DISCUSSION PAPER SERIES

OPTIMAL ECONOMIC SEARCH: AN EXPERIMENTAL STUDY

Andrew Schotter
New York University

and

Yale Braunstein
Brandeis University

No. 79-20 June 1979

C. V. STARR CENTER FOR APPLIED ECONOMICS

NEW YORK UNIVERSITY
FACULTY OF ARTS AND SCIENCE
DEPARTMENT OF ECONOMICS
WASHINGTON SQUARE
NEW YORK, N.Y. 10003

Individual copies of papers may be obtained free of charge by writing to:

The C. V. Starr Center for Applied Economics
New York University
269 Mercer Street, 3rd Floor
New York, NY 10003-6687

http://www.econ.nyu.edu/working/

OPTIMAL ECONOMIC SEARCH: AN EXPERIMENTAL STUDY

Andrew Schotter
New York University

and

Yale Braunstein
Brandeis University

No. 79-20 June 1979

The authors would like to thank Steven Salop and Bernard Wasow for their valuable suggestions and help. The research and computational help of Eugenio Omedeo and Dubi Silverstein and Alias Jonas is also greatly appreciated.

Professor Schotter's participation in this project was made possible by the partial support of Contract No. N00014-C-0598 of the Office of Naval Research.

OPTIMAL ECONOMIC SEARCH: AN EXPERIMENTAL STUDY*

Andrew Schotter and Yale Braunstein

This paper presents the results of a series of laboratory experiments whose purpose was to test some hypotheses existing in the theoretical literature on "optimal" economic search. Our intent was to create an experimental framework which would allow us to directly test a wide variety of theorems commonly referred to in the literature. As such, we have tried wherever possible to recreate in the laboratory the theoretical world of the theorist and to test whether the behavior we observe is supportive of his predictions. As is usually the case, our final conclusions are mixed. More specifically, while the aggregate behavior of our subjects does seem to confirm a great many hypotheses about the way people search or ought to search, the individual behavior of subjects seems much harder to explain. Consequently, the statement, "People seem to search optimally," appears to be true of some fictitious "average" subject, yet not necessarily true of any individual "real" one. For the macro policy oriented economist, this divergence between what is true in the

aggregate and what is true in the isolated individual case may not be of import, since he is interested primarily in the movement of group or aggregate quantities. For the micro-theorist, however, the ability to explain aggregate phenomena without explaining the individual agent behavior supporting it is a pyrrhic victory to say the least.

In this paper we will proceed as follows: In Section I we will discuss some methodological points about the need for experimental research in heavily theory-laden fields of economics such as the field of search economics. In Section II we will present a very brief development of the basic search model--search from a known distribution with constant search costs, risk neutrality, infinite time horizons and perfect recall--and derive the optimal search rule for this situation. No attempt will be made to develop any other theoretical results or to prove new and original ones. The particular search model presented is developed at some length because it represents the basic search paradigm from which all others are derivative. Using this basic search paradigm (BSP) as a starting point, we will then state a set of theorems existing in the literature which indicate what can be expected to happen when any characteristic of the BSP is changed--i.e., when there is no recall or

imperfect recall, when search costs increase, when risk aversion is introduced, etc. In Section III we will explain the experimental procedures used to test the various hypotheses stated in Section II. In Section IV we will present a step by step test of each hypothesis. In many cases, several tests of the same hypothesis are presented and the conclusion to be drawn from each discussed. Finally, in Section V we will offer some conclusions and some warnings as to how we feel the results of our studies should be taken. Before proceeding to Section I, however, it is imperative that we state that much of what we will be discussing here was inspired by the very excellent two-part survey article of the optimal economic search literature offered by Lippman and McCall (1976).

Section I

Experimentation and Abstract Economic Theory

To those economists who have had the honor and thrill to create a piece of abstract economic theory, it is clear that the world of the theorist is a pristine, clear and beautiful one. The assumptions necessary to make a particular mathematical result hold change the

world as we know it, and whether the results derived still hold true for the real world is sometimes left open to doubt. For the theorist the answer is clear: "If the world is not what I state it to be, then so much the worse for the world." However, such a view does not help the policy maker or government consultant who, unfortunately, does not have the luxury of creating any world that he wishes but must deal with the world given to him by history.

The literature surrounding the topic of optimal economic search is a particularly interesting one to look at in this light. It has two striking characteristics. First, it is loaded with a great variety of theoretical results and yet is strikingly devoid of any real empirical verification. As a result, the abstract world of the theorists is left intact and unchallenged. In essence an entire theoretical edifice has been constructed describing the way people search without any empirical testing as to whether or not people actually do search that way.

The second characteristic of the literature is what we shall call a potential for "self involvement." By this we mean the following: To date, as Rothschild (1973) points out, most search models are partial or one-sided models depicting the optimal search behavior of

either buyers or sellers in isolation. Very few two-sided market models exist, but when they are constructed it is clear that the results already generated will be used in their construction. Consequently, by involving previous results or incorporating previous results about buyer and seller search behavior in the construction of more complex market or macro models, any undetected errors existing in previous results will tend to be compounded in these larger and more complex models, rendering them useless. Put differently, there is a real danger that elaborate macro- or market models may someday be constructed employing behavioral search equations which have never been tested and which do not realistically describe the way people search. Consequently, by properly testing these micro-search theories before their inclusion into larger models is completed, the eventual errors that could result may be eliminated. It is precisely this mission that we set for ourselves in this paper. In brief, we intend to experimentally test a wide variety of results already established in the theoretical search literature, yet empirically untested. Our methodological stance is simple. Experimental techniques can be of great use in helping to falsify already established behavioral theorems in economics. We view experimental methods as tools which will allow us to

weed out those results about human behavior which cannot be verified in the laboratory. We have less faith, however, in experiments whose aims are positive, i.e., to prove a theorem, or where results are taken as the basis for policy recommendations. Such inferences we feel cannot easily be drawn. In short, we feel that experimental techniques can be of benefit to economics in casting doubt on previously accepted or seemingly logical behavioral results. More ambitious positive objectives can certainly be attempted, but the burden of proof falls more heavily on the researcher in these circumstance. It is in this light that we present the following experimental results.

Section II

The Basic Search Paradigm

The Basic Search Paradigm (BSP) as presented by Lippman and McCall (1976) is closely paraphrased as follows:

> 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 perfect recall of job offers). Finally, the searcher has a utility function which is linear in income (the searcher is risk neutral).

This paradigm is basic to the literature since the literature has developed by investigating the consequences that result when any of the characteristics of this search situation are changed, i.e., when there is less-than-perfect recall, risk aversion, finite horizons, discounting of future income, variable search cost, variable search intensity, etc. Before we investigate the ramifications of these relaxations, let us consider the optimal search behavior of an agent searching in the circumstances defined above as the Basic Search Paradigm.

