	6	6	9	11	11	6

APPENDIX 5:1 (b)

This appendix reproduces the experimental data for subjects in the no knowledge condition from experimental group D during phase 2.

Stud. No./	Trial	Price Quotes Received	Consistent with Search Rules							
1	1	245 188 231 208 196								
	2	85 96 97 96 84								
	3	194 206 168 222								
	4	92 79 82 83 92								
2	1	226 188 192 179								
	2	98 90 90			D		F	G	H	
	3	239 168 202	B		D		F	G	H	J
	4	94 84 73 94	B		D				H	
3	1	275 200 195 196	B		D				H	
	2	81 90 87		C		E	F	G	H	
	3	238 240 194 230								
	4	76 93 87		C		E	F	G	H	
4	1	218 197 223	B		D		F	G	H	
	2	90 75 62 75	B		D				H	
	3	221 177 218	B		D		F	G	H	J
	4	87 66 92	B		D		F	G	H	
5	1	200 191 177					F	G		
	2	89 87 91 100		C		E				J
	3	175 184 217		C		E		G	H	J
	4	91 81 66 81	B		D				H	
6	1	215 199 199 219 241 195								J
	2	73 80 81 87								
	3	300 226 188 215 212 212 255								
	4	91 88 78 93 80		C		E				
			8	5	9	5	8	9	12	5

APPENDIX 5:1 (c)

This appendix reproduces the experimental data for subjects in the no knowledge condition from experimental group A during phase 3.

Stud. No./	Trial	Price Quotes Received	Consistent with Search Rules							
1	1	311 355 327		C		E	F	G	H	
	2	119 127 152		C		E	F	G	H	J
	3	323 291								
	4	110 146	B		D					J
2	1	386 350 281 293 389		C		E				
	2	136 134 154 124								J
	3	357 311 411 314 307 316 308 372 315								
	4	143 132					F			J
3	1	241 316 328 273								
	2	162 104 132	B		D		F	G	H	J
	3	254 216 365 321		C		E				
	4	117 108 145 142		C		E				
4	1	332 362 300					F	G	H	
	2	155 126								
	3	306 327 370 316								J
	4	112 138 142 163 157 114								
5	1	326 321 311						G		
	2	125 131 123				E		G	H	
	3	356 295								
	4	135 132 146	B			E		G	H	
6	1	264 277 360		C		E	F	G	H	
	2	123 140 136		C		E	F	G	H	
	3	384 322 306 374	B		D				H	J
	4	143 137 120						G		
			4	7	3	9	7	10	9	7

APPENDIX 5:1 (d)

This appendix reproduces the experimental data for subjects in the <u>no knowledge</u> condition from experimental group B during phase 3.

Stud. No./	Trial	Price Quotes Received	Consistent with Search Rules							
1	1	319 309 356 302 335 270								J
	2	127 141 146 126								J
	3	342 375 352 289								J
	4	117 150 120		C		E	F	G	H	
2	1	317 247 323	B		D		F	G	H	
	2	117 135 139		C		E	F	G	H	J
	3	295 285 326 354		C		E				
	4	134 122 102						G		
3	1	416 355 260 324	B		D				H	
	2	143 140 139			D			G	H	
	3	379 320 339 267 289								
	4	152 131 140 128				E				
4	1	322 375 317				E	F	G	H	
	2	141 121 108 125	B		D				H	
	3	313 330 290					F	G	H	J
	4	125 121			D		F			J
5	1	327 302 329	B		D		F	G	H	
	2	121 128 137		C		E	F	G	H	
	3	324 275 346	B		D		F	G	H	J
	4	146 143 124						G	H	
6	1	389 347 350	B		D		F	G	H	
	2	121 135 115					F	G	H	J
	3	290 234 317	B		D		F	G	H	J
	4	118 148 132		C		E	F	G	H	
			7	5	9	7	13	15	16	9

APPENDIX 5:1 (e)

This appendix reproduces the experimental data for subjects in the full knowledge condition from experimental group A during phase 2.

Stud. No./	Trial	Price Quotes Received	Consistent with Search Rules						
1	1	238 179 204 228							
	2	95 90 82		A			L		
	3	213 198	A*				L	M	N
	4	100 84 89			K	K*			
2	1	239 200 232 207 190	A*		K	K*		M	
	2	81 96 100 84 92			K	K*			
	3	200	A*				L		
	4	89 65	A*		K	K*	L	M	N
3	1	268 191 213 194							
	2	107 80	A*				L		
	3	220 184	A*		K	K*	L	M	N
	4	78	A*			K*	L	M	N
4	1	189 228 194 213 201 217 167		A					N
	2	76	A*		K	K*	L	M	N
	3	221 205		A			L		
	4	75	A*		K	K*	L	M	N
5	1	258 222 180	A*		K	K*	L	M	N
	2	97 77	A*			K*	L	M	N
	3	250 212 248 218							
	4	81 81		A					
6	1	205		A					
	2	78	A*			K*	L	M	N
	3	184	A*		K	K*	L	M	N
	4	100 92 83	A*		K	K*	L	M	N
			14	5	10	13	15	12	12

APPENDIX 5:1 (f)

This appendix reproduces the experimental data for subjects in the full knowledge condition from experimental group B during phase 2.

Stud. No./	Trial	Price Quotes Received						Consistent with Search Rules						
1	1	205	164					A*		K	K*	L	M	N
	2	88	77	84	75				A	K				
	3	219	228	214	183			A*		K	K*	L	M	N
	4	87	87	62				A*		K	K*	L	M	N
2	1	245	229	202					A			L		
	2	77						A*			K*	L	M	N
	3	224	215	272	223	191		A*		K	K*	L	M	N
	4	79	77	87	85	110	82							
3	1	194	212	226										
	2	91	75					A*		K	K*	L	M	N
	3	243	197	203										
	4	84	93											
4	1	221	217	229	235	183		A*		K	K*	L	M	N
	2	81	96	85	80				A					
	3	252	221	206					A			L		
	4	100	94	76				A*		K	K*	L	M	N
5	1	205	230	204	221	241								
	2	89	88	96										
	3	213	194					A*			K*	L	M	N
	4	78						A*			K*	L	M	N
6	1	218	250	199					A			L		
	2	83	79					A*				L	M	N
	3	230	194					A*			K*	L	M	N
	4	94	70					A*		K	K*	L	M	N
								13	5	9	12	16	13	13

APPENDIX 5:1 (g)

This appendix reproduces the experimental data for subjects in the full knowledge condition from experimental group C during phase 3.

Stud. No./	Trial	Price Quotes Received	Consistent with Search Rules						
1	1	317		A					
	2	115	A*			K*	L	M	N
	3	353 339 290	A*			K*	L	M	N
	4	125 131 118 126 114		A					
2	1	309 251	A*		K	K*	L	M	N
	2	147 143 130 102	A*		K	K*	L	M	N
	3	305		A			L		
	4	155 132 126	A*		K	K*	L	M	N
3	1	249	A*		K	K*	L	M	N
	2	157 162 128 141 134			K	K*			
	3	320 304		A			L		
	4	124	A*				L	M	N
4	1	294 337 294 303 342 316 259	A*		K			M	N
	2	112	A*		K	K*	L	M	N
	3	262	A*		K	K*	L	M	N
	4	101 134 144 113 109 118 127 117 148 143							
5	1	298 240	A*		K	K*		M	N
	2	116 134 123 155 127 94		A					
	3	260	A*		K	K*	L	M	N
	4	136 140 116 135 133 136 142 114 126 124							
6	1	291 282	A*		K			M	N
	2	130 123 119	A*					M	N
	3	340 302 372 302		A					
	4	127 102		A	K	K*		M	
			14	7	12	12	12	15	14

APPENDIX 5:1 (h)

This appendix reproduces the experimental data for subjects in the full knowledge condition from experimental group D during phase 3.

Stud. No./	Trial	Price Quotes Received	Consistent with Search Rules						
1	1	338 299 307 273	A*		K	K*		M	N
	2	152 117 136 127 121 137 111		A					
	3	327 366 310 309 294	A*		K	K*		M	N
	4	124	A*				L	M	N
2	1	334 329 313		A					
	2	124 102	A*		K	K*		M	N
	3	315 349 310		A			L		
	4	150 119	A*				L	M	N
3	1	363 356 366 351 316 349 330 287	A*			K*	L	M	
	2	108 139 127 132							
	3	282	A*		K	K*	L	M	N
	4	116	A*			K*	L	M	N
4	1	313 302 314							
	2	134 164 119	A*				L	M	N
	3	399 308		A			L		
	4	136 135 134		A	K	K*			
5	1	203	A*		K	K*	L	M	N
	2	118	A*				L	M	N
	3	229	A*		K	K*	L	M	N
	4	120 131 105		A	K	K*			
6	1	284 314							
	2	100 138 145							
	3	292 307 307							
	4	93	A*		K	K*	L	M	N
			13	6	9	11	12	13	12

CHAPTER

SIX

CHAPTER SIX

PRICE SEARCH BEHAVIOUR WITH PARTIAL PRIOR KNOWLEDGE

INTRODUCTION

In the experimental work described in chapters 4 and 5, search rules have been suggested that match well with observed behaviour and perform well in comparison with the optimal model, both when searchers have "full" prior knowledge of the price distribution (that is, searchers know its shape, and, in the case of the Normal distribution, its mean and its standard deviation), and no prior knowledge.

In practice, neither of the knowledge conditions above is likely. Full knowledge is implausible given that markets exhibit continual change in terms of the number of participants at any one time, and the specific price and availability of specific items at specific outlets. No knowledge, though, is equally unlikely. The mind is a consuming organ that stores vast quantities of information that may or may not be useful at some future time (Schelling, 1988). An individual buyer searching for a specific product is likely from the outset to have some idea of an expected "ballpark" price level for that product from, for example, previous purchases of related products, from catalogues, and/or from word of mouth.

This chapter describes a new experiment conducted in the more realistic setting where purchasers initially have partial knowledge of the price distribution. This prior knowledge can be used, in conjunction with knowledge gained from the search process itself, to determine an appropriate course of action. The aim of the experiment is to discover the search rules that might be employed in this context, and to assess their performance in comparison with an optimal full knowledge model.

In the first part of this chapter, the experimental details are described, and some new search rules are presented that have been derived by analysis of the price quotations received in conjunction with verbal protocols recorded at the time of the experiment. The second part of the chapter describes a series of simulations that seek to discover how well these new search rules perform over a large number of trials. That is, how little extra expenditure is incurred, on average, as a result of adopting one of the new rules instead of the optimal reservation price rule.

THE EXPERIMENT

Task

Subjects were required to purchase unspecified, common items. In each case there was some variation in the price quotes that could be received, and, therefore, a potential benefit from shopping around. There was, however, a constant non-zero search cost. Thus, subjects needed to estimate and compare expected costs and benefits in determining their decision strategy.

A partial knowledge framework was established by presenting the subject, at the outset of each purchase, with two initial prices generated randomly from the distribution. These act as "guide prices" though the searcher is unaware of their representativeness, in terms of where they occur within the distribution, or their specific location, in terms of which sales outlet supplies them at these prices. All price quotes received were available for the duration of each experiment (ie. there was full recall), and, within each purchase, were from the same distribution. Prices were generated, displayed and selected by means of a user-friendly interactive computer program (developed and implemented in Turbo-Pascal on an IBM compatible).

Procedure

For each subject the experiment consisted of two initial trials, to enable familiarisation with the program, followed by six separate purchases. These purchases were made from each of the six price distributions described in Table 6:1 below, the exact sequence being randomly determined. The distributions were similar to those used in the experiment and simulation of chapter 5.

The subjects performed the experiment in separate 15 minute sessions in the presence of the author to avoid any problems or misunderstandings. They were encouraged to think aloud, their verbal protocols being recorded on tape.

TABLE 6:1

PRICE DISTRIBUTIONS

Number	Mean £	Standard Deviation £	Search Cost £	Reservation Price £	Std.Dev./ Search Cost
1	86	10	4	86.1	2.5
2	86	10	2	81.1	5
3	215	25	5	202.5	5
4	215	25	2.5	192.5	10
5	215	25	1.25	183.75	20
6	86	10	10	95.0	1

Subjects

34 subjects participated in the experiment, all being second or third year undergraduate students at the Warwick Business School with no previous exposure to search theory. As an incentive, subjects were paid a fixed fee of £2 plus a bonus proportional to their performance. The bonus was calculated by comparing the amount spent by the subject over the six purchases with the amount that would have been spent using an optimal, full knowledge, reservation price model. Where there was no difference, the incentive bonus was £5, reducing linearly to zero where the subject's overall performance was 10% or more worse than the optimum. A "lucky" student could earn more than £5 by successfully taking advantage of the random nature of the prices generated.

RESULTS AND ANALYSIS OF EXPERIMENT

Students exhibited a wide range of performance in the experiment, bonuses achieved varying from zero to £6.50. with a mean of £3.74 and a standard deviation of £1.62. Appendix 6:1 displays details of the price quotes received for all 34 subjects. Careful analysis of such sequences, together with the verbal protocols recorded, led to the formulation of several new search rules. These are described and discussed below. The search rules with which observed behaviour was consistent are also highlighted in Appendix 6:1. Excerpts from the verbal protocols have been reproduced as supporting evidence, though they are necessarily restricted due to space limitations.

Three categories of search rules are distinguished. Simple rules are concerned with either a maximum number of searches or a fixed target value, but not both. Intermediate rules contain a target value, which may be fixed or variable but is related to the guide prices only, plus a limit on the number of searches allowed. Complex rules again contain a target value and possibly a search limit, but are characterised by using all available price and search cost data. Note that it is possible for the same observed search behaviour to correspond to more than one search rule.

In describing the rules, G will represent the higher guide price, g the lower, p_i the actual price quotes received, n the number of searches, c the search cost, and μ the average of all guide and actual prices so far received.

Simple rules

Two simple rules (P and Q) are proposed. Table 6:2 summarises their overall average occurrence across the varying values of σ/c. This relates to the percentage of all trials in which observed behaviour matched the given rule.

TABLE 6:2

OVERALL AVERAGE OCCURRENCE OF SIMPLE RULES

	Standard Deviation / Search Cost					
	1	2.5	5	10	20	Overall
(n	34	34	68	34	34	204)
Rule						
P	50%	29%	26%	15%	0%	25%
Q	53%	53%	47%	41%	56%	50%

Rule P - Keep searching until the total search cost, nc $\geq$ 5% μ.

This rule simply requires the searcher to focus solely on the total amount spent on search as a function of all price information so far gathered, and then accept the lowest price to date. As such, it is a variation of the no knowledge Rule J described in chapter 5. The protocol extract below for subject 32, purchase 5 (distribution 4) illustrates this focus on search cost:

[g 210, G 215, c 2.5]: "[204] ... The price given this time is lower than the guide prices, so perhaps I shouldn't search, but I think that I shall ... [238] ... this time I've been given a high price ... I'll search again ... [225] ... and the cost has gone up ... might as well try again ... [208] ... this time the price has gone down again, but the cost is more ... I'll try again ... [250] .. this time it's gone up a lot; my cost is continuing to go up ... I think I'm best stopping there, because my cost keeps on going up."

Although the overall average occurrence of Rule P is relatively low, especially for high values of σ/c, it is included here because it performs well in comparison with the optimal, full knowledge model (see later).

Rule Q - Keep earching until a price, p, is located such that $p \leq g + c$.

Thus, this rule sets a target value that focuses on the lower guide price, after allowing for the extra cost that an additional search would involve. The rationale, then, is simply to try to beat the guide prices. Rule Q reflected the behaviour of subjects in 101 of 204 trials. As an illustration, consider the protocol extract reproduced below for subject 5, purchase 5 (distribution 3):

[g 213, G 238, c 5]: "[240] ... Search cost of 5 ... the price is too high ... [215] ... the price is quite low compared to the guide prices ... I think I'll stop there."

Although simple, Rule Q is likely to perform badly in situations where the guide prices are high compared with the true mean and the search cost is low, as it will lead to search ceasing too early. Additionally, it may perform badly in situations where the smaller guide price is comparitively low, as search may continue too long. The latter problem would be mitigated to some extent by introducing a constraint on the number of searches, while at the same time maintaining a target value. This forms the basis of the "intermediate" and "complex" rules described below.

Intermediate rules

Two intermediate rules (R and S) are proposed, their relative average occurrence being shown in Table 6:3.

<u>Rule R</u> - Keep searching until a price, p, is located such that $p + nc \leq g$, but with a maximum total search cost of 10% μ.

This rule sets a target value lower than the target value of Rule Q above, but restricts the number of searches available to achieve this target. The rule focuses on the total cost that would be incurred at any one time; that is the minimum price received plus the total amount spent so far on search.