Let x_i be a job (wage) offer made to the searcher in any period, where each x_i is a random variable with cumulative distribution function $F(\cdot)$, $E(x_i) < \infty$, and x_i's are mutually independent. Since the job searcher can retain or recall any previous job offer, the return

from stopping after the n^{th} search is $Y_n = \max(x_1, \ldots, x_n) - nc$ where c is the cost of search. The searcher wants to maximize $E(Y_n)$. Now, since the distribution that the searcher is searching from is stationary and all job offers are mutually independent of each other, and there is an infinite horizon, the decision to stop or continue at any point in time is identical. In short, the worker should continue to search if the expected benefit from one more search is greater than the expected cost (which is a known constant), and this rule remains true no matter how many searches have already been made (i.e., sunk search costs should not influence the searcher's marginal decisions). This logic leads to the definition of a wage ε called the reservation wage which has the property that at any time $t \geq 1$ the worker should stop searching and accept an offer x_t if $x_t \geq \varepsilon$ and continue to search if $x_t < \varepsilon$. This is true because ε is defined as that wage such that given $F(\cdot)$ if any wage below ε is rejected, the expected benefits from one more search will just equal the expected cost of that search--c. To demonstrate this, consider the searcher decision in period 1 after he has generated his first wage offer (since the situation is stationary, the logic offered here is sufficient for any $t \geq 1$ also, so this derivation is general). Let ε be defined as the expected gain net

of search cost that a searcher can expect at any time if he searched "optimally" in the future. After the generation of the first wage, the expected return from this optimal policy is

$$E \max(\varepsilon, x_1) - c . \tag{1}$$

Since ε is defined as the expected benefit from pursuing the optimal search rule, it follows by definition that

$$\varepsilon = E \max(\varepsilon, x_1) = c . \tag{2}$$

Now $E \max(\varepsilon, x_1)$ can be rewritten as

$$E \max(\varepsilon, x_1) = \varepsilon \int_0^{\varepsilon} dF(x) + \int_{\varepsilon}^{\infty} x dF(x) . \tag{3}$$

This expression has a simple explanation. The first term is the expected value that will be forthcoming if the wage offer on the first search is below ε since, in that case, the searcher will continue to search with the expectation of receiving ε, the expected gain from optimal search. The second term is simply the expected value of a wage offer above ε which would be accepted. Adding $\varepsilon \int_{\varepsilon}^{\infty} dF(x)$ to the first term and subtracting $\int_{\varepsilon}^{\infty} dF(x)$ from the second, we find

$$E \max(\varepsilon, x_1) = \varepsilon \int_0^{\varepsilon} dF(x) + \varepsilon \int_{\varepsilon}^{\infty} dF(x) + \int_{\varepsilon}^{\infty} x dF(x) - \varepsilon \int_{\varepsilon}^{\infty} dF(x) \quad (4)$$

$$= \varepsilon + \int_{\varepsilon}^{\infty} (x - \varepsilon) dF(X) \quad (5)$$

Equation (2) then yields

$$c = \int_{\varepsilon}^{\infty} (x - \varepsilon) dF(x) = H(\varepsilon)$$

where

$$H(\varepsilon) = \int_{x}^{\varepsilon} (y - x) dF(y) \quad (6)$$

The optimal stopping rule which is then to set a reservation wage ε such that the expected benefit from one more search $\int_{\varepsilon}^{\infty}(x - \varepsilon) dF(x)$ is equal to the expected cost of that search-- c. Notice that the rule is myopic in that at any time t, the only information relevant is the search cost, c and the presently generated offer, x. Past history and future anticipations are irrelevant.

Another interpretation of what ε is will be useful for us later. Let N be the number of searches needed until ε is exceeded. Then N will be a random variable with a geometric distribution with parameter

$p = 1 - F(\varepsilon)$ and $E(N) = 1/p$. If g is the expected gain from following the policy in (6)--if $1 - F(\varepsilon) > 0$--satisfies

$$g = \frac{-c}{1 - F(\varepsilon)} \quad \frac{\int_{\varepsilon}^{\infty} x dF(x)}{1 - F(\varepsilon)} . \tag{7}$$

Rearranging, we find

$$c = \int_{\varepsilon}^{\infty} (x - g) dF(x) \tag{8}$$

However, from (6) we know that $c = H(\varepsilon)$ and then $\frac{(g - \varepsilon)}{1 - F(\varepsilon)} = 0$, hence $g = \varepsilon$, <u>the expected return from following the optimal search policy is equal to the reservation wage</u>. Consequently, if the searcher contemplates what return (net of search costs) he can expect to receive from optimal search before he even searches for the very first time, the amount defined by that calculation is identical to the optimal reservation wage. This will be of use to us later in Section IV.

As we have indicated above, the literature on optimal economic search has developed by relaxing the conditions defining the basic search paradigm and investigating how these relaxations affect the optimal searching behavior of the searcher. Since our space is limited here, we will not be able to investigate the

intuition behind each of the results that we are interested in testing and will certainly not be able to prove any of them. However, wherever possible we will offer a reference which will contain the result in its entirety. (The reference offered is usually the reference whose results are tested and not necessarily the primary or original source of the theorem. In other words, wherever possible we attempted to satisfy the assumptions made in these particular references as closely as possible and therefore refer the reader to these sources instead of others. The exclusion of several important contributions is explained by this fact.) The basic results that were tested experimentally are the following:

Hypothesis 1. The Reservation Wage Hypothesis. People actually search according to the reservation wage rule specified by (6) and on average tend to set the optimal reservation wage ε.

Hypothesis 2. (Nachman, 1972, theorem 11): Risk Aversion with Recall. Risk averse searchers searching in the basic paradigm search situation search less (stop sooner) and

tend to be less selective of wages (i.e., tend to settle for lower wages and are willing to accept some wages rejected by risk neutral searchers in the same situation).

Hypothesis 3. (Nachman, 1972, theorem 11): Risk Aversion Without Recall. Risk averse searchers who are searching in the basic search paradigm situation without recall tend to search less and are less selective of wages than are risk neutral searchers searching under the same circumstances.

Hypothesis 4. (Sakaguchi, 1961; Kohn and Shavell, 1974): Increased Search Costs. A risk neutral or risk averse searcher searching in the basic search paradigm will tend to search less, be less selective of wage offers, and set a lower reservation wage, the higher are the costs of search.

Hypothesis 5. (Kohn and Shavell, 1974): Increases in Risk--Mean Preserving Spreads. If a searcher is searching under the conditions specified by the basic search paradigm,

and is searching from a stationary distribution $F(\cdot)$, then if $F(\cdot)$ is transformed by a mean preserving spread (becomes more risky in the Rothschild-Stiglitz sense) into $F'(\cdot)$, all else remaining the same, the reservation wage of the searcher will tend to increase. (Remember, searchers in the BSP are risk neutral.)

Hypothesis 6. (Karnai and Schwartz, 1977): Uncertain Recall. If the basic search paradigm is modified such that:

1) the expected gain from search is finite (true in basic paradigm also);

2) as time goes on the probability of being able to recall a past wage offer decreases;

3) the marginal search cost increases with time; and

4) the marginal cost of soliciting a previous wage offer is equal to the marginal cost of generating a new one,

then the reservation wage in this situation of uncertain recall is bounded

below by the reservation wage of search with no recall and bounded from above by the reservation wage of search with perfect recall.

Hypothesis 7. (Karnai and Schwartz, 1977): No Recall. Searchers searching in the basic search paradigm with uncertain recall should never solicit past wage offers. The reservation wage for a searcher searching in the basic search paradigm without recall is less than the reservation wage of a searcher searching in the same circumstance with perfect recall.

Hypothesis 8. (Kohn and Shavell, 1974): Time Preference. The reservation wage tends to increase with an increase in the time preference of the searcher.

Hypothesis 9. (Lippman-McCall, 1976; Mortensen, 1970): Constant Reservation Wage. In searching in the basic search paradigm, reservation wages are constant through time.

Hypothesis 10: (McCall, 1974): Finite Horizon. In searching in the basic search paradigm

with a finite horizon, the reservation wage is a decreasing function of time.

Hypothesis 11. (Kohn and Shavell, 1974): Unknown Distributions. The reservation wage of a searcher searching from an unknown distribution is at least as great as the searcher searching from a known distribution if the searcher is allowed to include current information into the revised estimate of the distribution he is searching from before he decides to stop or search again.

Hypothesis 12. (Telser, 1973; Kohn and Shavell, 1974): Unknown Distribution. Searchers searching in the basic search paradigm when the distribution of wages they face is unknown tend to search longer than the same searchers when they search knowing with certainty the distribution from which they are searching.

These hypotheses are then formulated to test a series of theoretical results existing in the literature. In a future paper we will present a set of results that

we obtained which comment on some more policy oriented questions such as the effect of unemployment insurance on search, the impact of a minimum wage, the value of information in labor markets, the robustness of search strategies, and the rate of decline in the reservation wage. Space prohibits such a discussion here, however.

With the basic hypotheses stated, let us now proceed to examine the experimental design used in our experiments.

Section III
Experimental Design

The experimental design used to test the hypotheses stated in Section II was created to emphasize the characteristics of the basic search paradigm and its modifications. To that end, a total of 56 undergraduate males and females were recruited over a three week period from three separate undergraduate economics principles courses at New York University and divided into three groups without their knowledge. The three groups can be identified by nicknames as follows: Group I, Basic Search Paradigm Group, or Risk Neutral Group; Group II, the Risk Averse Group; Group III, the Uncertainty Group. Each group came totally from a separate

class. To fully explain the experimental design, let us look at the separate experiments performed by these three groups.

Group I: The Basic Search Paradigm Group, or the Risk Neutral Group. Students in Group I were scheduled for hour-long appointments and brought into an enclosed room one at a time. In the room was a principal investigator, a desk upon which was an interactive computer terminal, and two chairs. The subject was then given a 10 page set of instructions and told to read them. These instructions explained 12 experimental search trials that he would partake in, so that each subject knew he would perform twelve search trials, some of them identical to each other, but most of them different. They were told that the instructions would be gone over in detail by the principal investigator and a practice period performed before the actual experiment took place. The instructions (available from the authors upon request) contained the following information.

The subject was told that he was going to participate in an experiment whose purpose it was to investigate how people go about searching for wages and prices. He was told that if he wanted to, he could think of himself as a worker looking for a job for which the only characteristic of the job of interest was its wage. Two facts were

relevant. First, the exact wages existing were not known with certainty but rather were random and described by some probability distribution to be told to him. Consequently, in order to obtain a satisfactory wage, it was necessary to search. In addition, each time he searched, he would incur a cost and his final payoff would consist of the wage accepted minus the total search costs incurred. The actual searching procedure was simple. The student would sit in front of the computer terminal and, to start searching, would type the word SEARCH into the terminal. The computer would then offer him a wage by typing back "$\underline{w}$ is my offer," where $\underline{w}$ would be some wage derived from a given probability distribution which the searcher always knew or at least thought he did. The wages offered were denominated in points which in all cases, except two, ranged from 0 to 200 points. Each search cost c points, where c varied from trial to trial (always known by the searcher). If the subject was satisfied by the wage offered, he would type STOP into the terminal and his final payoff would be his accepted wage $\underline{w}$, minus c points. If the wage was not satisfactory, the subject would again type SEARCH into the terminal and another offer would be tendered. Again, the searcher could either accept or reject by typing SEARCH or STOP into the terminal. If the searcher searched n times and

then accepted a wage of $\underline{w}$ points, the final point payoff would be $\Pi = (\underline{w} - nc)$ points and in Group I all subjects were given one penny for each point they earned. Since each subject performed this searching procedure under 12 different circumstances, it is best to stop and explain each circumstance separately--i.e., explain each experimental trial.

Experimental Trial 1

In experimental trial 1, the searcher was informed that he was searching from a symmetric triangular wage distribution $p(w)$ with mean 100 and range 0 to 200 points. The formula for the function used was

$$p(w) = \begin{cases} \frac{w}{10,000} \text{ for } 0 \leq w \leq 100 \\ \frac{100 + (100 - w)}{10,000} \text{ for } 100 \leq w \leq 200 \end{cases}$$

In this trial he could search as many times as he wanted to and each search cost 5 points. In addition, any wage offered was always available so that all searchers here had perfect recall and by typing STOP at any time t, the final point payoff of any searcher in this trial was $\Pi = \max(w_1, \ldots, w_t) - tc$.

This trial, then, contains all of the characteristics of the Basic Search Paradigm--i.e., a known

distribution of wages, constant search cost, and perfect recall. In addition, if the reader is willing to grant that the utility functions of all subjects are approximately linear in dollars over the range of payments made for these trials (0 to $2.00), then having a linear conversion function of points into pennies and paying one penny for every point, we can take these searchers to behave as if they were risk neutral and this characteristic can be added to the list above. If one is not willing to assume that these subjects have linear utility functions over the range of payoffs offered them, then we could call this group the "less risk averse" group when compared to Group II as we will see. This conversion (of 1 penny for each point) was preserved for all 12 trials in Group I, so that this group was risk neutral in every trial. The theoretically optimal reservation wage in this trial was $\epsilon = 133.00$.

Experimental Trial 2

As far as the subjects were concerned, Experimental Trial 2 was identical to Experimental Trial 1. It in fact was, except that unknown to them we had preselected a sequence of wages that we drew previously from the symmetric triangular distribution. This sequence was given to all Group I subjects in Trial 2 and was also

given to subjects in Groups II and III. The first five numbers in this sequence were 80.292, 78.657, 115.641, 110.747 and 146.348, presenting the searcher with four wages below the theoretically optimal reservation wage of 133. Clearly, the theory would dictate that the subject wait for the 146.348 wage offer to appear.