TABLE 6:3

OVERALL AVERAGE OCCURRENCE OF INTERMEDIATE RULES

	Standard Deviation / Search Cost					
	1	2.5	5	10	20	Overall
(n	34	34	68	34	34	204)
Rule						
R	74%	53%	37%	29%	47%	46%
S	68%	53%	46%	32%	41%	48%

Rule R matched observed behaviour in 46% of purchases. As an illustration of its adoption, consider the following two extracts from the protocol of subject 22 in purchases 5 and 6 (distributions 3 and 6):

> [g 207, G 216, c 5]: "[192] ... Guide prices 207, 216 ... price 192, cost 197 overall ... I think I'll buy, it seems like a reasonable purchase."

> [G 97, g 95, c 10]: "[86] ... The search cost is quite a lot here, 10, so that's going to push the cost up ... so, again, I think I'll buy; I'm sticking on 96."

The two sequences are consistent with Rule R and indicate a definite focus on the total cost to date, p + nc. Note that a property of this rule is that as search continues over time (up to the maximum allowed) the price required to satisfy the target value for p + nc must decrease by c each search in order to compensate.

Rule S - Keep searching until a price, p, is located no greater than the targets defined below:

$g + c - 1/2\ (G-g)$	if	$nc \leq$	$5\%\ \mu$
$g + c$	if	$nc \leq$	$10\%\ \mu$
$g + c + 1/2\ (G-g)$	if	$nc \leq$	$15\%\ \mu$
$G + c$	if	$nc \leq$	$20\%\ \mu$
$G + c + 1/2\ (G-g)$	if	$nc \leq$	$25\%\ \mu$

Stop if the total search cost exceeds these limits.

Rule S, like Rule R, sets a target value dependent on the guide prices only. This target, though, varies and becomes less restrictive as search costs increase, so that its performance is not too adversely affected in situations where the minimum guide price is very low in the distribution. The following three consecutive extracts from the protocol of subject 27, purchases 1, 2 and 3 (distributions 6, 2, and 4), are examples of its adoption, illustrating how the level of acceptability of a price quote in relation to the guide prices can vary with the total search cost to date.

> [G 76, g 73, c 10]: "[88] ... I'll try another one, because it's quite a high price, though it's expensive ... [80] ... I think I'll stop there, because it's going to cost me a lot more as the search cost is so high. I just think I'll have too many costs, so I'll accept that one."

[G 93, g 88, c 2]: "[69] ... I think I'll stop there, because it's a low price compared to the guide prices."

[g 216, G 230, c 2.5]: "[259] ... It's quite a low search cost and it seems to be quite a high price, so I'll try again and search for another one ... [211] ... which is a lot better ... I'll stay there, because it's quite a low price."

A property of rule S is that a price originally rejected as being too high, may subsequently be acceptable as the target value increases. For instance, subject 29 purchase 6 (distribution 2) was presented with guide prices of 91 and 83, with a search cost of £2. The first actual price quote received was 83, slightly higher than the rule S target of 81 (83 + 2 - 1/2[91 - 83]). The second quote, 98, was also unacceptable, the target still being 81. The third quote was 88, but by now £6 had been spent on search, 6.77% of the average of all the prices so far encountered. The target price, therefore, was now 85, and so the initial quote could be accepted.

Overall, rule S matched 48% of observed behaviour, having a similar occurrence profile to rule R across the distributions.

Complex rules

Two complex rules (T and Z) are proposed, their relative average occurrence being shown in Table 6:4.

TABLE 6:4

OVERALL AVERAGE OCCURRENCE OF COMPLEX RULES

	Standard Deviation / Search Cost					
	1	2.5	5	10	20	Overall
(n	34	34	68	34	34	204)
Rule						
T	59%	53%	29%	35%	29%	39%
Z	53%	50%	44%	29%	24%	41%

Rule T - Keep searching until a price, p, is located such that p $\leq$ 90% μ, but with a maximum search cost of 10% μ, unless minimum $p_i > \mu + c$.

Essentially, rule T is seeking to locate a bargain; that is, an actual price at least 10% lower than the current average of all available data. A search limit again applies, though this restriction may be lifted where there seems to be a strong likelihood of improvement, by allowing an extra search if the minimum, actual price quote received is more than one search cost above the current estimate of the mean. This situation may occur where one or both of the guide prices are low in the distribution. 39% of observations matched rule T, and the following extract from the protocol of subject 8, purchase 1 (distribution 2) illustrates its adoption:

> [g 78, G 95, c 2]: "[83] ... I'm looking at the prices trying to get a guess at the spread of the distribution, and then relating the value that I've been given to that spread ... on that basis, I'm going to try again ... [83] ... hasn't worked, costs are going up ... [97] ... computer's not being very helpful, try again ... [74] ... I've got a good one; I'm going to take it."

Again, rule T has the property that a price initially seen as being too high may later become acceptable as subsequent price quotes are received.

<u>Rule Z</u> - Estimate the mean of the distribution (μ as above) and the standard deviation (σ, by standard calculation using all data) after each search. Keep searching until a price is located less than or equal to a reservation price, R, where $R = \mu + \sigma z$, and $z = 3\sqrt{c/\sigma} - 2$.

This rule is an attempt to estimate a reservation price from the available data, using the best available statistical resources. The given formula is taken from expert rule N in chapter 5, and has a correlation coefficient of 0.98 with the true value of the reservation price. It is included here for comparison, but it is not suggested that any students adopted it in practice, and so no protocol extracts are presented.

THE SIMULATION

The previous section identified six rules of thumb which match student behaviour reasonably well. In order to analyse these rules further, some additional computer programs were developed. The particular tasks performed by these programs were: first, to test the matching of the rules with the experimental data (thus, giving the results shown in Tables 6:2, 6:3 and 6:4); second, to test the performance of each rule against large numbers of simulated purchases; and third, to generate a set of purchase decisions based on random stopping, against which all of the rules can be tested to discover any underlying fit that might not be accounted for by "intelligent" behaviour.

To some extent, the first two of the above tasks constitute an iterative process, in that the programs enabled systematic fine-tuning with the objective of discovering the form of each rule that represented the best compromise between matching and performance, while retaining a reasonable degree of simplicity. The six rules presented in the paper are the versions established after such an iterative process.

In all cases, "performance" was defined (consistently with previous studies) as the average percentage spend over the theoretical average spend of the optimal (full knowledge) model discussed earlier. It was shown in the simulation section of chapter 5 that this definition reduces to simply the average percentage spend over the true reservation price, R, for each distribution.

The simulation program generated prices randomly and in turn from five of the six Normal distributions in Table 6:1, thereby ensuring a reasonable spread of possible price distributions, the σ/c parameter ranging from 1 to 20. Distribution 2 was excluded as it is a simple multiple of, and therefore equivalent to, distribution 3. Each run simulated 5000 purchases for each distribution in turn under the same constraints as the live student experiment. The program generated enough prices for each purchase to test each decision rule. The spend for each rule was accumulated, and then averaged over each distribution and for the run overall. The results are shown in Table 6:5.

For a simple rule, rule P performs exceptionally well, and is reasonably consistent across all price distributions. Indeed, where the search cost is very low in comparison with the standard deviation of the price distribution, rule P out-performs all of the other rules.

Rule Q is the simplest search rule both to remember and to use, but is the worst performer with an average excess spend of 3.8%. This performance, however, is still better than all but one of the eight "no knowledge" rules reported in prior studies. Several variations of this

TABLE 6:5

PERFORMANCE OF SEARCH RULES ACROSS DIFFERENT DISTRIBUTIONS

	Expenditure over theoretical minimum					Average Performance	Occurrence	Underlying Occurrence (random stopping)
σ/c value distribution	1 (6)	2.5 (1)	5 (3)	10 (4)	20 (5)			
Search Rules								
Simple								
P	1.1%	2.1%	2.8%	3.1%	2.8%	2.4%	25%	20%
Q	4.5%	3.4%	2.7%	3.0%	5.4%	3.8%	50%	22%
Intermediate								
R	0.9%	1.7%	2.0%	2.6%	4.7%	2.4%	46%	25%
S	0.6%	1.1%	2.0%	2.6%	4.1%	2.1%	48%	22%
Complex								
T	0.3%	1.8%	1.3%	1.3%	3.1%	1.6%	39%	19%
Z	0.6%	2.2%	3.1%	3.8%	4.0%	2.7%	41%	24%

rule were tested, using a target "reservation" value of the form $g + \alpha c + \beta(G - g)$. Setting $\alpha = 2$ and $\beta = 0$ improves performance to 3.0% above the optimal, while a performance of 3.3% together with an occurrence matching of 51% is achieved by setting $\alpha = 1$ and $\beta = 1/3$; that is the target is twice as near to g as to G, after allowing for the cost of one more search. The addition of a cut-off on the number of searches (thereby producing an "intermediate" rule) can further improve performance. For example, a 10%μ search limit with a target of $g + c$, performs at 2.6% while retaining a 50% matching. Eventually, however, rule P was chosen for its simplicity, intuitive plausibility, and contrast with the intermediate rules that follow.

The two intermediate rules, R and S, behave similarly, both performing progressively less well as the parameter σ/c increases. Both rules suffer relatively badly when $\sigma/c = 20$, as they are likely to set too high a target value compared with the true reservation price.

Rule T is the best performing rule, averaging a less than 1.2% extra spend above the theoretical minimum for values of σ/c from 1 to 10, though once again losing out a little on distribution 5 ($\sigma/c = 20$) with an overspend of 3.1%. Only rule P, however performs better than rule T on this rather extreme distribution. The other complex rule, rule Z, averages an overspend of 2.7%, which is a poorer performance than rule T or either intermediate rule. This is perhaps surprising as, supposedly, rule Z uses all available knowledge in the way that statistical methods would best prescribe. Clearly this outcome demonstrates the potential inaccuracy inherent in any attempt to formally estimate the parameters of a distribution on the basis of a very small sample size.

Finally, totally random stopping behaviour was considered by testing the performance of stopping after a random number of searches between one and r, over 5,000 simulated purchases for integer values of r varying from one to ten. The best performance was 7.1% above the theoretical minimum, corresponding to r = 3. That is, the search rule requires one, two or three searches (determined randomly), and then acceptance of the lowest price offer received.

The matching of all six quoted rules was compared with their underlying occurrence when measured against 5,000 generated sequences of random (1 to 3) stops, for each of the five distributions. The results are shown in the final column of Table 6:5. Most rules exhibit an apparent occurrence substantially higher than their underlying, random occurrence. Rule P is an exception to this, however, and so cannot be said to match well with student behaviour.

SUMMARY

This chapter has extended the work on single parameter price search to consider the situation where searchers have partial prior knowledge of the price distribution. The partial knowledge framework is not one that prior research studies have investigated, which is surprising as, in general, it would seem a more realistic setting than the full or no knowledge settings previously adopted.

Six search heuristics have been discovered, characterised by varying degrees of complexity, that perform well in comparison with the theoretical, optimal, reservation price model, and/or concur well with observed behaviour. Table 6:6 below compares rule T, the best performing of these new heuristics, with the best performing search rules in the full knowledge and no knowledge states.

The results indicate clearly the value of knowledge. Thus, the better informed a searcher is about the underlying price distribution, the better, on average, will he/she perform in comparison with an optimal (full knowledge) model, by utilising the best available search heuristics.

TABLE 6:6

A COMPARISON OF THE "BEST" SEARCH RULES

State of Prior Knowledge about the distribution	Search Rule	Average spend above theoretical minimum
Full	K	1.1%
Partial	T	1.6%
None	J	2.4%

The findings of this experiment will help set some interesting research questions for the future, including, in particular, the issue of how do individuals change their search behaviour over time (if at all)? In this context, a "learning" effect might be characterised by settling onto one rule. In the current experiment, the behaviour of one subject matched the same rule (rule Q) throughout all six trials, while eight other subjects matched the same rule in five of the six trials. The average bonus payment earned by these nine subjects was £4.50, compared with £3.46 for the remaining 25, thus suggesting that these nine had "settled" on, or learned, a strategy they believed reasonable, and, consequently, had gained some advantage in performance. Five further subjects matched the same rule on their last three purchases, again indicating a possible learning effect.

An alternative learning process would be shown by a gradual migration to more complex, and better performing rules - for example, from rule Q to rule S, and then to rule T. To investigate this possibility in particular, and learning effects in general, however, further experimental work is required, with more subjects making many more purchase decisions. The results of such work will lend important insights to understanding the search behaviour and purchasing strategies of individuals over time, both in the single parameter price search situation discussed here, and in broader, more general, decision making contexts.

Finally, it is noticeable that of the five search rules apparently being used by subjects (rule Z is excluded as there was no evidence of its adoption), only one (rule T) is characterised by a target value dependent on all available price information. No target value is used in rule P, while rules Q, R and S have target values based on the guide prices only. This suggests that subjects may have difficulty in using price quotes received to update their knowledge of the distribution. Instead, they are seen solely as offers to sell at that price. This is linked to the concept of functional fixation in psychology. The next chapter reviews some findings from the human information processing literature that are relevant to price search studies, and focuses in particular on functional fixation, as a foundation for a new experiment concerning this phenomenon described in chapter 8.

APPENDIX 6:1

This appendix reproduces the experimental data for all subjects.

Student	Trial	Dist'n	Guide Prices	Price Quotes Received	Consistent with Search Rules
1	1	3	223 233	232 226 204	P R S
	2	5	217 146	222 226 218 177 222 256 230 218 225 161	Q R S Z
	3	6	101 97	92	P Q R S T Z
	4	4	222 224	198 212 247 225 193	P
	5	2	75 89	84 79 93 75	Q R S T
	6	1	97 72	99 90 90 70	Q S
2	1	5	213 219	211 252 212	
	2	3	238 243	194	Q R S T Z
	3	6	71 89	75 85 82	
	4	4	199 221	242 242 240 191	Q T Z
	5	2	84 69	90 84 86 76 86 83 65	Q
	6	1	88 98	99 70	P Q R S T Z
3	1	5	217 235	207	Q R S
	2	3	238 213	182	Q R S T Z
	3	2	73 89	83 78	Z
	4	6	83 84	89 88 80	
	5	4	248 173	193	
	6	1	96 92	83	Q R S Z
4	1	2	79 95	87 87 97 104	Z
	2	3	169 196	223 221 232 200	R T
	3	6	86 75	94 85	Q R S
	4	1	85 92	99 88	P Q R S T Z
	5	4	233 234	248 187	Q R S T Z
	6	5	196 242	203 193	Q R
5	1	1	78 91	79 83 92 69	
	2	6	97 71	80 81 76 81 73 96 88 93	
	3	5	194 175	208 207 203 198 185 206 203 201 251 250	Q R S T
	4	2	86 86	69	Q R S T Z
	5	3	213 238	240 215	Q Z
	6	4	208 246	232 260 224 184	Q R S T Z
6	1	6	91 77	81	P Q R S T Z
	2	1	90 87	86 75 91	
	3	2	90 108	83 92	
	4	5	232 255	230 237 211 204 208	
	5	4	249 271	200 228 218	
	6	3	195 245	215 187	Q T Z

APPENDIX 6:1 (continued)

This appendix reproduces the experimental data for all subjects.

Student/ Trial/ Dist'n.	Guide Prices	Price Quotes Received	Consistent with Search Rules
7 1 2	72 74	82 71	P Q S Z
2 3	206 218	208 240 206	P S
3 6	76 70	73 112 81 93 89	
4 1	100 76	88 72	P Q R S T Z
5 5	243 248	213	Q R S
6 4	221 247	238 236 181	Q R S T Z
8 1 2	78 95	83 83 97 74	Q R S T Z
2 1	84 99	74	Q R S T Z
3 6	80 64	94 102 92 78	
4 4	185 207	249 197 239 210 186	P Q S T
5 5	191 215	238 199 245 212 173	Q R S T Z
6 3	190 197	199 240 216 186	Q R S T
9 1 4	195 240	250 163	Q R S T
2 5	198 209	276 219 198	Q T
3 2	85 82	89 81	Q S Z
4 1	97 100	77	Q R S T Z
5 6	84 96	96	P R S T Z
6 3	211 204	180	Q R S Z
10 1 3	279 218	207	Q R T
2 5	198 216	203 244 201 231 192	Q
3 6	89 92	85	P Q R S T Z
4 2	93 73	81 99 98 73	Q R S T Z
5 1	86 90	75	Q R S T Z
6 4	180 212	243 199 197 194 239 186	
11 1 3	220 224	160 228	
2 5	231 197	272 236 191 225 206	
3 2	90 94	103 92 85	P
4 6	66 76	77 76 93	
5 1	97 80	113 82	P Q R S T Z
6 4	188 256	203 233 188	Q T
12 1 5	212 208	207 190 199 217	
2 4	173 180	217 202 185 236	P
3 2	94 84	84 85	
4 1	82 87	87 94	P R T
5 6	68 86	89	P R T Z
6 3	220 183	217 161	P Q R S T Z

APPENDIX 6:1 (continued)

This appendix reproduces the experimental data for all subjects.