Experimental Trial 3

In Experimental Trial 3 all search rules were identical to the rules used in Trial 1--i.e., perfect recall, constant search costs, known distributions, etc., except that the subjects in this trial searched from a rectangular distribution in which all wages were equally likely--i.e., $p(w) = 1/200$, $0 \leq w \leq 200$. This rectangular distribution can be obtained from the triangular by a series of mean preserving spreads and hence was a "more risky" distribution than the triangular one, in the Rothschild-Stiglitz (1970) sense.

Experimental Trial 4

In Experimental Trial 4, all conditions were identical to Experimental Trial 1--i.e., search from a symmetric triangular distribution with perfect recall, except that each search cost 10 points and not 5 points as before. Clearly this trial tried to isolate the effect of increased search costs.

Experimental Trial 5

Experimental Trial 5 was identical again to Trial 1, except that the distribution searched from was a truncated symmetric triangular distribution in which the searchers were told that they were searching from a symmetric triangular distribution but one in which they would never be offered a wage below 50 points. In other words, the computer program operating here was choosing wages from a symmetric triangular distribution but if a wage below 50 points ever arose, it would be ignored and not offered. Consequently, subjects knew that they would never have to spend 5 points and obtain a wage below 50 points. This truncation had a certain similarity to the imposition of a minimum wage on Experimental Trial 1 and the effects of this imposition will be reported in a later paper.

Experimental Trial 6

In Experimental Trial 6, all subjects were told that they were simply repeating Experimental Trial 3, where they searched from a rectangular distribution $p(w) = 1/200$, $0 \leq w \leq 200$. In actuality, the computer was giving them wages from a right triangle distribution $p(w) = (1/100 - (1/20{,}000)w)$ so that they were deliberately misinformed about the distribution of wages. This trial

represented our attempt at evaluating an issue raised by Gastwirth (1976) concerning the robustness of reservation wage search strategies since, as far as the subjects were concerned, they were acting in a situation identical to what would occur if they had misspecified the distribution they were searching from.

Experimental Trial 7

Experimental Trial 7 had a change in search rules. Here, the subjects were again searching from a symmetric triangular distribution with a 5 point search cost. However, they could search at most 7 times (i.e., a finite horizon existed) and there was no recall at all. Each wage was a take-it-or-leave-it proposition. Clearly, horizon effects and recall effects were simultaneously treated here.

Experimental Trial 8

Experimental Trials 8 and 9 contained a different search scenario for the subjects to follow than did Trials 1-7. In these trials the subjects were told that they were searching from a symmetric triangular distribution defined over the interval 0 to 20. They could search at most 10 times, each search cost 5 points, and their final payoff in Trial 8 was calculated in quite a different way, as follows: If at search t, $t \leq 10$, a

subject decided to stop searching, he would receive that wage equal to $\max(w_1, \ldots, w_t)$ both in search period t and in all of the remaining 10 - t periods so that his final point payoff by stopping at period t was

$$\Pi = [\max(w_1, \ldots, w_t)][(10 - t + 1)] - 5t.$$

In other words, if a subject received wages of 10, 5, 3 in periods 1, 2, 3 and decided to stop searching at the end of search 3, his final points payoff would be $[(10) \times (8) - (5) \times (3)] = 65$ points, representing a per period wage of 10 points for eight periods minus 3 search costs at 5 points each. All subjects were then given one penny for each point they earned.

This trial simulated the characteristics faced by workers who have a finite (10 period) participation in the labor market and for whom every period in which a job is not accepted defines a shorter productive life in the labor market or a shorter payback period for the investment in search.

Experimental Trial 9

Experimental Trial 9 introduced discounting into the situation defined in Trial 8. Here all aspects of the experimental trail were identical to those in Trial 8 except payoffs were calculated as discounted present

values of income streams net of search costs discounted back to period 1 by a 10% discount rate. In other words, if a subject received a sequence of 10, 5, 3 in the first 3 periods and decided to stop searching after search 3, he would receive a final point payoff of

$$\Pi = \sum_{t=3}^{10} \frac{10}{(1+.10)^{t-1}} - \sum_{t=1}^{3} \frac{5}{(1+.10)^{t-1}}$$

and he would then be given one penny for each point achieved. This discounting process was explained to the subjects by explaining that their payoffs were defined as if wages accepted deteriorated as time goes on and a table was given to them defining what their final payoff in points would be if in some period t they accepted a wage of w.

Experimental Trial 10

In Experimental Trial 10, all conditions were identical to the ones specified in Experimental Trial 1, except for the fact that for the first five times a subject searched he would receive a 3 point subsidy making the net marginal cost of the first five searches only two points each. From search 6 onward, the marginal cost of search returns to 5 points. This trial attempted to simulate conditions existing under the institution of

unemployment insurance in which the benefit period was 5 periods. The effects of this institution will be discussed in a later paper.

Experimental Trial 11

In Experimental Trial 11 all conditions existing in Trial 1 were recreated, except that no recall was allowed. Consequently, each wage was a take-it-or-leave-it offer and at any time only current wage offers were available. This was identical to Experimental Trial 7, except for the fact that in Trial 7 a seven search horizon (or limit) was imposed.

Experimental Trial 12

Experimental Trial 12, as far as the subjects knew, was identical to Trials 1 and 2. However, in this trial we again pre-selected the sequence of wages that each subject would get. This clearly controlled for the sequences received by the subjects and comparisons of the behavior of subjects in Group I receiving this sequence could be compared to the behavior of subjects in other groups receiving identical sequences. The first six offers of the trial sequence were 93.945, 43.578, 65.862, 82.865, 74.881, 147.764, making it a "worse" sequence than the period 2 sequence and one in which the subject

had to wait 6 periods to receive a wage above the theoretically optimal reservation wage.

Before each subject performed these twelve trials, he practiced on a practice program in which he was allowed to draw as many wages as he wanted to from all distributions used in the experiments. In addition, the properties of these distributions were explained to him, and then he was allowed to practice in searching circumstances identical to those in which he would soon be searching. These practice sessions continued until the principal investigators felt that the subjects were totally familiar with all distributions and search procedures. The final payoff of each subject was the sum of his payoffs in each trial and in Group I final payoffs average approximately $13.30, a one hour session. The incentives in the experiment were very considerable as they were for each individual trial. A total of 20 subjects participated in Group I, and they were paid as they left.

Group II: The Risk Averse Group. Subjects in Group II performed all experimental trials that subjects in Group I performed except Experimental Trials 8 and 9. However, in each trial their final dollar payoff was

calculated using a different conversion function to transform a subject's final point payoff into a final dollar payoff. More specifically, instead of the linear one penny for one point function used in Group I, subjects in Group II were given a final dollar payoff calculated by taking their final point payoff and converting it into a dollar payoff by the following formula:

$$\$ = \frac{(\Pi)^{1-\lambda}}{1 - \lambda}$$

where $\lambda = .05$. This function is concave with

$$\frac{d\left(\frac{-\$''(\Pi)}{\$'(\Pi)}\right)}{dw} < 0 .$$

$-\$''(\Pi)/\$'(\Pi)$ is a measure we can call relative point aversion which is comparable to the Arrow-Pratt measure of risk aversion. The effect of this conversion function is to simulate risk averse behavior since if the function

$$\$(\Pi) = \frac{(\Pi)^{1-\lambda}}{1 - \lambda}$$

is a concave function mapping points into dollars, and if all subjects have a utility function for dollars

$u = U(\$)$ which is linear over the range of payoffs defined in our experiment, then the composite function, $h = g(\pi) \times U(\$)$, mapping points into utility, is concave thereby simulating a concave utility function exhibiting decreasing risk aversion. As a matter of fact, even if they do not have linear dollar utility functions Group II subjects would still be more risk averse than Group I subjects. Consequently, Group II is called the risk averse group and since they perform the exact same trials as Group I, we hope to explain differences between these groups on the basis of the concavity of the conversion function used. Trials 8 and 9 were omitted in an effort not to compound the risk aversion and discount rate effects which work in the same direction. Because of the conversion function and the smaller number of trials, subjects in Group II had an average payoff of $10.00 which is still quite substantial for a one hour experiment. Consequently, incentives in this group, we feel, were comparable to those in Group I. Group II then presents risk aversion as a treatment variable. A total of 21 subjects participated in Group II, and they were paid as they left.

Group III: The Uncertainty Group. Experimental Group III contained a total of 8 experimental trials

designed to treat various forms of uncertainty not contained in the experimental design for Groups I and II.

Experimental Trial 1

Subjects were told that they were searching from one of four distributions of wages chosen with equal probability by the computer. The distributions were the symmetric triangular, the rectangular, the right triangular and the left triangular, all defined over the inverval 0 to 200 points. They could search as many times as they wished, search costs per search were 5 points, and they had perfect recall. Consequently, all conditions were identical here to Experimental Trial 1 in Group I except that there they knew the distribution they were searching from, while here they are told it could be any one of four. Actually, in Experimental Trial 1 the distribution that they searched from was the symmetric triangular so that this trial isolated knowledge of the distribution searched from as a treatment variable when compared to Trial 1 of Group I, the Basic Search Paradigm group. Subjects were given one penny for each final point profit they obtained in all Group III experimental trials.

Experimental Trial 2

All conditions in Experimental Trial 2 are identical to Experimental Trial 1, except that unbeknownst

to them they were actually searching from a right triangular distribution.

Experimental Trial 3

All conditions in Experimental Trial 3 were identical to Trials 1 and 2, except that unbeknownst to the subjects they were actually searching from a rectangular distribution.

Experimental Trial 4

In Experimental Trial 4, subjects were told that they were searching from the symmetric triangular distribution, that each search cost 5 points, and that they could search as many times as they wanted, as is true of all subjects in Group III. In addition, their final dollar payoff was derived by offering the subjects one penny for each point earned. In short, they searched under identical conditions as did the subjects participating in Trial 1 of Group I. One major difference did exist, however. In Trials 4 and 5 of Group III, subjects did not have perfect recall of past wage offers. They had what may be called "uncertain recall" in which at any time the only wage that was definitely available for them was their currently offered wage. However, they could go back and find out if a wage offered to them in the past

was still available for them by typing the period that that wage was offered to them into the computer. This "backward solicitation" of wages cost 5 points, just as if it were a new search. The computer would tell them whether this previous wage was still available. The subjects were informed that the probability that a wage offered to them k periods ago had a 1/k chance of still being available and a (k - 1)/k chance of not being available, making the probability of past wages not being available a decreasing function of the time past since they were offered. This is actually how their availability was determined. Once a past solicitation was made and a wage found to be available, the subject could either accept it, search again, or solicit some other previously offered wage. This trial, then, isolated the existence of "uncertain recall" as a treatment variable and the behavior of the subjects on this trial can be compared to the perfect and no recall cases to study the effect of this variable.

Experimental Trial 5

Trial 5, as far as the students were concerned, was identical to Trial 4. This is true in fact, except that in this trial the preselected sequence used in Experimental Trials 2 of Groups I and II whose first 5 offers were 80.292, 78.657, 115.641, 110.747, 146.348

was given to all subjects. This, of course, further controlled the experimental environment in trying to isolate the effect of uncertain recall by holding the actual sequence offered subjects constant across groups.

Experimental Trial 6

In Trial 6 subjects searched in circumstances identical to the ones existing in trial 1 of Group I (the Basic Search Paradigm Group), except here they were (and knew it) searching from a right triangular distribution whose formula is

$$p(w) = \left[\frac{1}{100} - \frac{1}{20,000}\, w\right]$$

Experimental Trial 7

In this experimental trial all of the conditions existing in Trial 1 of Group I existed here. However, here subjects were (and knew it) searching from a rectangular distribution.

Experimental Trial 8

In Experimental Trial 8, as far as the subjects knew, all of the conditions existing in Trials 1, 2 and 3 also existed here. In actuality, all subjects were given the sequence used in Experimental Trial 12 in Group I (also Trial 10 of Group II), in which the first six offers were 93.945, 43.578, 65.862, 82.865, 74.881, 147.764.

Fifteen subjects participated in Group III and they were paid as they left. The average payoff in this group was $9.10 for 3/4 hour of time, preserving roughly the same incentive structure as Groups I and II.

Qualitative Procedures. As the subjects in each group searched they were asked a series of questions whose aim was to try to solicit some unobservable qualitative information about their searching strategies. In Group I this was done by asking each subject before each trial what was the minimum amount he would accept (hypothetically) that would make him indifferent between searching and simply accepting the amount requested. In short, he was asked the minimum bribe he would accept not to search. This answer, if the searcher behaved rationally and was capable of making all of the proper calculations, should be equal to the optimal reservation wage as we have shown before in Section II (equation 8). Therefore in an indirect manner we were able to find out how different their answers were from those that would be given if indeed they searched optimally. In Experimental Trial 12 we not only asked this question but also before each search we asked the subjects if they would continue to search and, if so, what would be the minimum wage offer that they could get on the next search that would cause

them to stop searching and accept that wage. Finally, when all of the trials were finished, each subject was asked to write a one paragraph summary of what he felt was the best or optimal way to search, as well as to describe how he searched.

Group II subjects were asked the identical questions and again asked to report on their searching strategies.