Student	Trial	Dist'n	Guide Prices	Price Quotes Received	Consistent with Search Rules
13	1	2	85 81	94 93 84	P Z
	2	4	238 224	182 200	Z
	3	6	70 76	109 82	R S T Z
	4	1	83 79	75 90	T
	5	5	201 201	181 187 207	
	6	3	194 206	221 201 194	P Q S
14	1	5	196 202	227 266 219 194	Q S T
	2	1	100 91	91 85	P R S T
	3	4	209 178	189 227 224 198	
	4	6	87 66	77 90 81	
	5	3	199 188	205 234	
	6	2	77 94	76	Q
15	1	5	223 215	251 193	Q R S T
	2	2	93 77	78 82 77	P S
	3	3	200 235	238 259 217 272	Z
	4	6	83 69	96 103 80 94 82	
	5	4	222 176	203 258 237	
	6	1	90 87	75	Q R S T Z
16	1	4	206 205	198	Q R S Z
	2	3	214 216	258 206	Q S Z
	3	5	177 191	197 196 207 209	
	4	1	102 99	83	Q R S T Z
	5	2	100 70	90 80 97	P
	6	6	79 84	93 84	Q R S
17	1	1	106 99	91 73	P T
	2	3	209 211	253 195 183 231 224	
	3	6	89 95	88	P Q R S T Z
	4	4	239 230	224 223 197 219 207	P
	5	5	198 229	245 206 256 247 179	Q R S Z
	6	2	89 112	91 87 85	P S
18	1	1	88 85	82	Q S Z
	2	3	163 233	258 238 228 198	R T
	3	5	201 219	212 208	
	4	4	219 191	220 211 200	
	5	2	70 100	78	
	6	6	97 72	93	P R S T Z

This appendix reproduces the experimental data for all subjects.

Student/	Trial/	Dist'n.	Guide Prices		Price Quotes Received	Consistent with Search Rules
19	1	3	235	186	152	Q R S T
	2	4	236	209	263 161	Q R S T Z
	3	1	84	96	94 89 88 85	
	4	5	252	238	184 201	
	5	6	81	80	85	P Q R S T Z
	6	2	92	74	84 86 82	P Z
20	1	2	94	100	88	Q R S Z
	2	5	196	262	262 204 266	
	3	1	76	75	104 98 72	Q R S T Z
	4	6	89	79	77	P Q R S T Z
	5	4	238	249	178 229	Z
	6	3	212	180	207 239	
21	1	5	249	228	213 213	
	2	4	243	183	200 252 221 204	
	3	3	248	207	233 237 220	P Z
	4	2	99	93	87	Q R S Z
	5	6	73	102	88	P R S T Z
	6	1	86	89	91 86	P Q R S T
22	1	5	220	242	234 198	Q R S T Z
	2	4	212	174	212 204 226 230 228 246 203 225 229 270	Q R S
	3	2	80	83	79 97 75	P
	4	1	73	91	99 93 84 66	Q
	5	3	207	216	192	Q R S Z
	6	6	97	95	86	P Q R S T Z
23	1	4	180	236	225 191 222	
	2	6	76	92	66	P Q R S T Z
	3	1	88	101	85 70 78	
	4	3	187	236	229 219 208 201 187 220	
	5	5	231	193	167 191 198 203 201	
	6	2	77	87	76 92	
24	1	2	77	76	88 80 80	P Z
	2	6	91	72	95 91	R S
	3	4	231	233	241	
	4	5	212	193	252 212	
	5	3	202	264	228 212	
	6	1	84	93	83	Q S Z

APPENDIX 6:1 (continued)

This appendix reproduces the experimental data for all subjects.

Student/	Trial/	Dist'n.	Guide Prices		Price Quotes Received	Consistent with Search Rules
25	1	5	217	233	201	Q R S
	2	1	89	104	91 74	P R S T
	3	4	227	214	222 253 217	
	4	3	264	222	217	Q R
	5	6	96	94	70	P Q R S T Z
	6	2	75	83	107 84	
26	1	1	91	73	80	Z
	2	3	164	273	183 222	
	3	4	171	199	221 219 170	Q T
	4	5	228	275	216	Q R
	5	2	103	78	75 94 77 93 89 94	
	6	6	83	90	77	P Q R S T Z
27	1	6	76	73	88 80	Q R S
	2	2	93	88	69	Q R S T Z
	3	4	216	230	259 211	Q R S
	4	5	267	196	186	Q R T
	5	1	104	89	93	Q Z
	6	3	217	236	187	Q R S T Z
28	1	4	229	200	206	
	2	5	207	188	243 147	Q R S T
	3	2	74	65	82 85 80 105 89 93 92	
	4	6	75	91	77	P Q R S T Z
	5	1	76	72	92 78	R S T Z
	6	3	272	221	199	Q R S T
29	1	4	214	186	236 172	Q R S T
	2	1	75	88	80	Z
	3	5	185	202	261 188 176 178 216 239 249 224 223 199	Z
	4	3	238	272	200	Q R S T Z
	5	6	81	86	76	P Q R S T Z
	6	2	91	83	83 98 88	P S
30	1	1	71	78	80 94 76 93 94 88 68	Q
	2	5	207	217	246 244 227 225 217 213 194	Q R S T Z
	3	2	77	96	89 66	Q R S T Z
	4	6	81	99	106 75	Q R S T
	5	4	212	239	230 177	Q R S T Z
	6	3	247	184	245 171 209 174	

APPENDIX 6:1 (continued)

This appendix reproduces the experimental data for all subjects.

Student	Trial	Dist'n.	Guide Prices	Price Quotes Received	Consistent with Search Rules
31	1	3	189 202	219 188	P Q S Z
	2	5	277 257	206	Q R S T
	3	4	251 219	204 173	T Z
	4	6	93 88	84 81	R
	5	2	81 101	72 84 75	P
	6	1	80 73	100 94 71 101 81	
32	1	5	203 191	212 223 176 259 246 200	
	2	1	96 85	86 110 79	R
	3	2	97 88	86 79	S
	4	3	232 229	247 235 217	P Q S
	5	4	210 215	204 238 225 208 250	P
	6	6	86 82	107 75	Q R S T
33	1	6	88 84	95 94 94	
	2	3	172 211	195 228 228 228	R T Z
	3	5	241 241	245 255 249 253 224	Q R S Z
	4	4	193 200	187 189	
	5	2	74 96	85 71	Q T Z
	6	1	77 77	88 99 79 73 80	
34	1	3	232 208	192	Q R S Z
	2	1	79 101	84 99	P R T
	3	2	88 86	76 73	
	4	4	269 221	216 229	
	5	6	94 90	57	P Q R S T Z
	6	5	213 208	169 184 198	Z

CHAPTER

SEVEN

CHAPTER SEVEN

HUMAN INFORMATION PROCESSING CONSTRAINTS

INTRODUCTION

The central context of this thesis is the search for a suitably favourable price quotation for a consumer product or service, where some variation exists in the prices that might be located. An individual, then, sets out with whatever initial information she has about the price distribution, and then receives her first price quote. The acceptability of this quote is determined in comparison with her prior knowledge about both the price distribution and future search costs, and a choice is made either to accept the current offer (in which case, the search process is terminated), or to look for a better offer (in which case the process continues).

This chapter seeks to embed the scenario described above into an overall conceptual model of judgement, and then to examine some constraints or barriers that might interfere with an individual's decision making processes.

Mostly, these barriers will be discussed only briefly as no new, formal work concerning them is presented in this thesis. One potential interference effect source, however, "functional fixation", is reviewed in greater detail as a prelude to a new research experiment presented in Chapter 8.

First, though, consider the following extract from Carroll (1980, p 69):

> "You sit in the audience as the magician makes pigeons appear and disappear. You know it is a trick, that the pigeons are stowed quietly in the magician's clothes. You watch with intense concentration to see the pigeon transferred from hand to coat or coat to hand. You are sure that it happens, but you never see it. The magician is the master of illusion and we are enthralled by illusion.
>
> Why can't we catch the magician? One reason is mis-direction : the magician gets us to look at his or her face or hand gestures, the behaviours to which we continually attend. A second reason is mis-representation : we believe we know how the trick is done and attend carefully to our "theory" of the trick, but we are wrong and the magician works the trick through unmonitored paths. Related to this, we perceive the trick as composed of those elements we can see. We under-estimate the back-stage preparation - the props, the teamwork, the hours of practice. A third reason is that we have misplaced faith in our eyes : we believe that we can see any hand movement the magician makes, but we are wrong. In front of our bright and wary eyes, the magician's hands are simply faster than our perception.
>
> In some ways, recent research reveals the decision maker and the decision analyst in the roles of magician and audience. The decision analyst is mis-directed by the importance of the moment when the decision maker identifies a selection. We are seduced by language and common sense into believing that the choice <u>is</u> the decision. Yet ... the choice is the end product of the decision, the moment when we see the pigeon in the magician's hand. The decision is a process of arriving at a choice, the process by which the pigeon got into the magician's hand."

This extract is an important reminder that a decision is more than a final choice, more even than a problem solving strategy or a heuristic such as those identified in earlier chapters. Thus, for example, Rule K from Chapter 5, which states in the context of price search :

> "Keep searching until a price is found at least one standard deviation below the mean, up to a maximum of σ/c searches (rounded)",

tells only a part of the decision making story. Akin to the magician producing the pigeon, it is the rule that governs selection. In order to understand the decision making process more fully, however, it would be necessary to understand <u>why</u> Rule K is adopted. This would involve assessing, from the outset, how the decision maker portrays her representation of the task, how data is generated, used and processed, and how the outcomes of past decisions might be fed back into future selections.

A CONCEPTUAL MODEL OF JUDGEMENT

Hogarth (1987) has developed a conceptual model to help structure the various findings of research studies into decision processes adopted in the context of tasks involving human judgement. He conceives of judgement taking place within a system composing of three elements - the individual, the task environment, and the actions resulting from judgement. These three are inter-related via a continuous feedback loop. The model is reproduced as Figure 7:1 below.

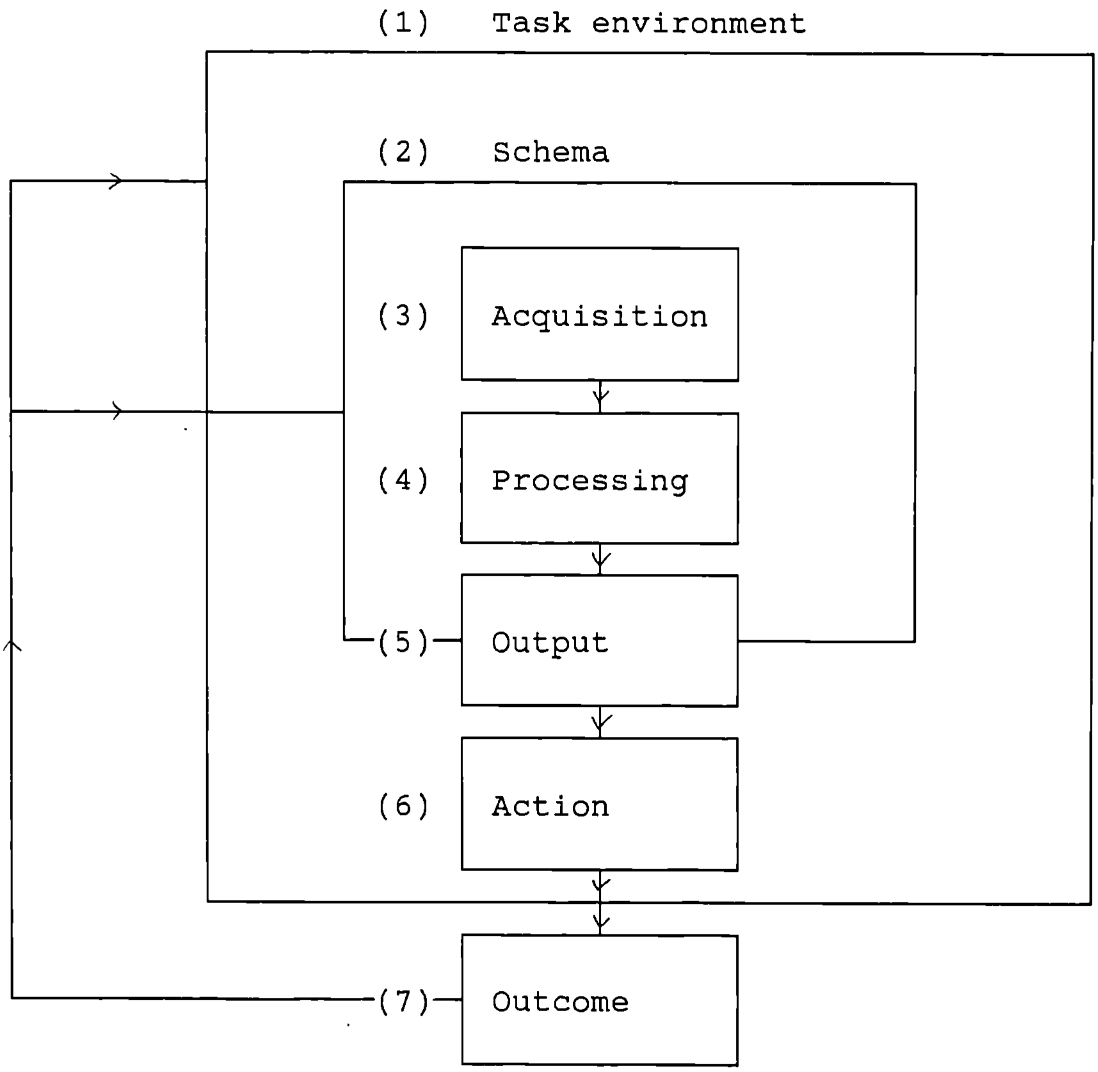

Figure 7:1 ... A conceptual model of judgement

Hogarth (1987, p 157) offers the example of a waiter in a restaurant to illustrate this inter-relatedness :

> "(The waiter) believes that young people do not tip generously. Consistent with his belief, he concentrates attention on older customers. The result is that younger customers receive poor service which they reflect by giving small tips. This, in turn, reinforces the waiter's beliefs."

Judgement, then, occurs within a task environment (box 1) within which is the individual's schema (box 2). This is concerned with the individual's beliefs regarding the task environment and her representation of it, and includes the actual processing of information, as decomposed into acquisition of information (box 3), processing (box 4) and output (box 5). The latter is characterised as being at the interface of the person's schema and the task environment to emphasise the location of its occurrence, and may be indistinguishable, at least to a third party, from the action (box 6). The choice of action leads to an outcome (box 7), (for instance, the level of tips in the waiter example), which may then reinforce, or possibly alter, the person's schema, and even, perhaps, the task environment itself (young diners may choose to eat elsewhere, thus effecting the overall age distribution of the restaurant's clientele).

Other proposed models of human information processing are broadly similar to that outlined above. For example, Libby and Lewis (1982) employ a three-way classification of information processing variables into input (concerned with information set cues), process (concerned with the characteristics of the judge, and the characteristics of the decision rule adopted), and output (concerned with the quality of the judgement, and subsequent self-insight).

The important issue with which this chapter is concerned is whether, in considering the conceptual model of judgement in its entirety, there are any judgemental biases, inherent in an individual's decision processes, that might impact on the accuracy and optimality of subsequent choices.

In the case of the price search examples discussed in earlier chapters, several of Hogarth's "boxes" are clear and unambiguous. Since the context is so precisely structured, the task environment (box 1) can be straightforwardly defined as a search for a suitably low price, though the exact interpretation of "suitably" will vary from individual to individual. Again, within a person's schema (box 2), the acquisition of data (box 3) is restricted to the direct visual display of the search cost together with all prices so far received, and, further down Hogarth's model, boxes 5, 6 and 7 representing respectively output, action and outcome are similarly clear. The output of the decision process is either to search again, or to stop searching and accept the lowest price to date; and the action and the outcome are direct consequences of this output.

Thus, the main potential source of judgemental error or bias occurs in the processing of data (box 4). Apart from basic arithmetical errors that may infiltrate any calculation, inaccuracies may also occur where subjects attempt to assess probabilities, for example the probability that the next price is more than one search cost lower than the minimum price so far. Kahneman and Tversky (1972, p 430) conclude about this aspect of the psychology of uncertainty that:

> " ... perhaps the most general conclusion, obtained from numerous investigations, is that people do not follow the principles of probability theory in judging the likelihood of uncertain events. This conclusion is hardly surprising because many of the laws of chance are neither intuitively apparent, nor easy to apply. Less obvious, however, is the fact that the deviations of subjective from objective probability seem reliable, systematic, and difficult to eliminate. Apparently, people replace the laws of chance by heuristics, which sometimes yield reasonable estimates and quite often do not."

This conclusion is also confirmed by several later experimental studies investigating the manipulation of probabilities, for example, Bar-Hillel (1982) and Salop (1987).

An additional potential source of bias is known as "anchoring and adjustment". This may occur where a subject estimates some value by starting with an initial value, and then adjusting. Typically, the size of adjustment is insufficient (Slovic and Lichtenstein, 1971), being biased towards the initial values, which consequently are labelled anchors. Tversky and Kahneman (1974, p 1129) reported the following powerful demonstration of this effect:

> "Subjects were asked to estimate various quantities, stated in percentages (for example, the percentage of African countries in the United Nations). For each quantity, a number between 0 and 100 was determined by spinning a wheel of fortune in the subjects' presence. The subjects were instructed to indicate first whether that number was higher or lower than the value of the quantity, and then to estimate the value of the quantity by moving upward or downward from the given number. Different groups were given different numbers for each quantity, and these arbitrary numbers had a marked effect on estimates. For example, the median estimates of the percentage of African countries in the United Nations were 25 and 45 for groups that received 10 and 65, respectively, as starting points. Payoffs for accuracy did not reduce the anchoring effect."

The experiments on price search suggest two ways in which an anchoring effect may occur. First, where subjects have an initial budget against which to judge expenditure, the budget figure may be used as a target value, and, therefore, strongly influence search behaviour (in the partial or no prior knowledge cases). However, although the Hey (1982) experiment provided subjects with such targets, they were excluded in the experiments reported in Chapter 5 and Chapter 6.

Second, in the situation where subjects are given two guide prices as partial prior knowledge of the price distribution, commonly subsequent quotes received were evaluated in relation to the two guide prices only, rather than in relation to all the gathered data. The guide prices, therefore, acted as anchors. This also suggests that the price quotes actually received are often perceived simply as offers to sell at that price, rather than as offers to sell plus data which may be used to update an individual's knowledge of the overall price distribution. Thus, subjects may have difficulty in using the same data for two different purposes. This is the concept of "functional fixation". It is discussed further in the next section, and investigated experimentally in the next chapter.

FUNCTIONAL FIXATION

In many situations, solutions to problems may depend on a subject's ability to represent the environment in novel ways. Generally, decision making is facilitated and improved with the benefit of previous training and experience. As Eyesenck (1984, p 273) notes, however,

> "...it is perhaps less obvious that knowledge acquired in the past can sometimes seriously disrupt, and interfere with, subsequent attempts to solve problems.
>
> ...for example, we tend to regard any particular object as suitable for a strictly limited range of purposes, and often experience difficulty in realising that the object can be used in other ways."

This phenomenon is known as "functional fixation", and was first investigated by Maier (1931). In his experimental design, subjects entered a room in which two strings were hanging from the ceiling, the strings being sufficiently far apart that they could not both be grasped at once. The task was to tie the strings together. Other objects in the room included a chair and a pair of pliers. Many subjects unsuccessfully attempted to solve the problem using the chair. The "correct" solution, however, involved tying the pliers to one string, swinging them like a pendulum, and holding the other string until the swinging string was close enough to grasp. The two strings could now be tied together. In Maier's experiment, only 39% of subjects managed to solve the problem within ten minutes. The difficulty arises from not perceiving that the pliers could be used as a weight at the end of a pendulum as an alternative to their more conventional use.

Experiments seeking to investigate functional fixation should be characterised, therefore, by the following three properties:

(1) - the behaviour of individuals is investigated,

(2) - subjects have undergone some pre-utilisation training (either within the experimental instrument itself, or within general past experience) for some specified object, and

(3) - subjects are required to discover a new function for the specified object above.

Over the last few decades, several research studies that focus on experience as a barrier to problem solving have been reported in the accounting literature. In particular, the issues addressed have included the influence on managerial decisions of alternative inventory flow assumptions (Dyckman, 1964a, 1964b ; Bruns, 1965 ; Dopuch and Ronen, 1973), the influence of changes in the underlying cost information provided on pricing decisions (Ashton, 1976 ; Barnes and Webb, 1986), the ability to respond to valuation method changes (Chang and Birnberg, 1977), and the effect of cost and profit information on market-based decision models (Haka, Friedman and Jones, 1986). In each case, available evidence indicated that decision makers' behaviour is impaired; that is, decisions were made that were, in some sense, sub-optimal.

Detailed reviews of (most of) these studies and their link with the functional fixation literature in psychology are provided by Ashton (1976) and Wilner and Birnberg (1986).

None of the studies reported in the accounting literature, however, have maintained all three of the characteristics mentioned above within their experimental design. For instance, in Ashton's (1976) study, subjects were required to establish selling prices for products that their hypothetical company planned to introduce in the future. They were presented with three variables "generally recognised" as being important in pricing decisions - elasticity of demand (see Watson, 1968, pp 51-54), unit product cost (see Horngren, 1972, pp 373-374), and the nature of competition (see McCarthy, 1964, pp 327-337). Only the second of these was manipulated experimentally, subjects being presented with either full cost data, including fixed factory overhead cost, or variable cost data. Thirty pricing decisions were then made using one type of cost data. This enabled a decision model to be established for each individual, in a linear regression form. Subjects then made 30 further pricing decisions using (except for those subjects in control groups) the other type of cost data. This second set of prices was then compared with the set of prices that would have been predicted by each subject's decision model, that is with the prices obtained under complete fixation where no change occurs in the process used. Ashton (1976, p 14) found that:

> "the data suggest that a large proportion of the subjects in the experimental groups failed to adjust significantly their decision processes in response to an accounting change, thereby providing evidence of the existence of functional fixation in an accounting context."

While this is an interesting finding, in reality it is not evidence of functional fixation in an accounting context. In fact, it is better described as evidence of "data fixity" in an accounting context, since subjects were required to make the same type of decision with two different types of data. They were finding one "function" for two "objects", rather than two "functions" for one "object".

A similar criticism applies to the other published research studies reputedly concerned with the issue of functional fixation in accounting. No study has yet attempted to investigate dual applications for the same accounting object.

The experiment reported in Chapter 8 attempts to remedy this deficiency. It investigates whether familiarity with a data set and a method for its application, prohibits subsequent uses of that data set for different purposes.

Thus, the current study differs from prior accounting research, and is closer to the concept of functional fixation in psychology, because it stresses a new use for a familiar data set. In this experiment, subjects, accustomed to using a component's "cost-card" for inventory valuation, are required to use a similar "cost-card" to calculate a component's minimum cost. Hence, the study explores subjects' ability to find two distinct functions for the same object, as required.

SUMMARY

This chapter has introduced a conceptual model of judgement within human information processing. Decisions are not always totally objective in nature; they are made by humans. Their subjective component can interfere with choice behaviour that might be prescribed by an outside, "rational" observer (though again, it is unlikely that the outside observer herself is totally objective).

In particular, one potential source of bias in decision making - functional fixation - has been reviewed in some detail. This is directly relevant to the work on price search since, especially in the normal situation where a subject has partial prior knowledge of the underlying price distribution (in the form of two initial "guide" prices), there is a general tendency to view subsequent price quotes received solely as possible purchase prices, and not additionally as data with which to update the knowledge of the overall price distribution.

Some new experimental evidence concerning the existence of functional fixation in an accounting context is presented in the next chapter.

CHAPTER

EIGHT

CHAPTER EIGHT

NEW EXPERIMENTAL EVIDENCE ON FUNCTIONAL FIXATION

INTRODUCTION

In the previous chapter some potential sources of judgemental error or bias were introduced and discussed. In particular, individuals may suffer an interference effect when attempting to use price quotes not only as straightforward offers to supply the product or service at that price, but also as sources of information with which to update their knowledge of the overall price distribution. They may be "functionally fixated", finding it difficult to discover this new function for a familiar object (a price).

This chapter describes a new experiment that seeks to investigate this phenomenon. It is set, however, not in the context of the partial knowledge price search framework described earlier, but in a different, though related, context, so designed in order to facilitate the objectivity of analysing any possible fixation effects.

That is, the context has been deliberately chosen so that the given problem has a unique "correct" answer, which may be compared with a specific "incorrect" answer that would be consistent with a fixation effect.

RESEARCH METHODOLOGY

Hypothesis

The research hypothesis of the current study is that prior use of a data set will inhibit the creative use of that data set in a new way. The null hypothesis is that familiarity with a procedure that uses a data set for the valuation of inventory will not affect subjects' use of that data set for minimum cost calculation.

Task and Procedure

Subjects were undergraduate students from the Warwick Business School. All were enrolled on a Managerial Accounting course and all had previously taken (and passed) an Introduction to Accounting course.

Subjects were divided into two equal groups of 40 by the random selection of playing cards (without replacement) on entering the lecture theatre. All subjects completed an objective test on basic accounting topics in order to establish equivalence between the two groups. The objective test is also a useful mechanism for assessing the ability of subjects, as individuals with little or no competence in accounting might use previously learned data-handling techniques for a new task for reasons other than being functionally fixated (as discussed later).

The main drawback of using an objective test is that the test itself may cause interference effects, especially if it focuses on directly relevant knowledge. For the current experiment, it was decided that the benefits of using an objective test outweighed this drawback, and so a short, five question multiple-choice test was adopted (question 2 is reproduced in Appendix 8:1 as an example).

Experimental Group

On completion of the pre-test, subjects in the experimental group were given some background information on Shannon Engineering Technologies Limited (SET), as reproduced in Appendix 8:2 (a). SET was described as a long-established manufacturing company. The description also included details of SET's adopted inventory valuation procedures (see Appendix 8:2 (b)).These procedures essentially valued materials and labour on the basis of standard cost, although adjustment would be made to current cost in certain, specified circumstances. Overheads, split between specific and general, were added on a standard allocation rate basis, and a provision was deducted amounting to 3 percent of the total materials and labour costs. This provision represented an allowance for losses from total inventory value arising from obsolescence etc.

Subjects were also presented with the up-to-date "cost card" for one component and a solution for its overall valuation. Their task was to apply the inventory valuation procedures to three finished goods components, a cost card being given for each one (Appendix 8:2 (c)). The importance of this preliminary task was for subjects to become accustomed to, and to try to apply, the given inventory valuation procedures. Analysis of responses to this part of the experiment revealed that 28 subjects valued all three components correctly. The other 12 subjects (9 of whom scored two or fewer on the multiple-choice test) all valued the first two components correctly, but made the same error on the third, using current cost for one of the labour processes where this was 8 percent less than standard cost. SET's procedures, however, only allow a current cost basis for labour where current cost <u>exceeds</u> standard cost by 5 percent or more.

In the second part of the experiment, subjects were again presented with a cost card, but the task was now to calculate the minimum cost at which a particular component (the ZV_{10}) could be produced (as described in Appendix 8:2 (d)). This might lead to a management opportunity to utilise spare capacity and make extra profit by offering the component at a special, reduced price. The component required two parts and three labour processes (in none of which did standard cost exceed current cost by 5 percent or more). Table 8:1 compares the cost of the ZV_{10} component based on SET's usual inventory valuation procedures with the minimum cost for the special order.

Control Group

The members of the control group were given similar background information on SET (see Appendix 8:2 (e)), but not the data on SET's inventory valuation procedures. They carried out only the "minimum cost" part of the experiment. After calculating the "minimum cost" they attempted an additional question on break-even analysis intended to keep them occupied for the same length of time as the experimental subjects. The overall sequence and timings are summarised in Table 8:2.

TABLE 8:1

VALUATION BASIS FOR THE ZV10 COMPONENT

	Inventory	Minimum cost
Materials		
Part A_{56}	Standard cost	Current cost
Part B_{30}	Current cost	Current cost
Labour		
Process R	Standard cost	Current cost
Process N	Current cost	Current cost
Process V	Standard cost	Current cost
Overheads		
Specific	Include	Include
General	Include	Exclude
Provision		
Obsolescence	Include	Exclude

TABLE 8:2

SUMMARY OF EXPERIMENTAL PROCEDURE

Task	Duration (mins)	Task	Duration (mins)
Objective test	20	Objective test	20
SET 1 (inventory val'n)	35	SET (minimum cost)	20*
SET 2 (minimum cost)	15	Break-even analysis question	30
	70		70

* - the control group's extra five minutes enabled familiarisation time with SET and the cost card format.

A final issue regarding the experimental design concerned the choice of an appropriate incentive scheme; one that would motivate subjects to perform to the best of their ability. An incentive scheme that pays a fixed fee to each subject would certainly help to ensure a high number of volunteers, but if receipt of the fixed fee is not conditional upon performance, then the scheme is not actually providing any incentive. An improvement on this would be a scheme that rewards subjects by paying a variable fee directly linked to performance (perhaps with a fixed payment element as well as this).

The special difficulty in the current experiment, though, is that there is not a suitable, variable performance measure that might act as a basis for such an incentive scheme. Subjects either achieve the "right" answer or they do not. It would seem a contradiction to reward a "wrong" answer, but payments only for "right" answers would raise issues of equity, since subjects in the control group could earn the same bonus as those in the experimental group, with a substantially reduced, relevant workload (the bonus only being linked to SET), and with less interference effects to overcome.

After weighing up these considerations, and in common with most previous experimental studies on functional or data fixation, no incentive scheme was adopted. Although this represents a design limitation, almost 90% of students registered on the course agreed to participate in the experiment, and there was no indication that they did not work through their tasks in a serious and committed manner.

RESULTS

No significant ($p < .05$) difference was found between the performance of the experimental and control group members on the initial objective test. It can be concluded that the two groups were equivalent for analytic purposes. Subjects' solutions revealed, however, a lower standard of accounting knowledge than had been anticipated. 24 experimental group members and 19 control group members correctly answered fewer than three of the five questions. This suggested that these subjects had a poor general comprehension of accounting and could not be relied upon to sufficiently understand the SET problem which confronted them. For these students rather than causing fixation, the inventory valuation procedures may have actually provided a means of achieving a solution - a way out of their confusion. An examination of these subjects' responses supports this view. For example; of the 24 experimental group members, labour cost was calculated correctly by 8 (33%), as per inventory valuation procedures by 15 (63%), and in some other way by 1 (4%). Corresponding figures for the 19 control group members were 8 (42%), 0, and 11 (58%), respectively. Thus, most (86%) of the shift is from "other" in the control group to "inventory valuation" in the experimental group. For this reason, these subjects' responses to the minimum cost experiment were excluded from analysis.

The remaining subjects' responses were classified into five categories and three conditions. The five categories are :

(1) - <u>overall</u> ... the complete response

(2) - <u>materials</u> ... responses for the two parts within the ZV_{10} component taken together

(3) - <u>labour</u> ... the three processes taken together

(4) - <u>overheads</u> ... specific and general

(5) - <u>provision</u> ... obsolescence

The three conditions of response within each category represent minimum cost calculated :

(1) - <u>correctly</u> ... see Table 8:1

(2) - <u>as per inventory valuation procedures</u> ... see Table 8:1

(3) - <u>other</u> ... any other way

These responses are presented in Table 8:3 on the next page.

TABLE 8:3

ANALYSIS OF RESPONSES TO THE SET MINIMUM COST PROBLEM

Group	Overall	Mats	Labr	Ovhd	Prov
Experimental (n=16)					
% calculating min. cost					
- correctly	19	62	31	69	81
- as per inventory valuation rules	-	19	50	6	19
- other	81	19	19	25	-
	100	100	100	100	100
Control (n=21)					
% calculating min. cost					
- correctly	57	100	62	95	100
- as per inventory valuation rules	-	-	-	5	-
- other	43	-	38	-	-
	100	100	100	100	100

A fixation or interference effect would be demonstrated by a movement away from the "correct" condition in the control group to the "inventory valuation" condition in the experimental group. Its magnitude is the lower of the decrease in the percentage of subjects calculating minimum cost correctly (from the control group to the experimental group) and the increase in the percentage calculating it as per the inventory valuation procedures.

Across the sample of 16 experimental group members an interference effect is apparent in 3 (19 percent) regarding materials, 5 (31 percent) regarding labour, and 3 (19 percent) regarding the obsolescence provision.

A two-way chi-square test with Yates' correction was conducted over the two groups for each of the response categories. First, the number of subjects calculating minimum cost (for the category) correctly or in accordance with the inventory valuation procedures was compared with the number calculating minimum cost in some other way. There were no significant differences. The "other" responses were excluded, therefore, and a second two-way chi-square test (again with Yates' correction) compared for each category the number of subjects calculating minimum cost correctly with the number using the inventory valuation rules. A significant ($p < .01$) difference was found only for labour ($chi^2 = 8.847$). Thus, there is some support for the interference effect described above for the labour valuation, though a cell size of four for two of the cells indicates rather a weak test.