Group III subjects were asked the same questions. However, in Trials 1, 2, 3 and 8 they were also asked to tell us the maximum amount of money they would be willing to pay to find out which one of the four "equally probable" wage distributions they would actually be searching from. This was done in an effort to find out if they had an accurate estimate of the value of such information since this can be useful in understanding whether workers correctly evaluate the value of labor market information when unemployed.

Having explained our experimental procedure in detail, we can now proceed to discuss the tests of our hypotheses.

Section IV

Results

In this section we shall present the results of the tests of the twelve hypotheses described in Section II.

Hypothesis 1: The Reservation Wage Hypothesis. People actually search according to the reservation wage rule specified by Equation 6 and on average tend to set the optimal reservation wage .

It is, of course, impossible to devise one test which will unambiguously decide whether people search optimally by setting a reservation wage and searching until a wage equal or greater than it is offered. However, it is possible to investigate whether the behavior of our subjects was consistent with the type of behavior we would expect from agents who were searching "optimally" in the experimental situation they were presented with. This is what we attempted in our tests below.

First, if a searcher is searching according to the reservation wage hypothesis, he would never use his recall option in the Basic Search Paradigm since he is supposed to search until his reservation wage is met or surpassed

and stop as soon as it is. Consequently, we would expect that the average number of times a wage was recalled would be zero (i.e., searchers would not avail themselves of that option). This hypothesis was tested using our data for Group I, Trial 1 and Group II, Trial 1. We found that the average number of times any searcher availed himself of recall in these trials was .462 for Group I, Trial 1 and .353 for Group II, Trial 1, both of which were not significantly different from 0 at the 99 percent level of significance.

The next hypothesis that we investigated was whether searchers acted as if they set reservation wages and whether our agents had the ability to set a reservation wage equal to the theoretically optimal reservation wage. These hypotheses were tested as follows. In trials 1, 2, 3 and 12 of Groups I and II (Risk Neutral and Risk Averse Groups), we asked each subject what would be the minimum bribe we could hypothetically offer him not to search in that trial. The answer to that question, as we discussed in Section II (Equation 8), should represent the reservation wage of the searcher. Consequently, if we took the average answer to this question in each of the separate trials as the reservation wage of the searchers, we could compare it to the theoretically optimal reservation wage to see if it

was significantly different. If it is significantly different, we can still test the hypothesis that the searchers searched as if they had set a reservation wage (albeit the wrong one), by looking at the average wage actually accepted and testing the hypothesis that the searchers were acting as if they had set a reservation wage equal to the one they reported. For instance, in Group I, Trial 1, the theoretical optimal reservation wage was 133. In averaging all of the responses to our questions in this trial we found, remarkably, that the average response was to report a minimum bribe of 134.50 (see Table 1). Now given this response, if they searched from a symmetric triangular distribution as if they had set a reservation wage of 134.50, we would expect them to accept, on average, a wage of 155. From Table 1 we see that they accepted wages averaging 146.50 which was not significantly different from what we would expect. Hence, searchers in Group I, Trial 1 (as well as in Group I, Trials 2, 3 and 12--see Table 1) did appear to be searching as if they had set a reservation wage. In fact they seemed to be searching as if they had set the theoretically optimal reservation wage which was a surprising result.

For risk averse searchers, as can be seen in Table 1, the results are similar. Due to an unfortunate

choice of the point-to-dollar conversion function, the optimal reservation wages for the risk averse group were very close to those of the risk neutral group. In fact, in Trial 1 of Group II the theoretically optimal reservation wage was 130 which is very close to the optimal reservation wage of 133 for the risk neutral group (Group I) on the same trial. Consequently, we would expect that it would be hard to observe differences in the behavior of the subjects in these two groups across Trial 1. What we actually observed, however, was that what we called risk averse searchers set an average reservation wage of 109.72 which, while seemingly low, was not significantly below the theoretically optimal wage of 130 (see Table 1). In short, our subjects tended to exaggerate their degree of risk aversion and decrease their reservation wage, but still set reservation wages not significantly different from the optimal reservation wage. Given their diminished reservation wage of 109.72, we would expect that the average wage accepted by our subjects would be 136 if, indeed, they used 109 as their reservation wage. As Table 1 indicates, they accepted wages that averaged to be 141.40 which was not significantly different from what we would expect at the 95% level of significance. Consequently, risk averse searchers first exaggerate their degree of risk aversion, lower

their reservation wage, but still seem to behave in a manner that is not significantly different from what the theory predicts.

Our final test of whether people search as if they set reservation wages was to observe the highest rejected wages of our subjects before they finally accepted a wage. The point here is simple. If people are searching as if they had set the reservation wage they reported, then they should not reject any wage higher than it. Consequently, by observing the highest rejected wage, we have an approximation "from below" of the reservation wage they used, and this can be compared to the theoretically optimal reservation wage. The results of these tests are presented in Table 1 and confirm our expectations.

In summary, what we have called risk neutral searchers both stated optimal reservation wages and searched in a manner that confirmed the belief that they actually used these reservation wages in their search. What we have called risk averse searchers tended to exaggerate their degree of risk aversion and acted more cautiously; yet, on a statistical basis, they seemed to behave optimally.

TABLE 1

TESTS OF H^1 (OPTIMAL SEARCH BEHAVIOR)

Parameter Tested & Trial Number	Group I: Risk Neutral		Group II: Risk Averse	
Reservation Wage	Optimal R.W.	Actual Mean of Reported R.W.	Optimal R.W.	Actual 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*
Highest Rejected Wage	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*
Accepted Wage	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*

Note: Comparison of the behavior of Groups I and II on Trials 1, 2, 3, and 12.

*Significant at 95% level.

Hypothesis 2: Risk Aversion with Recall. Risk averse searchers searching in the basic search paradigm situation search less (stop sooner) and tend to be less selective of wages (i.e., tend to settle for lower wages).

By using the results from Trials 1, 2 and 12, we have data for three separate tests of the hypothesis that risk averse searchers, who have the ability to use recall, search less and are less selective of wages and tend to have lower "highest rejected wages" than risk neutral searchers in the same situation. By comparing the behavior of subjects in Groups I and II on Trials 1, 2 and 12 (results in Table 2), we show that the risk averse searchers do, on average, search less, have lower "highest rejected wages" and accept lower wages. However, the comparison of the average accepted wages is only statistically significant in Trial 2, the trial in which the sequence of wage offers was fixed for all searchers. With this one excpetion, none of the differences of the average accepted wages, the highest rejected wages, or the number of searches were statistically significant. However, all of the comparisons of average stated reservation wages were statistically significant. In short, significant differences existed between risk neutral and risk averse searchers only when the sequence of wages was held constant (Trial

TABLE 2

TESTS OF H^2 (RISK AVERSION)

Parameter Tested & Trial No.		Group II Risk Averse	Group I Risk Neutral	Difference
Reservation Wage:	1	109.72	134.50	24.78*
	2	107.95	135.75	27.80*
	12	107.74	136.00	28.76*
Highest Rejected Wage:	1	107.27	123.17	15.90
	2	106.34	114.97	8.63
	12	99.07	102.02	2.95
Accepted wage:	1	141.41	146.45	5.04
	2	123.75	139.15	15.40*
	12	124.70	134.31	9.61
Number of Searches:	1	3.33	2.70	-0.63
	2	4.29	5.15	0.86
	12	5.86	5.70	-0.16

*Significant at the 99% level.