DISCUSSION AND CONCLUSION

The experiment revealed limited evidence of functional fixation in an accounting context. There were, however, several weaknesses in the experimental methodology that must be considered in evaluating any extrapolations from these findings.

Firstly, the sample size was small. After excluding 24 subjects following their poor performance on the objective test, only 16 subjects remained in the experimental group. This led to rather weak statistical evidence. Any re-run of the experiment should be performed with a larger and more knowledgeable pool of subjects.

A second concern relates to the initial objective test. It is a useful instrument for ensuring the competence of individual subjects and the equivalence of the two groups. It is possible, though, that the presence of the test, and in particular the presence of a question on relevant costs for decision making, may itself have induced a set response. The effect would be to magnify the difference between the two groups as the control group had sat the objective test immediately prior to the experimental task. This would be alleviated in any re-run by having the control group perform the break-even analysis question before the SET problem. In addition, this would balance any fatigue effects across the two groups.

Thirdly, no reward structure was provided to motivate subjects in the direction of the correct answer. This lack of incentive may have adversely affected subjects' performance in the experimental task, especially experimental group members' who had been at work for almost one hour before attempting the minimum cost problem.

Another concern relates to the lack of feedback given to subjects regarding their performance in the experimental tasks. This is in common with all previous accounting studies on fixation, but as noted by Wilner and Birnberg (1986, p 6) :

> "...feedback information about the quality of prior decisions may be a useful signal that the decision process needs adjustments or that it should be left alone."

The experimental task had one right answer, yet subjects had no way of knowing whether they had achieved it or not. There was no learning process, therefore, that could aid subsequent attempts at a similar task.

Finally, it must be recognised that an individual calculating minimum cost in accordance with the inventory valuation procedures may have done so for reasons other than fixation. He may have had other preconceptions about how to respond; he may have mis-understood the task itself or felt it was framed ambiguously; or, perhaps, for some or all of the reasons already discussed, while realising that a change in decision process was required, he simply did not want to make the effort.

Despite these initial weaknesses of experimental design, the results presented here show tentatively that familiarity with a data set, and a method for its application, can interfere with subsequent, alternative applications of the data set. If a more rigorous experimental design reinforces these exploratory results, there remains a clear need to understand <u>why</u> people are functionally fixated.

APPENDIX 8:1

This appendix reproduces question 2 from the five question multiple-choice objective test.

Last year, a firm started to produce a single product with a unit selling price of £16. In the first year of operation standard capacity was 50,000 units, production was 50,000 units, and sales were 40,000 units. The actual costs incurred were :

	Fixed	**Variable**
Raw materials	-	£3.00 per unit produced
Direct labour	-	£2.00 per unit produced
Factory overhead	£200,000	£1.00 per unit produced
Selling and dist'n expenses	£80,000	£1.00 per unit sold

Actual variable costs did not diverge from standard.

Using absorption costing, what was the unit cost of closing inventory?

A £ 6.00

B £ 7.00

C £10.00

D £11.00

E £13.00

APPENDIX 8:2

This appendix reproduces the complete experimental details and handouts used in the Shannon Engineering Technologies Limited study. The details are organised as shown below.

Appendix 8:2 (a)	-	Background Information for Experimental Group (1 page)
Appendix 8:2 (b)	-	SET Stock Valuation Procedures and Example for Experimental Group (3 pages)
Appendix 8:2 (c)	-	Stock Valuation Cost Cards for Experimental Group (3 pages)
Appendix 8:2 (d)	-	Additional Task Information for Experimental Group (2 pages)
Appendix 8:2 (e)	-	Background and Task Information for Control Group (1 page)

APPENDIX 8:2 (a)

BACKGROUND

You are a recently appointed Cost and Management Accountant for Shannon Engineering Technologies Ltd. (SET), a well-established company manufacturing a wide range of components mainly for use in the automotive and aerospace industries.

The year-end figures are currently being prepared, but unfortunately, there has been a breakdown in the company's management information system. While most essential year-end figures had been produced prior to the breakdown, the computer information concerning the valuation of finished goods in stock has been lost. This part of closing stock, therefore, must be calculated manually.

Relevant available information consists of :

1) ... Details of SET's valuation procedures for finished goods in stock.

2) ... Up-to-date cost cards for each component.

3) ... Year-end stocktake sheets listing quantities of finished goods in stock.

TASK

Using the attached SET finished goods valuation procedures and the given example as a guideline, you are required to produce the stock valuation for the three components - **ZE_{40}, ZX_7** and **ZN_1**. A cost card information sheet is given for each component. Quantities in stock per the year-end stocktake sheets were as follows :

Component	**Quantity of Finished Goods in Stock**
ZE_{40}	3
ZX_7	1
ZN_1	10

APPENDIX 8:2 (b)

SET STOCK VALUATION PROCEDURES

SET operate a standard costing system for materials, labour inputs and overheads. Generally, the year-end stock valuation is based on the above standard costs, though, in certain circumstances, adjustment may be made to current cost. Specifically, the valuation procedures for finished goods in stock are as given below :

Materials - valued at standard, unless current cost differs by more than 10% of standard, in which case current cost is used in the valuation. There are never any materials usage variances.

Labour - inputs are costed at standard hours and standard rates (and are paid on a piece-rate basis). SET make every effort to ensure the standard hours for a process are an accurate reflection of the time actually taken. Standard hours figures can, therefore, be relied upon for valuation and decision making purposes. However, if current labour rates exceed standard labour rates by more than 5%, then the current rate would be used in the year-end stock valuation.

Overheads - (a) Specific - those overheads identifiable as relating to the finished goods themselves.

(b) General - other allocated overheads.

Both types of overhead are included in the year-end stock valuation using standard overhead absorption rates per unit. Overhead variance calculations indicate these rates to be acceptable.

Stock Provision - A provision of 3% of the total materials and labour costs is deducted from the finished goods valuation as an allowance for obsolescence and other expected losses. The provision is rounded to the nearest £.

Final Valuation - The overall unit cost (materials + labour + overheads - provision) is then multiplied by the number of units in finished stock to arrive at the final stock valuation.

This stock valuation system has been in existence for several years, and has the approval of internal management and external auditors alike.

STOCK VALUATION EXAMPLE

COMPONENT ZX3 (Quantity in Stock - 8)

COST CARD INFORMATION

Materials

Part No.	Quantity	Costs per unit in £ Standard	Current	Variance
A118	10	23	23	-
A119	2	145	128	- 12%

Labour

Process	Standard Hours	Labour Rates per hr in £ Standard	Current	Variance
C	5	5.00	5.40	+ 8%
X	20	4.80	4.90	+ 2%

Overheads

	Standard Absorption Rate per unit in £
Specific	70
General	50

STOCK VALUATION EXAMPLE - SOLUTION

COMPONENT ZX_3 **(Quantity in Stock - 8)**

	Basis	Working	Valuation £	£
Materials				
A_{118}	Standard	10 x £23	230	
A_{119}	Current	2 x £128	256	486
Labour				
C	Current	5 x £5.40	27	
X	Standard	20 x £4.80	96	123
				609
Overheads				
Specific			70	
General			50	120
				729
Less **Provision**		3% x £609		- 18
UNIT VALUATION				711
OVERALL VALUATION :		8 x £711	=	**£5,688**

APPENDIX 8:2 (c)

COMPONENT ZE_{40}

COST CARD INFORMATION

Materials

Part No.	Quantity	Costs per unit in £ Standard	Current	Variance
A_{56}	5	14	15	+ 7%
B_{103}	3	36	36	-

Labour

Process	Standard Hours	Labour Rates per hr in £ Standard	Current	Variance
E	10	4.70	5.00	+ 6%

Overheads

	Standard Absorption Rate per unit in £
Specific	37
General	20

COMPONENT ZX_7

COST CARD INFORMATION

Materials

Part No.	**Quantity**	**Costs per unit in £** **Standard**	**Current**	**Variance**
A_{91}	6	30	26	- 13%
B_{22}	1	150	138	- 8%
B_{23}	3	40	47	+ 18%

Labour

Process	**Standard Hours**	**Labour Rates per hr in £** **Standard**	**Current**	**Variance**
P	10	5.00	5.30	+ 6%
X	5	4.80	4.90	+ 2%

Overheads

	Standard Absorption Rate per unit in £
Specific	45
General	30

COMPONENT ZN_1

COST CARD INFORMATION

Materials

Part No.	**Quantity**	**Costs per unit in £** **Standard**	**Current**	**Variance**
A_{73}	3	8	9	+ 13%
B_{66}	2	39	41	+ 5%

Labour

Process	**Standard Hours**	**Labour Rates per hr in £** **Standard**	**Current**	**Variance**
J	5	5.00	5.20	+ 4%
K	5	5.00	4.60	- 8%
N	2	4.50	4.50	-

Overheads

	Standard Absorption Rate per unit in £
Specific	13
General	8

APPENDIX 8:2 (d)

SET - ADDITIONAL TASK

The directors of the company are keen to utilise some of the existing spare capacity. One way of achieving this is to manufacture a new component, the **ZV_{10}**, currently required by the Ministry of Defence. In order to assist the directors with their negotiations, you have been asked to calculate the minimum cost for which a ZV_{10} component can be produced.

FURTHER INFORMATION

Attached is the cost card that has been prepared for component ZV_{10}.

Note, in addition, that :

1) Materials - Parts A_{56} and B_{30} are often used by SET for other components. Though none is currently in stock, both parts are readily available from local suppliers.

2) Labour - Labour is paid on a piece-rate basis. There is sufficient spare capacity on each of processes R, N and V to enable production of the ZV_{10}.

3) Overheads - SET's overall general overheads will not alter as a result of producing the ZV_{10}.

COMPONENT ZV_{10}

COST CARD INFORMATION

Materials

Part No.	Quantity	Costs per unit in £ Standard	Current	Variance
A_{56}	3	14	15	+ 7%
B_{30}	4	63	72	+ 14%

Labour

Process	Standard Hours	Labour Rates per hr in £ Standard	Current	Variance
R	15	5.00	5.20	+ 4%
N	8	4.25	4.50	+ 6%
V	20	5.50	5.30	- 4%

Overheads

	Standard Absorption Rate per unit in £
Specific	72
General	30

APPENDIX 8:2 (e)

TASK

You are a recently appointed Cost and Management Accountant for Shannon Engineering Technologies Ltd. (SET), a well-established company manufacturing a wide range of components mainly for use in the automotive and aerospace industries.

The directors of the company are keen to utilise some of the existing spare capacity. One way of achieving this is to manufacture a new component, the **ZV_{10}** , currently required by the Ministry of Defence. In order to assist the directors with their negotiations, you have been asked to calculate the minimum cost for which a ZV_{10} component can be produced.

FURTHER INFORMATION

SET operate a standard costing system for materials, labour inputs and overheads. While materials prices, and labour and overhead rates change from time to time, there are never any materials usage variances, and SET make every effort to ensure the standard hours for a process are an accurate reflection of the time actually taken. Standard hours figures, therefore, can be relied upon for valuation and decision making purposes.

For any component, all accounting information regarding the unit costs of that component is kept on an individual and up-to-date cost card. Attached is the cost card that has been prepared for component ZV_{10}.

Note, in addition, that :

1) Materials - Parts A_{56} and B_{30} are often used by SET for other components. Though none is currently in stock, both parts are readily available from local suppliers.

2) Labour - Labour is paid on a piece-rate basis. There is sufficient spare capacity on each of processes R, N and V to enable production of the ZV_{10}.

3) Overheads - These are split between "specific" (those overheads identifiable as relating to the finished component itself), and "general" (other allocated overheads). SET's overall general overheads will not alter as a result of producing the ZV_{10}.

CHAPTER

NINE

CHAPTER NINE

SEARCH BEHAVIOUR IN A LESS WELL STRUCTURED ENVIRONMENT

INTRODUCTION

The information search behaviour described in the chapters so far, has been investigated with particular emphasis on search processes in experimental product or service markets that are homogeneous in all aspects except price. The experiments conducted have been highly structured, in that they have been characterised by a single, clear objective, with participants being fully aware in advance of the type and form of all additional information available, and being confronted by a simple two-way choice mechanism - search again or buy.

While the findings from these experiments are important in themselves, they may also lend insights to information search behaviour in decision situations that are less well structured. This chapter describes an experiment that is designed to explore individuals' information search behaviour in a more complex decision environment

- a competitive tender. The experiment is an exploratory one, since in spite of the number of developments that have occurred in academic management over the past few decades (for example, the information "economics" revolution, agency and contingency theories etc.), there has been a surprising lack of attention given to the issue of how managers search and use information for business decisions. Partly, this absence may be due to there being no clearly defined methodology for researching the complexities of business decisions. Nevertheless, the growing number of MBA courses demanding a more integrated approach to the teaching of accounting, economics, business policy and strategic management, may eventually force this situation to be changed.

This chapter describes the results of conducting a relatively unstructured business decision game; the purposes of the description being twofold. First, to share the initial understanding that the experiment has given as to how information for business decisions is searched and used. Second, to highlight and discuss a number of the methodological issues that were encountered during the study.

Whilst information is clearly needed at a number of levels in the management of the firm, the primary concern here was to understand the search for and use of information for strategic decisions. The business context adopted to explore this was a competitive tender. In the business world competitive tendering has long been commonplace for large one-off contracts; for example, the building of part of a chemical or steel plant. In recent years, competitive tendering has spread from the private to the public sector, where a number of organisations have assigned parts of their activities to outside contractors; for example, hospital cleaning services and local authority waste collection (see Domberger, 1989, for a discussion of the potential efficiency gains achievable by subjecting public sector activities to competitive tendering). Generally, situations of this type are characterised by incompleteness of information and uncertainty about competitors' actions. Decision makers are faced with two important issues, therefore: choosing an appropriate problem solving strategy, and searching for further, relevant information. As will be discussed below, these should not be seen as two independent issues.

In the next section, a general model of decision making is presented as a framework, and three hypotheses are developed from the existing literature on information search and use. While most of this previous work has been developed within the confines of highly structured tasks, it suggests one relevant hypothesis that warrants testing in more complex tasks such as a competitive tender. The general literature on decision making and information use suggests two further hypotheses concerning information search in a business decision context. Following this review, the experimental procedure is described, and methods of analysis together with the results of the experiment are then presented and discussed in detail.

BACKGROUND AND EXPERIMENTAL HYPOTHESES

Most text books on management accounting and control include at least one chapter devoted to analysing relevant costs for decision making, and incorporate some decision making model as a framework for general consideration. Figure 9:1, reproduced from Arnold and Hope (1990, p 12), is typical. Two important properties implicit in such search models are first, that the decision is presented as following a logical, step-by-step flow from conception to implementation and review, and second, that each step in the process is well defined and straightforward. This is certainly true for the highly structured price search studies discussed earlier. In a competitive tender, however, working through the model is a less clear-cut procedure. In particular, the collection and analysis of data about alternative courses of action (step 2) may involve a search into the unknown, as the type and form of information available may not be known at the outset, and, further, neither may be the total number and type of alternatives open to management.

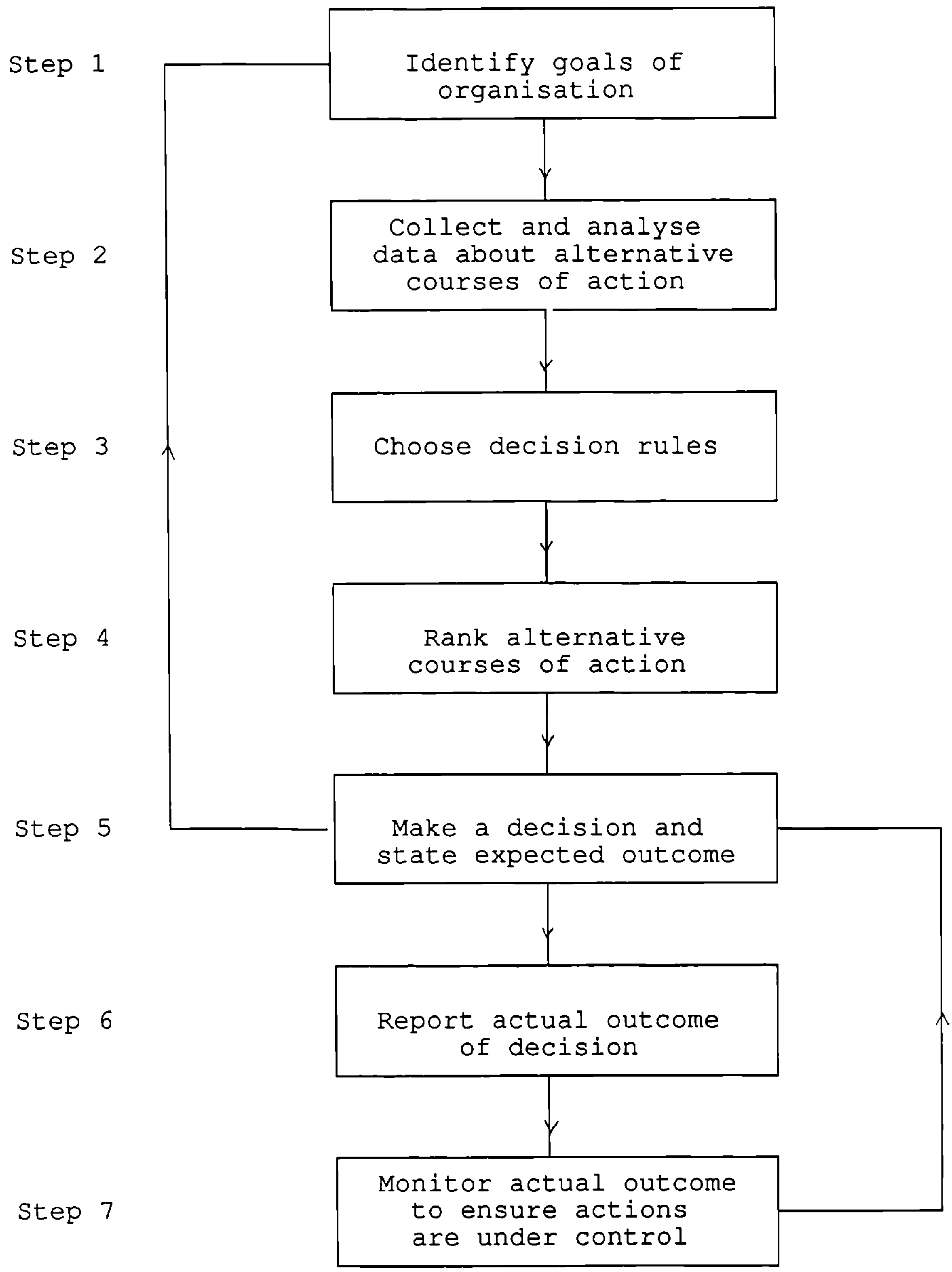

Figure 9:1 ... A framework for managerial planning, decision making and control (including two feedback loops)

Although the existing literature on information search and use has been concerned primarily with highly structured situations (as per chapters 3 to 6), it does provide some general guidelines for the analysis of the unstructured experiment described here. A common, relevant finding of these studies (as well as other studies concerned with decisions across two or more parameters, such as a product's price, size and location; for example, Payne, 1976; Shields, 1980) is that the problem solving strategy adopted by a participant governs to some extent the subsequent information search procedure. For instance, in the price search studies discussed earlier, Hey suggested six rules of thumb that might be used in considering each price quote received. The simplest such rule, Rule B, (1982, p73) stated:

> "have at least 2 searches; stop if a price quote is received larger than the previous quote".

Adoption of a Rule B problem solving strategy unambiguously determines how long to keep searching. Accordingly, the first of the information search hypotheses that will guide the analysis of the experiment considered here is as follows:

H1 - Information searched will be influenced by the problem solving strategies adopted by participants concerning the pricing of the tender and the overcoming of the capacity constraint.

As the business problem considered in this chapter is relatively unstructured, hypotheses derived from the wider decision making and information use literatures should prove useful in conducting the present analysis. One of the major developments in decision theory post war was Simon's (eg. 1957) recognition that in complex decision situations individuals may act in a boundedly rational way, as discussed in Chapter 1. In particular, they may satisfice rather than optimise because of the costs (in the most general sense) involved in gathering and evaluating information. From this view of decision making the second guiding hypothesis regarding information search and use is derived:

H2 - Where it is possible from the given information, participants will choose to accept given costs or estimate costs rather than explicitly search for them.

A similar but distinct view of decision making proposed by Lindblom (1959, 1979) argues that, contrary to the usual assumptions inherent in classical decision theory (for instance, expected utility theory), decision makers in practice have difficulties in isolating how a problem should be defined, how it should be approached, how courses of action should be identified, and how actions should be evaluated, chosen and implemented.

In terms of the decision analysed in this study, the pricing of a competitive tender by an outside contractor would normally involve the contractor requesting certain information from the "purchaser", and searching his own organisation's information system for data relevant to the estimation of costs. As the contract will often involve new and unique characteristics of operation for a contractor, the information available may have to be substantially adjusted to reflect these characteristics. Thus, the total number of dimensions of information required for a complete analysis of the problem will not necessarily be apparent from the outset. At each stage the information acquired and the conclusions reached might feed into other stages of the analysis. It may even lead the decision maker to re-think his objective function. Such feedback loops are familiar components of conceptual models of judgement (see, for example, Hogarth 1987, as reproduced in Chapter 7). This "muddling through" view of decision making gives rise to the third and final research hypothesis:

H3 - Information search will not flow directly from an initial identification of the objectives to be met.

THE EXPERIMENT

Task

The experimental instrument used to analyse information search and use within a business context was a modified version of Moon's (1988) incident process case on competitive tendering and under-capacity. Each participant represented an identical manufacturer of garden gnomes with the opportunity to tender for a special offer, and, therefore, make some use of existing spare production capacity. A block order of 300 gnomes was required by GGC (Galactic Gnome Corporation) for export to the Far East, the gnomes having to be ready for delivery within 3 months.

Procedure

A profit and loss account for the year just ended, together with some brief supporting notes, was given to each participant at the outset, as a reflection of information that would be readily available to the manager(s) responsible for the decision. Participants were also given a problem sheet containing details of the opportunity facing the company to utilise the existing spare capacity. The handouts are reproduced in Appendix 9:1. This background information enabled a preliminary, ballpark estimate of the costs involved in pursuing the tender. The intention was to provide sufficient information to make a start, but not enough to enable an easy conclusion.

Participants were informed that further information could be searched. This raised the difficult issue of how to provide further information; the adopted solution needed both to approximate reality and be experimentally robust. From the latter viewpoint an interactive computer program would have been ideal, as it would have ensured consistency of information provision. A menu driven databank was clearly unacceptable from a reality viewpoint, however, as it would have "falsely" directed the search process. Other forms of computerised databank were also inappropriate because of the possibly wide ranging style and type of information requests.

Consequently, the approach adopted was one where the author acted as the available dataset. While this has the benefit of being able to decode similar questions with different phrasings, it does have the shortcoming that it could lead to potential inconsistencies in the provision of information. This was overcome, as far as possible, by running the case a large number of times before the formal experimental run was conducted. These pre-experimental runs highlighted the questions which were commonly asked, and, for these, standard written answers were prepared (for example, the cost of manufacturing a mould, the overtime rate etc.). Other questions were treated as being equally admissible, and answered as considered most appropriate, the answers given then being carefully recorded to ensure consistency in the event of another participant asking the same question. A fixed fee of A$200 was charged for each and every information request, in order to render the information costly. This is a relatively unsatisfactory part of the experimental process, but there seems to be no obvious alternative solution.

An additional associated problem is that the individual sessions could not be run in parallel, thereby risking subjects discussing the case with those still to participate, and colluding. The random element embedded within the incentive scheme (see below) alleviated the latter risk, while, regarding the former risk, subjects were specifically requested not to discuss the case until after all sessions had been completed.

Participants were informed that they were competing against four other similar companies. They were allowed a maximum of 45 minutes to decide on the action they wished to take and to submit a sealed tender if desired. Again, this time limit was set following the experience of several pre-experimental trials. The experiment was run in separate, individual sessions in the presence of the author. Subjects were repeatedly encouraged to think aloud, and their verbal protocols recorded along with all information requests and responses.

Subjects

Several pre-experimental trial runs were undertaken involving, at various times, undergraduates, MBA students and corporate executives. While, in theory, the latter are likely to be more familiar with the characteristics of competitive tenders, and so might be preferable subjects, the trials revealed no systematic differences in information search, use, and price setting behaviour across the different types of subject. The participants in the current experiment, the last in a long series, were 20 undergraduate students majoring in Economics and Accounting at the University of Sydney, all of whom had previously taken and passed courses in both financial and management accounting.

As an incentive each subject was paid a fixed fee of A$5. Following all 20 experimental runs, the sealed bids were randomly divided into four equal groups. The sealed bids were then opened, and within each group, the contract awarded to the company submitting the lowest priced tender (there are no quality differences). This produced four "winners" each of whom was paid a bonus in addition to the fixed fee. This bonus was at the rate of A$1 for every A$200 profit made from the contract (after deducting the cost of information requests), with a minimum bonus of zero, and, at least theoretically, no upper limit. Structuring the incentive scheme in this way motivated participants to take the experiment seriously, minimised the risks of collusion, and maintained realism in that it was a reasonable model of the actual direct benefits of a successful tender.

RESULTS AND ANALYSIS

The basic data to be used to derive the results of this paper are the direct recording of specific information requests and the verbal protocols. A primary problem was ensuring that the output of participants was interpreted consistently. One of the main purposes of the analysis was to establish the type and sequence of information searched and used. As individual participants' train of thought often stopped and started and meandered from objectives to information requirements, it was not always clear exactly which pieces of information were being sought and used at any given time. Accordingly, an iterative process was adopted whereby the recorded protocols were monitored carefully, thus enabling an initial analysis of the information search and use. This analysis was then explored further by listening again to the protocols, and refining, until eventually a final analysis was reached as complete and precise as possible.

The results and findings are presented in three sections, focussing in turn on the choice of strategy, flows of information search, and the three research hypotheses.

The Choice of Strategy

The decision problem facing the participants necessitated their making a number of strategic choices - whether to tender, how to overcome the capacity constraint, and what pricing strategy to adopt. These three choices are investigated below.

i) **Tender Choice**: ... despite the possibility of not submitting a tender, all participants decided to do so. This is not surprising given that to win one of the bonus payoffs, a participant had to have submitted the lowest tender within his grouping. This drive towards competing also effectively precluded participants from giving much consideration to any alternative uses they might choose to make of the available spare capacity. Thus, although the problem states,

> "... as director of the company you are now considering alternative ways of utilising the existing spare capacity ... decide on the action you wish to take."

any action other than tendering was effectively taken as not competing in the game. Only two subjects specifically considered alternative uses, and one of them, subject 3, made no use of the information acquired due to insufficient time. Subject 8 raised the issue early on:

> " ... I think I'm also going to be assuming in all this that I can't use the excess capacity for anything else ... although it says that `the company now trades from significantly larger premises' ... looks like I possibly could increase the production because I've still got 20% excess capacity ... so probably take into account other ways of utilising spare capacity. I guess a possible question that I might consider asking would be: do I have any information on any other projects I could use? ... I'm not going to ask that question yet ... though I may later"

The subject later requested information on alternative items that might be manufactured using the existing spare capacity. This led to an allowance being made for an extra opportunity cost (though it was incorrectly calculated).

These instances apart, then, the strategic options are basically restricted to a choice of the methods used for dealing with the capacity constraint in meeting the GGC order, and to the choice of pricing strategy. This raises the issue of how to motivate subjects to actively and realistically participate in an experiment without directing their basic strategic choices.

ii) **Capacity Constraints**: ... working at full capacity would enable 250 additional gnomes to be produced in the ten week period. There are three alternative ways of creating the production needed for the extra

50 gnomes required for the GGC contract. Normal output could be reduced (13 subjects), incurring a consequent loss in contribution (and risking an additional loss in goodwill as existing customers may decide to purchase elsewhere), normal stock levels could be built-up before the start of the 10 week special production period (1 subject), risking a subsequent fall in activity levels in the event of the tender being unsuccessful, or capacity could be increased by hiring extra employees or asking existing employees to work overtime (1 subject). Some subjects considered more than one alternative, while five subjects effectively ignored the whole capacity problem. Table 9:1 discloses the capacity strategies considered and adopted by all 20 participants.

iii) **Price Strategy**: ... Table 9:1 also indicates the tender prices submitted by subjects, together with the average cost per gnome of the tender (as perceived by each subject) and the amount charged for information requests. All subjects first calculated the costs associated with making the extra 300 gnomes, and then added a "suitable" profit margin. Prices submitted varied from A$220.50 to A$310.00 (μ = 270.27, σ = 27.03), with profit margins varying from a maximum of 35.9% to a marginal loss. This reflects the substantial

TABLE 9:1

SUMMARY OF TENDERS SUBMITTED

Subject/ Group		Tender price	Average cost (*)	Inf'n costs	Tender margin (**)	Capacity Strategy adopted	others considered
		A$ per gnome	A$ per gnome	A$	%		
1	B	256.00	212.40	400	16.5	R	S
2	**A**	**277.49**	269.61	600	2.1	-	-
3	D	230.00	214.40	1,000	5.3	R	-
4	C	283.75	236.44	400	16.2	R	-
5	A	297.50	208.34	600	29.3	S	-
6	B	263.29	239.11	1,000	7.9	R	S O
7	D	296.67	237.42	800	19.1	R	-
8	B	306.67	299.00	400	2.1	R	-
9	C	270.00	218.01	800	18.3	O	-
10	**B**	**244.67**	227.00	200	6.9	-	-
11	C	310.00	310.00	200	(0.2)	R	-
12	D	279.08	253.71	200	8.9	R	-
13	A	295.00	294.92	200	(0.2)	R	-
14	**C**	**240.00**	227.66	1,000	3.8	R	O
15	C	241.38	211.40	600	11.6	R	-
16	A	300.00	192.18	-	35.9	R	-
17	**D**	**220.50**	210.80	400	3.8	-	-
18	B	255.00	206.93	800	17.8	-	-
19	A	288.46	262.84	400	8.4	R	S O
20	D	250.00	231.90	-	7.2	-	-

Entries in bold represent winning tenders

(*) as per the subject's data, excluding information costs
(**) as per the subject's data, including information costs

Capacity Strategies - R = reduce normal output
S = stockpile
O = work overtime

differences in price strategies adopted. For instance, consider the following protocol extracts:

> [subject 16] " ... Last year we sold our gnomes for a price of A$300 each ... but this may need to be increased as it is a special order."

> [subject 14] " ... I should at least break even ... but why would you go into business to break even? Garbage! I wouldn't ... but then this could be one of those types of project that opens the door ... but I don't know ... I still want to make some money out of this, but I mean if it's going to open the door, I could accept less."

The former subject eventually settled on the existing A$300 sales price, while the latter applied half of last year's average net margin to the incremental cost of the order, arriving at a rounded price of A$240. Only the lower tenders, however, were likely to win the GGC order, the average winning bid being A$245.67. Bonus payments to winners were A$36 for subject 2 and A$1 for subject 14, while winning subjects 10 and 17 both made losses on the order and so received no bonus. The bonus calculations were based on the most accurate available information for labour rates, extra fixed costs etc., but retained subjects' own assumptions concerning, for example, discounts and the number of moulds (if greater than three).

Flows of Information Search

As one of the primary purposes of this experiment is to start to understand how information to deal with an ill-defined problem is accessed, a classification of the ways in which information is searched is needed. Figure 9:2 displays an information search model, derived from the iterative analysis of participants' responses to the simulation.

The flow diagram starts from the idea that a cost element or piece of data is somehow highlighted and then evaluated in terms of its relevance for the decision at hand. The data might be implicitly evaluated and discarded without becoming part of the protocols. This is, of course, a problem affecting all research based on verbal protocols - the non-verbalisation of part of the process. Alternatively, a piece of data could be highlighted, explicitly evaluated, but then discarded for its lack of relevance. This is traced as information search route H. For example,

> [subject 18; discussing advertising] " ... well, advertising's going to remain the same, because I'm going to be selling straight to GGC ... so, there's no need for me to advertise."