2), indicating that the randomness of the sequences in Trial 1 introduced sufficient "noise" to eliminate significant differences. Holding this randomness constant tended to produce significant results.

Hypothesis 3: Risk Aversion without Recall. Risk averse searchers who are searching in the basic search paradigm situation without recall tend to search less and are less selective of wages than are risk neutral searchers searching under the same circumstances.

This set of tests is similar to those used for H^2 except that in this case neither the risk averse group nor the risk neutral group were able to use recall. As a result, we compared the behavior of subjects in Groups I and II on Trials 11 and 9 where no recall was permitted, instead of on Trials 1, 2 and 12. In this case the risk averse group, on average, searched less, set lower reservation wages, and had lower highest rejected wages (although the last difference was not statistically significant). However, there was virtually no difference in the average accepted wages between the two groups (see Table 3).

Hypothesis 4: Increased Search Costs. A risk neutral or risk averse searcher searching in the basic search paradigm will tend to search less and be less selective of wage offers, and set a lower reservation wage the higher are the costs of search.

TABLE 3

TESTS OF H^3 (RISK AVERSION)

Parameter Tested	Risk Averse	Risk Neutral	Difference
Reservation Wage	97.29	128.05	30.76**
Highest Rejected Wage	91.84	98.43	6.59
Accepted Wage	138.57	138.24	0.33
Number of Searches	2.29	3.68	1.39*

Note: Comparison of the behavior of Group I, Trial 11 and Group II, Trial 11.

*Significant at the 95% level.

**Significant at the 99% level.

To test this hypothesis we simply compared the behavior of subjects in Group I and II on Trial 4, where search costs were increased from 5 points to 10 points while the searcher searched from the symmetric triangular distribution.

The effects of increased search costs on the reservation wages and search behavior are generally in the directions predicted by optimal search theory, but the degree of statistical significance differs between the risk averse and risk neutral groups. (This is shown in Table 4.) In the risk neutral group, there is a statistically significant decrease in reservation wages and highest rejected wage when the cost of each search was increased from five cents to ten cents. But the changes in the risk averse group, although in the predicted direction, are not statistically significant.

Hypothesis 5: Increases in Risk - Mean Preserving Spreads. If a searcher is searching under the conditions specified by the basic search paradigm, and is searching from a stationary distribution $F(\cdot)$, then if $F(\cdot)$ is transformed by a mean preserving spread into $F'(\cdot)$, all else remaining the same, the reservation wage of the searcher

TABLE 4

TESTS OF H^4 (INCREASED SEARCH COSTS)

Group & Parameter Tested		Cost per Search: 5 points	Cost per Search: 10 points	Difference
Risk Neutral:	Reservation Wage	134.50	128.25	- 6.25*
	Highest Rejected Wage	123.17	92.93	-30.24*
	Accepted Wage	146.45	147.19	0.74
	Number of Searches	2.70	2.10	- 0.60
Risk Averse:	Reservation Wage	109.71	101.14	- 8.57
	Highest Rejected Wage	107.27	95.72	-11.55
	Accepted Wage	141.40	139.60	- 1.80
	Number of Searches	3.33	2.62	- 0.71

Note: Comparison of the behavior of Groups I and II on Trial 4.

*Significant at the 99% level.

will tend to increase. (Remember, searchers in the BSP are risk neutral.)

If a distribution of wage offers is transformed by a mean-preserving spread (and thus is more risky in the Rothschild-Stiglitz sense), we expect searchers to set higher reservation wages and to search longer. This was tested by comparing the behavior of subjects within Groups I and II on Trials 3 (the rectangular distribution) and 7 (the symmetric triangular distribution). Our findings confirm these predictions--both the risk neutral and risk averse groups set higher reservation wages and accept higher wages on average in response to a mean-preserving spread of the offers. Similarly, the highest rejected wages and the number of searches also increase, but these changes are not always significant (see Table 5).

Hypothesis 6: Uncertain Recall. If the basic search paradigm is modified such that:

1) the expected gain from search is finite (true in basic paradigm also);
2) as time goes on the probability of being able to recall a past wage offer decreases;

TABLE 5

TESTS OF H^5 (INCREASES IN RISK)

Group and Parameter Tested		Degree of Risk: Low	Degree of Risk: High	Difference
Risk Neutral:	Reservation Wage	134.50	156.75	22.25**
	Highest rejected Wage	123.17	125.57	2.40
	Accepted Wage	146.45	170.38	23.93**
	Number of Searches	2.70	3.25	0.55
Risk Averse:	Reservation wage	109.71	136.24	26.53**
	Highest Rejected Wage	107.27	128.72	21.45*
	Accepted Wage	141.40	168.72	27.32**
	Number of Searches	3.33	3.90	0.57

Note: Comparison of Trials 3 and 1 within Groups I and II.

*Significant at the 95% level.

**Significant at the 99% level.

3) the marginal search cost increases with time; and
4) the marginal cost of soliciting a previous wage offer is equal to the marginal cost of generating a new one;

then the reservation wage in this situation of uncertain recall is bounded below by the reservation wage of search with no recall and bounded from above by the reservation wage of search with perfect recall.

While our experimental design did not satisfy all of the conditions stated above by Karnai and Schwartz (1977)--condition 3 was violated since our marginal search costs were constant--we feel that a test of this hypothesis could be constructed by comparing the behavior of subjects in Group III, Trial 4 (search from a symmetric triangular distribution with uncertain recall), with Group I, Trial 1 (search from asymmetric triangular distribution with perfect recall), and Group I, Trial 11 (search from a symmetric triangular distribution with no recall). The results, shown in Table 6, are mixed--the comparisons between the perfect recall and uncertain recall trials are

TABLE 6

TESTS OF H^6 (UNCERTAIN RECALL)

Parameter Tested	Trial Conditions		
	No Recall	Imperfect Recall	Perfect Recall
Reservation Wage	128.05 (1.15)	129.20 (5.30)	134.50
Highest Rejected Wage	98.43 (-4.40)	94.03 (29.14)*	123.17
Accepted Wage	138.24 (-5.47)	132.77 (13.68)	146.45

Note: Comparison of the behavior of Group III, Trial 4 with Group I, Trial 1 and Group I, Trial 11.

Differences between adjacent averages are shown in parentheses.