Where a piece of data has been considered relevant, the flow diagram continues by considering whether its need was signalled within the given information, whether there is sufficient information to calculate its relevant cost,

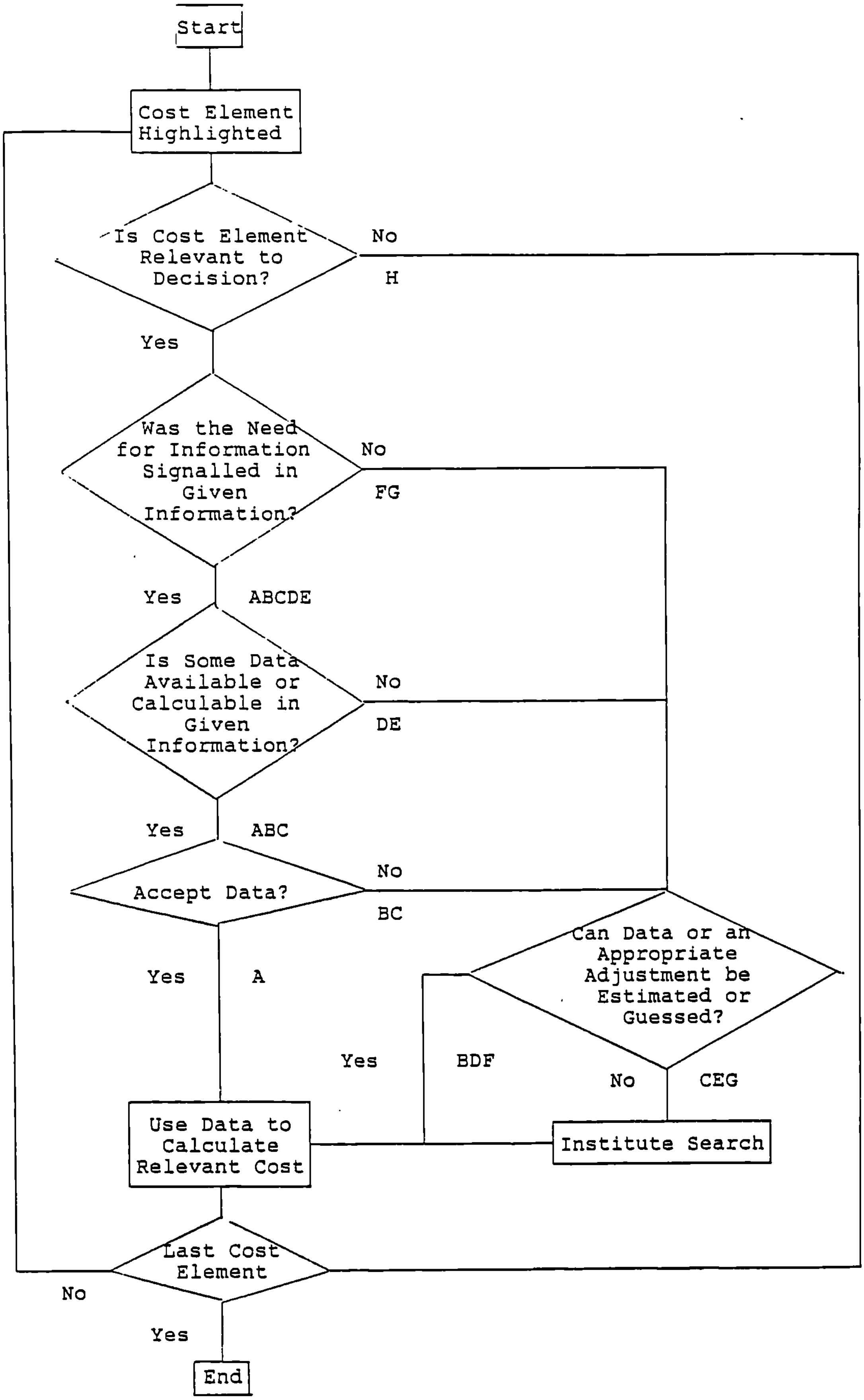

Figure 9:2 ... An Information Search Flow-chart

whether to accept that information and, finally, whether to estimate or search. As examples, consider the following two extracts that illustrate respectively routes B and E:

> [subject 4; discussing electricity] " ... we're increasing production, so we're bound to need more electricity ... A$23,600 last year and we made 4,800 gnomes ... so that's A$4.92, say about A$5 per gnome to add in ... but it probably won't go up that much ... so, I'm going to say an extra A$3 per gnome."

> [subject 12; discussing the cost of moulds] " ... we wouldn't need to have standard replacement moulds bought-in from outside suppliers; we would have to manufacture the moulds ... but I don't know how much they cost ... OK, how much would the moulds cost to manufacture?"

The particular "routes" used by the subjects to gather the information they needed to arrive at a tender bid are summarised in Table 9:2. It is clear from the results presented in the table that certain pieces of information were acquired in the same way by all of the participants (crates and paints), while other types (capacity of moulds) were acquired via different routes. Explanations for these similarities and differences are explored in the next section as part of the discussion of the three guiding hypotheses outlined earlier.

TABLE 9:2

INFORMATION ACQUISITION CHOICE BY SUBJECT

Category of Information	Subject number																			
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Materials																				
Stonemix (including Discounts)	A	A	A	C	C	C	A	A	C	A	A	A	A	A	A	A	A	C	A	A
Crates and Paints	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
Moulds (cost)	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	D	E	E	E	-
Moulds (capacity)	E	F	E	F	E	E	E	F	E	F	F	F	F	E	E	-	F	E	E	-
Production Labour																				
Normal rates	A	C	A	A	A	C	C	A	A	A	A	A	A	A	A	A	A	A	A	A
Overtime rates	-	-	-	-	-	F	-	-	G	-	-	-	-	G	-	-	-	-	-	-
Overheads																				
General overhead charge	H	A	H	H	B	H	H	H	H	H	H	A	H	H	H	H	H	H	H	A
Interest charge (*)	-	-	-	-	F	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Depreciation / New machinery (*)	-	A	C	-	-	-	-	-	-	-	-	A	A	A	C	-	C	-	A	-
Electricity consumption (*)	-	-	-	B	-	-	C/A	-	-	-	-	-	-	C	-	-	-	-	A	-
Extra fixed costs (*)	-	-	C	-	-	-	-	-	-	-	-	-	-	C	-	B	-	C	A	-
Opportunity Costs																				
Contribution lost from reducing steady sales	-	-	H	F	-	F	H	F	-	-	F	-	F	F	H	F	-	-	F	-
Contribution lost from not increasing normal sales by reducing price	-	-	G	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Contribution lost from not utilising spare capacity in other ways	-	-	-	-	-	-	-	G	-	-	-	-	-	-	-	-	-	-	-	-

(*) only included where some specific action taken; otherwise see general overhead charge

Information Search Hypotheses

H1: (Influence of Strategy on Search) ... As discussed above, differences occurred in the subjects' strategy choice for dealing with the capacity constraint. Of the 15 subjects that addressed the issue, 13 reduced normal output, one stockpiled, and one required employees to work overtime. The first method would require some allowance to be made in costings for the subsequent loss of normal contribution. Accordingly, this was done by eight subjects, all using route F in the flow diagram to arrive at a suitable estimate. Three subjects considered the possibility of losing contribution on the normal output reduced, but concluded that no allowance was necessary. For example,

> [subject 7] " ... well, if we cut production, during the ten weeks, of five normal gnomes per week, it wouldn't be a great loss ... because, you can always make it up after these ten weeks by operating at over 80%."

The other two subjects who reduced normal output did not explicitly explore the lost contribution. Subject 5 adopted a stockpiling strategy and again used route F to estimate an interest cost to compensate. The final alternative - working overtime - was adopted by subject 9 and resulted in explicit search for the overtime rate (route G).

The choice of problem solving strategy, then, has clear implications for the type of information required and in some circumstances this will lead to explicit information search.

H2: (Acceptance or Estimation in Preference to Search)

... This hypothesis is concerned with whether subjects are reluctant to undertake search in circumstances where some other alternative exists. All subjects assumed (correctly) that the materials cost was wholly variable. One area of difference, though, involved their treatment of discounts on stonemix. Subjects might be expected to search for as high a discount as possible on the extra stonemix required for the order. The problem is confounded, however, by the presence of some initial information on discounts received during the previous year, and this seems to have led some subjects to simply accept the given data and pro-rata it across all purchases, thus arriving at an assumed discount rate of 83 cents per gnome, rather than the maximum available rate of A$6 per gnome. Five subjects explicitly searched (route C), while seven chose to estimate, adopting the pro-rata solution above (route A). Surprisingly, eight subjects ignored discounts completely.

In terms of labour costs, the given background information enables last year's average hourly labour rate to be calculated at A$7. In any organisation, let alone one that has experienced such rapid growth, one would not normally expect the average rate to equate with the current rate due to the effect of pay rises. For decision making purposes, the relevant cost is the current cost. Explicit search would have revealed this to be A$8 per hour. In the event, only three subjects specifically requested the current rate (route C), the others all using the average, route A rate to arrive at a final figure for labour charges. Here, the reluctance to search probably reflects the fact that a solution, albeit an inaccurate one, is readily calculable. The following interchange was typical:

> [subject 11 S] "Is the wage rate given to us?"
> [author A] "You can ask me for it, and I can tell you."
> [S] "No, no, I just wondered. There are Production Wages A$672,000 ... that relates to?"
> [A] "That relates to producing the gnomes."
> [S] "About 4,800 gnomes this year."

The subject then proceeded to calculate the labour cost per gnome and per hour.

Considering the treatment of other costs, the case signals the importance of moulds, but contains insufficient information to enable the two key questions - how much and how many - to be answered. Accordingly, all but two of the subjects followed route E to explicitly request the cost of manufacturing a mould. Ten subjects additionally requested information about the capacity of moulds (route E again), while the others guessed (route F), estimates ranging from 1 mould (four subjects) to an extreme of 300 (one subject).

Regarding other overheads, subjects needed to assess which items were fixed costs and which were variable. Mostly, overheads were regarded as fixed, and, therefore, irrelevant for the decision at hand, but there were some, specific exceptions to this. For example, eight subjects considered that depreciation would increase if the contract was gained. Five of the eight used the existing data to derive an incremental depreciation charge (route A), while the other three searched for further specific information (route C). Four subjects were out of line with the others in their decision to include an allocation of all overheads in the cost structure for the GGC contract. In each case, their calculations were based on several cost behaviour assumptions for individual cost elements, but made no use of explicit search.

Overall, this section offers evidence in support of hypothesis H2 that subjects only explicitly search for information when there is no viable alternative.

H3: (Muddling Through) ... In the current study it was apparent that most subjects "muddled through" the task to some extent. For instance, the protocol extract below illustrates how the capacity constraint was discovered only after considering the availability and amount of discounts.

> [subject 5] " ... 20% discount on stonemix, A$6 per gnome. Discounts last year A$4,000 ... but they must have produced more than that ... (reads note 1 of the background information) ... 100 per week ... (long pause) ... 80% capacity means they can only make an extra 25 per week. So, they've got ten weeks, that's 250, and they need 300."

A second "muddling through" effect is where the evaluation of a particular set of alternatives might lead to other alternatives being searched without complete resolution of the initial area. Subject 2 moved to and from mould costs a number of times considering several other items in the interim:

> " ... I've got to put in an arbitrary price on what I think the mould ... these moulds ... will cost. But that's a question I could ask you is it?"
> ... ["yes"]
>
> (subject then spent 4 minutes considering extra information that might be available, whether she needed to be totally accurate, and profit margins) then:
>
> " ... but then I face the problem of these moulds; I don't know how much it will cost ... "
>
> (3 minutes attempting calculations of mould costs based on existing data, and considering price strategy again):
>
> "OK. I'll ask you. How much will a mould cost?"
>
> (The next 9 minutes were spent considering the depreciation policy for moulds, explicitly searching for the labour rate, establishing that she could discover how many moulds were needed to fulfil the contract by asking, but, finally, choosing to estimate):

> "I've just come to a very intuitive figure ... because I don't know exactly, I'm just taking what I suppose you could almost say is a number out of the air ... I'm assuming I need 8 or 9 moulds. I've put down the figure 8, to be lower."

Thus, the resolution of the problem and the search for information do not seem to flow clearly and directly from an initial identification of objectives.

SUMMARY

This chapter has tried to extend the work on the search behaviour of individuals reported in previous chapters, by developing an initial understanding of how accounting information is searched and used for a strategic decision. Somewhat surprisingly, there is currently an absence of literature addressing this topic. Whilst this might be surprising from a user perspective, it is not so when a research perspective is adopted. The study has highlighted a number of methodological issues that condition the success of researching the area. In attempting to gain an initial understanding of information search and use in a business context, a competitive tender experiment was analysed.

Several general conclusions arise from the study. In particular, two factors influence the specific type and amount of information search - choices concerning the problem solving strategy, and the viability of accepting given information about a cost element or estimating.

These results have important ramifications for the design of appropriate information systems. Given that a firm will face many different strategic choices throughout its life, the information system should be flexible in the type of information that can be accessed, and should not be viewed as providing information that is applicable for all purposes. Further, the findings suggest a need for systems to be designed so that they do not overly lead the information search process.

These conclusions, however, must be considered in conjunction with the inevitable constraint under which all experimental research must operate; classroom exercises cannot perfectly model the real world. While the incentive scheme used motivated participants to take the simulation seriously, its one-sided nature (profits are rewarded, but losses are not penalised) may have driven tender offers lower than they would otherwise have been. Most participants submitted tenders at a discount (sometimes substantial) from the normal selling price, creating little extra profit for all their extra effort (at least in the short-term). Ethical considerations, however, prevent the running of experiments that might result in subjects losing their own money. Although, this may be unrealistic, however, the choice of margin is not one that explicit information search can help anyway.

The experiment has also highlighted a number of other methodological issues that need to be considered when researching the search for and use of accounting information for strategic decisions. Particular problems that need to be addressed, in addition to the design of incentive scheme discussed above, include ensuring full and complete verbalisation of subjects' decision processes, finding an appropriate and consistent medium for the provision of additional information, and adopting a rich and incisive method for the analysis of data. A further issue in the current experiment concerns the lack of feedback given to subjects. This is a one-off simulation and so there is no learning curve effect, and subjects do not necessarily know whether they are approaching the task correctly. The only formal feedback is the response to questions asked. This limitation could only be overcome by running repeated experiments concerned with similar tasks.

Overall, then, the chapter informs as to the viability of conducting relatively unstructured business simulations, and helps approach a more complete understanding of problem solving strategy and information search, at least in competitive tendering contexts.

APPENDIX 9:1

This appendix reproduces the initial background information and problem sheet given to participants.

BACKGROUND INFORMATION

You are the director of a company that manufactures and sells very high quality garden gnomes of various shapes and sizes. The enterprise was started just over four years ago in a small garden shed, but since that time, growth has been rapid - profits exceeding A$100,000 for the first time last year - and the company now trades from significantly larger premises.

The profit and loss account for the year-ended 31 August 1990 is shown below.

	A$'000	A$'000	Notes
Sales		1,440.0	1
Cost of Goods Sold			
- Materials	339.8		2
- Production Wages	672.0		3
- Depreciation	41.0		4
		(1,052.8)	
Gross Profit		387.2	
Selling & Distribution Costs			
- Advertising	34.0		
- Export Expenditure	20.0		5
		(54.0)	
Administrative Costs			
- Management Salaries	121.6		
- Rent & Insurance	48.8		
- Electricity	23.6		
- Sundry Expenditure	19.3		
- Discounts on Stonemix	(4.0)		
		(209.3)	
Net Profit (before tax)		123.9	

NOTES

1. 4,800 gnomes were produced and sold during the year at a steady rate of 100 per week (there are 4 weeks annual holiday when the factory is closed). At this level of production, which will continue for the foreseeable future, the company is operating at 80% of its capacity.

2. Materials consisted of the following :

	A$'000	
Stonemix	144.0	2 large bags per gnome, at A$15 per bag
Wooden crates and other packing materials	120.0	A$25 per gnome
Paints	72.0	A$15 per gnome
Moulds	3.8	
	339.8	

While the company has the equipment and the expertise to manufacture the moulds themselves, none were made internally last year. The A$3,800 relates to standard replacement moulds bought-in from outside suppliers.

3. Labour is paid on a piece-rate basis. The standard labour time required to complete a gnome is 20 hours comprising :

Mixing and moulding		5
Tidying-up and inspection (after setting)		4
Painting :	first coat	3
	second coat	5
Touching-up		2
Packing		1
		20

4. Depreciation mainly relates to heavy lifting gear needed to move the set gnomes around the factory.

5. A$20,000 was spent during the year attempting to break into the export market. The campaign was not successful, and so the costs have been written off.

THE PROBLEM

It is now early September 1990, and as director of the company you are considering alternative ways of utilising the existing spare capacity.

You have heard that the Galactic Gnome Corporation (GGC) wishes to purchase several gnomes made to a certain specification with a view to exporting them to the Far East. Further investigation reveals that GGC actually require 300 identical gnomes for a one-off order. The firms invited to tender have been selected by GGC because they all offer the required quality of product.

The materials input and the labour time necessary for each gnome is the same as for those currently being manufactured by your company. Before production can commence, however, new moulds will have to be made, due to the somewhat unusual nature of the required stance of each gnome. For similar reasons, it is not possible to buy-in these moulds from outside.

All the gnomes must be ready for collection by GGC within 3 months. After allowing 2 weeks for calculating costs and prices, and submitting tenders, and 1 week for the preparation of moulds, that leaves 10 weeks for actual production.

GGC has not yet decided which company will win this prestigious order, but all tenders must be received by last post today.

REQUIRED

Decide on the action you wish to take. Quotations for the GGC order must be submitted in a sealed envelope to the instructor by the end of the session.

Further information is available from the instructor at a cost of AS200 per question.

PAYOFF

You are competing against four other, similar companies. The order will be given to the company submitting the lowest priced tender.

You will be paid a A$5 fixed fee for your participation. In addition, if you win the GGC order, you will receive a bonus payment of A$1 for every A$200 total contribution you make on the order.

CHAPTER

TEN

CHAPTER TEN

CONCLUSIONS

INTRODUCTION

This thesis has been concerned with investigating the information search behaviour of individuals required to make decisions in experimental markets. The majority of the work presented has had a particular focus on consumer product or service markets that are homogeneous in all aspects except price, though the study reported in Chapter 9 attempted to extend this focus to a wider, and more general decision making context.

In the first part of this concluding section, the contents and main findings of the thesis are summarised, chapter by chapter. Following this, some of the main methodological issues associated with running research experiments of the type recorded here are explored, while, finally, some suggestions are made for future research studies in the area.

SUMMARY OF WORK DONE AND ACHIEVEMENTS

As stated above, the primary concern of this thesis has been to explore information search behaviour in markets characterised by price dispersion, but retaining equality in all other attributes. Chapter 2 discussed the empirical evidence concerning the existence of such markets, and demonstrated price dispersion to be a widespread phenomenon; the highest price for which a specified item can be purchased, within a relatively small geographical area, being more than double the lowest price in about one-half of the cases surveyed, and more than six times the lowest price in one case (the styling brush).

Given this sometimes substantial level of price dispersion, there is a potential benefit to be gained from searching for a lower price. Thus, when making purchasing decisions, it is in the interests of individual consumers as well as managers within any organisation to attempt to take advantage of this potential benefit (particularly, in the latter case, where incentive schemes may operate to reward cost savings). In chapter 3 a formal, generalised search model was derived, by comparing the expected likelihood of finding a progressively lower price with the costs of search. The optimal strategy, when a buyer knows the cost of search and the general distribution of prices, though not their specific location, is to keep searching until a quote is received less than or equal to a given reservation price. This quote should then be accepted. The reservation price, R, is calculated from the expression below, where F(.) is the cumulative distribution function of the price distribution, and c is the (constant) unit search cost:

$$\int_{-\infty}^{R} F(x)\,dx = c$$

Although this formulation appears simple, applying it to calculate a reservation price necessitates evaluating a non-trivial integral. A new, alternative derivation enabling a solution to be found from tables, was also presented in chapter 3, though this method is limited to price distributions that are normal.

Chapter 4 reviewed the experimental studies that have sought to investigate whether individuals behave consistently with a reservation price model. While this has generally been found to be the case, the high computational demands of the reservation price model suggest that individuals were more likely to be employing some high performing heuristics or reasonable rules of thumb. The work of Hey (1981, 1982) led to the formulation of six such heuristics, though he made no distinction between rules that might be used in different prior knowledge conditions.

This theme was continued and developed in the new experiments described and analysed in chapters 5 and 6. In addition to the alternative states of prior knowledge about the overall price distribution that are prescribed in both the theoretical and experimental literatures (full knowledge and no knowledge), the more realistic partial knowledge setting was introduced. In this condition, a searcher starts from a knowledge base comprised of two "guide" prices taken (randomly) from the overall price distribution, though he does not know their representativeness nor their specific location. These guide prices may then help in the searcher's evaluation of subsequent, actual quotes received.

The studies uncovered several new search rules: four in the no knowledge condition, five in the full knowledge condition (including two "expert" rules), and six in the partial knowledge condition, sub-divided into two simple, two intermediate and two complex rules. All rules were evaluated in terms of their consistency with observed behaviour, and their performance in comparison with the optimal model above; the latter being measured by their average extra expenditure over a very large number of simulated purchases. The "best" heuristics, in terms of performance and plausibility, in each knowledge condition are reproduced below:

No Knowledge .... Rule J ... (2.4% performance)

Keep searching until the total search cost, nc, > 7.5% min p_i (where n is the number of searches so far).

Partial Knowledge ... Rule T ... (1.6% performance)

Keep searching until a price, p, is located such that $p \leq 90\%\mu$, but with a maximum search cost of $10\%\mu$, unless min $p_i > \mu + c$ (where μ is the average of all price data so far).

Full Knowledge ...... Rule K ... (1.1% performance)

Keep searching until a price is found at least one standard deviation (σ) below the mean, up to a maximum of σ/c searches (rounded).

As would be expected, the rules demonstrates the value of knowledge, in that the more complete the knowledge level, the better the possible performance; that is, the closer the average expected expenditure will be to an optimal search rule.

Chapter 7 introduced a conceptual model of judgement, and investigated human information processing constraints that might hinder the search process. In particular, one potential constraint - functional fixation - was highlighted and reviewed in some detail. Functional fixation relates to the difficulty commonly experienced in using a familiar object in a novel way. Regarding the price search studies, it was apparent that price quotes were often perceived simply as offers to sell at that price, rather than additionally as data with which to update knowledge of the distribution. Subjects acting in this way could be said to be functionally fixated. A new experiment concerning this phenomenon (though set in a different context), was described in chapter 8, some supporting evidence being found of the existence of functional fixation in accounting.

Finally, chapter 9 reported an experiment aimed at extending and developing the themes of the earlier chapters, to investigate information search behaviour in a wider, and less highly structured, decision making situation. Accordingly, the way in which subjects searched for and used accounting information in arriving at a competitive tender for a special contract was analysed. The main findings were that information search is closely linked to specific problem solving strategies adopted by individuals, and, inversely, to the ease with which estimation is possible. Often, though, the process is somewhat "muddled", rather than flowing from a clear, initial identification of the objectives to be met.

METHODOLOGICAL ISSUES

In conducting the four new research experiments, several methodological issues were confronted: the design of the experimental instrument, the design of the incentive scheme, the means for providing additional information, the means of recording decision processes, and the choice of subjects. Each of these issues is discussed briefly below.

i) Design of the Experimental Instrument

It is most important that the experimental task or case study be designed to meet the research objectives as exactly and as neutrally as possible. First, then, it should be sufficient to enable the investigation to proceed as required, but be free from information that might induce interference effects of some kind. Thus, for example, a case designed to test performance evaluation using accounting data, should not also contain non-accounting measures that might bias judgement. Second, the case should be neutral, in that a subject is not led down one solution path at the expense of other possible paths, because of the particular wording or emphasis of the case.

In addition, the instrument should be clear, understandable, and free from ambiguity. The time available to participants must be sufficient to enable the task to be satisfactorily completed, but this must be balanced by the possible fatigue effects associated with too lengthy a task. For instance, a weakness of the functional fixation study was that by the time subjects in the experimental group attempted the "experimental" task, they had been working on other tasks for almost one hour, and so were possibly becoming tired.

Obviously, as well as the points above, all the methodological issues below need to be addressed and resolved at the design stage.

ii) Design of the Incentive Scheme

For the results of any experimental study to be credible, there must be some evidence that subjects were motivated to approach the task seriously. Usually, this credibility is provided in the form of some monetary incentive, which might be a fixed fee just for participating, a variable fee related to performance, or a mixture of the two. The danger with the first approach is that as participants know they will be paid anyway, they may not be encouraged to concentrate throughout. Using a variable incentive structure, however, runs the risk that subjects may be de-motivated if they suffer a "bad" start, and feel they have little or no chance of improving their earnings position. A mixed incentive structure would seem to be the best compromise.

In the context of this thesis, one of the experiments, the functional fixation study, did not utilise any incentive structure (a design weakness). The other three new experiments, however, were all characterised by offering participants a fixed fee plus a bonus proportional to performance, though the bonus element in the first price search experiment (chapter 5) was probably a little too small in relation to the fixed element. Table 10:1 below summarises the incentive schemes used in the four experiments, and offers an assessment of them on a simple three point scale.

TABLE 10:1

SUMMARY OF INCENTIVE SCHEMES USED

Chapter/ Experiment		Time (mins)	-Incentive structure- Fixed Fee	Bonus payment Min	Max	Value
5	Price search - full/no knowledge	10	£1.00	£0.24	£0.65	Fair
6	Price search - partial knowledge	15	£2.00	-	£6.50	Good
8	Functional fixation	70	-	-	-	Poor
9	Competitive tendering	45	$5.00	-	$36.00	Fair

Note that the incentive for the competitive tendering experiment is only considered "fair", since although profits were rewarded, losses were not penalised. Ethical considerations, however, are always likely to prevent any alternatives that might involve subjects paying the experimenter, since biases favourable to the experimenter, and hindering subjects' performance, might be built into the design of the experimental instrument.

iii) Provision of Additional Information

Clearly, any experimental investigation into information search behaviour necessitates there being additional information that can be accessed by participants. Ideally, perhaps, the type and form (though not the content) of extra information available should be fully known to subjects from the outset, and further, exactly the same information set should be available to all subjects, at least within the same experimental group. This ideal is easy to arrange in highly structured tasks, such as the price search experiments, where the extra information simply comprises the next price quote recieved. It is also met in multi-dimensional decision making studies (for example, Payne, 1976) where the full amount of data available for each alternative under consideration is displayed form the outset, face-down on an information board. An individual's search behaviour is assessed by tracing which pieces of information are actually turned face-up. Here, though, as in any menu-driven information search system, the advantages gained in consistency and lack of ambiguity, must be off-set against the disadvantage that the imposed structure may actually lead the search and decision processes.

In a more complex, and less well structured task environment, such as the competitive tender described in chapter 9, the reverse may be true. Great care must be taken in the choice of method for providing additional information to avoid the possibility of ambiguity, misunderstanding and/or inconsistency. The solution adopted in the current study was to use a series of trial runs to establish those questions which were commonly asked, and then to prepare written responses to them. Other questions were also seen as admissible and answered as seemed most appropriate. In such cases, both the question and answer were carefully recorded, so that in the event of a similar question being asked by a different subject, the same answer could be given. This approach deals satisfactorily with the consistency issue where the experiment is run in series, but may be less effective where experimental runs are in parallel.

An additional drawback is that subjects may "game-play". They are aware that the instructor has more information, and so search may be motivated by trying to outsmart the instructor, rather than by some systematic needs-based analysis. However, no evidence was uncovered in the tendering study to suggest this to be a substantial factor.

iv) Recording of Search and Decision Processes

Essentially, there are two ways of assessing the search and decision processes adopted by individuals - the "information search" approach and the "verbal protocols" approach. The first of these simply records directly which pieces of information were searched, when, and in what order. Although this approach facilitates measurement, only limited subsequent analysis will be possible, since, as Payne, Braunstein and Carroll (1978, p 36) note:

> "One problem with the information search method is that it focuses exclusively on the subject's use of objective, external information. The method does not easily allow for insights into a decision maker's use of information stored in internal memory. Verbal protocols, on the other hand, can provide data on both external and internal search behaviour."

An analysis of verbal protocols, therefore, enables a closer understanding of the decision processes actually being adopted by the subjects.

Verbal protocols may be extracted either by asking the subject to think aloud during the experiment itself (concurrent data), or by asking him to summarise and explain his actions after completion of the experimental task (retrospective data). Which method is preferable has been the subject of much debate in the research literature (see, for example, Nisbett and Wilson, 1977; Ericsson and Simon, 1980), since while the timeliness of concurrent data may imply more objectivity, the requirement to verbalise may itself interfere with the decision process. Generally, though, concurrent data is usually considered superior (Bouwman, 1985). Accordingly, the three experiments in this thesis that utilise verbal protocols all adopt the "think aloud" approach.

There are, however, two further problems associated with using verbal protocols in research experiments. First, the protocols may be incomplete in so far as subjects choose not to fully verbalise their decision processes. There is some reported evidence that this may be linked to routines, or sub-routines, that carry a particularly high cognitive load (Johnson, 1964). Regular reminders to subjects to think aloud seems the only way to minimise this effect. Second, the procedure leads to the accumulation of a large amount of data that is obtrusive to collect, and does not lend itself easily to analysis, there being no well developed standard summary statistics applicable. Necessarily, then, conclusions may appear rather "loose". This issue is best resolved by combining concurrent protocols with directly recorded information search data, and ensuring the two link together in a plausible and consistent manner.

v) Choice of Subjects

The final methodological issue discussed here concerns the choice of subjects to participate in the experiment. Ideally, this choice should follow on directly from the design of the experimental instrument, as the level of expertise required may be specified, at least implicitly.

In the experiments reported in this thesis, all participants were undergraduate or honours students. For the price search studies, the requirement was simply for general consumers, the research objective being to uncover reasonable rules of thumb that might underlie search behaviour. No particular expertise was necessary, or even desirable, and so student subjects were an adequate choice. In the cases of the functional fixation and competitive tendering studies, however, subjects should have been ideally managers at an appropriate level within one or more organisations, perhaps cost accountants in the former case, and sales managers in the latter. Gaining access to a sufficiently large number of such personnel, however, presents obvious, logistical problems.

The limitation of using students is mitigated to some extent by the fact that the students who participated were all majoring in Accounting and Finance or Management Sciences and in each case, therefore, should have had a reasonably high level of relevant knowledge, if not the experience.

FUTURE RESEARCH DIRECTIONS

The research experiments documented in this thesis contribute significantly to the understanding of the information search behaviour of individuals in various decision contexts, and lay a foundation from which to investigate many, related research issues. Some of these issues that are of particular interest to the author are described below.

First, there is a need for further investigation into search behaviour in the highly structured price search setting. For example, the partial knowledge framework, as defined in chapter 6, has yet to receive attention in the theoretical search literature. It would be interesting to discover its properties in comparison with full knowledge models, and to see how these properties change as the number of initial guide prices is changed and, further, to examine the effect of having additional knowledge as to the reliability of the guide prices being reasonably representative.

Experimentally, there is a need for studies on search behaviour over time, seeking to discover whether subjects faced with a large number of consecutive purchase decisions, first learn specific strategies or rules that govern their search behaviour, and then modify and refine these rules in order to improve performance. For example, an improvement might be achieved by gradually migrating to one of the better performing, but more complex, rules described in chapters 5 and 6. Note that in the case of the partial knowledge setting, such a migration would lead to subjects learning to use all data to update knowledge of the overall distribution, thereby reducing the likelihood of functional fixation. Varying levels of feedback might also be used as a means of accelerating learning processes. Some measure of "ability" (for example, performance in a test designed to establish numeracy) would be important here, to discover whether more "able" subjects progress to and learn higher order search rules more quickly.

Finally, within the price search context, there is a clear need for empirical evidence reporting search behaviour actually observed in the real world. An appropriate research instrument might be some form of brief questionnaire that would be completed by customers at a suitable consumer product or service outlet (for example, a van hire firm - see chapter 2). The type of questions asked might include, for instance:

"Have you used this organisation before?"

"Did you contact any other organisations? ... If so, how many?"

"What prices were you quoted?"

Subsequently, the findings concerning actual search behaviour could be compared with those from the experimental studies, and explanations sought for the similarities and differences.

A second strand of future research possibilities builds on the ideas discussed in the competitive tendering experiment in chapter 9. The study attempted to develop a methodology for investigating information search and decision processes in more complex, and less highly structured business decision contexts. Two extensions follow from this. First, the experimental instrument used could be modified to allow alternative experimental groups with varying amounts of information available from the outset. The three hypotheses of chapter 9 could then be tested across the experimental groups, to assess whether there is an inter-relationship between search behaviour and the amount of initial information.

A second extension would be to apply the methodology across a whole range of other business decisions. The potential scope for analysis here is vast, as any decision requiring the examination of a large mass of data, some but not all of which is given at the outset, as well as an element of human judgement, would be a suitable candidate for investigation.

In particular, an important field of inquiry is concerned with bank lending decisions and the prediction of corporate distress. Previous work in this area has utilised three different types of methodology. Econometric models of bankruptcy (eg .. Altman, 1968; Altman, Haldeman and Narayanan, 1977) essentially involve scoring the company on the basis of several, specific, financial ratios. Behavioural studies of bankruptcy prediction (eg .. Libby, 1975; Zimmer, 1980) assess the success with which loan officers can predict failure given certain sets of financial information. Thirdly, simulation studies (eg .. Dietrich and Kaplan, 1982; Leeming, Whittred and Zimmer, 1984) have attempted to trace the judgemental process of the lender in a natural setting.

Most of these experimental studies, however, have been characterised by a menu-driven search procedure, with an information set that is carefully pre-selected by the experimenters. There is a clear need to carry out research studies in this area where solution pathways are not functions of the relatively rigid structure imposed on the subjects. The methodology developed and discussed in chapter 9 will be valuable in the design of such studies.

Attempts to explore these research directions will provide a useful contribution to the decision making literature, and increase further the understanding of the information search behaviour of individuals, as developed in this thesis.

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