*Significant at the 99% level.

consistently in the predicted direction, but the comparisons between the uncertain recall and no recall trials have mixed results. Only one of these differences is statistically significant. In short, searchers with perfect recall set higher reservation wages, are more selective of wages and accept higher wages than searchers with no recall but searchers with imperfect recall do not exhibit behavior that is consistently between these two extremes. Hence, the Karnai-Schwartz hypothesis can not be completely accepted on the basis of our tests alone.

Hypothesis 7: No Recall. Searchers searching in the basic search paradigm with uncertain recall should never solicit past wage offers. The reservation wage for a searcher searching in the basic search paradigm without recall is less than the reservation wage of a searcher searching in the same circumstance with perfect recall.

The test of hypothesis 7 was similar to that of hypothesis 6, except that for this hypothesis we controlled for the sequence of wages offered the subjects by comparing the behavior of subjects in Group III, Trial 5

with Group I, Trial 2 in which both groups received the same sequence, yet had different recall options. We found that the searchers in Group I who faced the same sequence as Group III searchers but had perfect recall availed themselves of the recall option 25 percent of the time while the imperfect recall group used recall only 8.3 percent of the time. In comparing differences in the reservation wage, highest rejected wage and accepted wage (Table 7), we find that all differences have the correct sign yet only the "highest rejected wage" was significantly different.

Hypothesis 8: Time Preference. The reservation wage tends to increase with an increase in the time preference of the searcher.

To test for the effects of changes in the time preference of searchers, we compare the results of the two Group I trials which had finite (ten period) horizons. One (Trial 8) had no discounting of incomes, while the other (Trial 9), did. The results, shown in Table 8, are mixed and the differences are not statistically significant. In other words, while we would expect the searchers to search less, accept lower wages, set lower reservation wages and be less selective of wages (lower "highest wage rejected"), when their income is

TABLE 7

TESTS OF H^7 (UNCERTAIN RECALL)[a]

Parameter Tested	Trial Conditions		
	Imperfect Recall	Perfect Recall	Difference[b]
Reservation Wage	129.20	135.75	(6.55)
Highest Rejected Wage	94.03	114.97	(10.94)*
Accepted Wage	132.77	139.15	(6.38)

[a]Using fixed sequence of offers.

[b]Differences between adjacent averages are shown in parentheses.

*Significant at the 99% level.

Note: Comparison of the behavior of Group III, Trial 5 and Group I, Trial 2.

TABLE 8

TESTS OF H^8 (TIME PREFERENCE)

Parameter Tested	Trial Conditions: No Discounting	Trial Conditions: Discounting	Difference
Reservation Wage	118.00	116.00	-2.00
Highest Rejected Wage	94.16	98.88	4.72
Accepted Wage	131.05	125.89	-5.16
Number of Searches	2.70	2.15	-0.55

Note: Comparison of the behavior of Group I , Trials 8 and 9.

discounted than when it is not, we find that while this is generally true (except for highest rejected wage) the differences are not significant. We feel, however, that because of the complicated instructions on this part of the experiment, the subjects may not have totally understood the subtleties of the experimental situation they were placed in.

Hypothesis 9: Constant Reservation Wage. In searching in the basic search paradigm, reservation wages are constant through time.

In an effort to test if the reservation wage remained constant over time, we asked each searcher in Groups I and II to record his reservation wage before each search during the last experimental trial. (This was only done during the last trial so as not to overly reinforce the searchers' use of reservation wages as a basis for search.) We then regressed these reported reservation wages against time both within each group and for the pooled set of data generated. The results presented in Table 9 indicate that reported reservation wages tend to fall over time for both groups. For the risk neutral group this fall was significant at the 99% level and averaged approximately 4.06 to 4.80%. These findings

TABLE 9

TESTS OF H^9 (STABILITY OF RESERVATION WAGE)

Group	N	n with reservation wage declining	Average Rate of Change Estimate 1[a]	Extimate 2[b]
Risk Neutral	19	16	-4.88*	-4.06* (-5.61)
Risk Averse	20	12	-1.37	-1.158 (-1.35)

Note: t-statistic is shown below estimate 2.

[a]Estimate 1 is average of slopes fitted through each searcher's reservation wage.

[b]Estimate 2 is slope of pooled regression fitted to all data from each group.

*Significant at the 99% level.

are not out of line with the econometric estimates of Kasper (1967).

The fact that our risk averse searchers have what appear to be constant reservation wages is interesting and may again reflect the fact that they exaggerate their degree of risk aversion in the beginning of search. Hence, their reservation wage is already low before they begin search and for that reason may not be lowered as search progresses.

Hypothesis 10: Finite Horizon. In searching in the basic search paradigm with a finite horizon, the reservation wage is a decreasing function of time.

We test for the effects of a finite horizon on search behavior in two ways. First, we compare the behavior of our subjects in Trials 7 and 11 of Group I, in which subjects search from a symmetric triangular distribution with a seven period horizon (Trial 7) and an infinite horizon (Trial 11). The results in Table 10A show the searchers facing a finite horizon searched less, accepted lower wages, and had lower reservation wages and lower "highest rejected wages." (The last two differences are statistically significant.)

TABLE 10A

TESTS OF H^{10} (FINITE HORIZON)

Parameter Tested	Trial Condition		
	Finite Horizon	Infinite Horizon	Difference
Reservation wage	113.25	128.05	14.80*
Highest Rejected Wage	80.35	98.43	18.08*
Accepted Wage	123.35	138.24	14.89
Number of Searches	2.95	3.68	0.73

Note: Comparison of the behavior of Group I, Trials 7 and 11.

*Significant at the 95% level.

TABLE 10B

FURTHER TESTS OF H^{10} (FINITE HORIZON)

Condition	Offer / Period 1	2	3	4	5	6	7
Finite Horizon:							
Mean	60.329	84.466	71.222	73.832	29.147		
Standard Deviation	21.365	22.501	24.003	14.419			
N	13	7	4	4	1		
Infinite Horizon:							
Mean	71.548	85.441	73.444	77.322	69.832	59.548	111.64
Standard Deviation	27.684	25.956	30.634	24.137	29.770	19.447	
N	16	13	8	7	3	3	1

Note: Comparison of the behavior of Group I, Trials 7 and 11. Each entry is the mean of the rejected offers during the first, second, ..., period. The differences between the means of the two groups are not statistically significant in any period.

The second test involved a comparison of the average rejected wages during each search (in effect, during each time period) for the same two trials. For each of the first four searches (periods) the group with the seven search limit has average rejected wages that are below those of the group with unlimited search. These results, shown in Table 10B, are as predicted, but the differences are not statistically significant. The major difference in search behavior is shown in the number of searchers rejecting offers in each period. This series drops off more rapidly in the trial with the seven period limitation.

Hypothesis 11: Unknown Distributions. The reservation wage of a searcher searching from an unknown distribution is at least as great as the searcher searching from a known distribution if the searcher is allowed to include current information into the revised estimate of the distribution he is searching from before he decides to stop or search again.

We are able to test the effects on the reservation wage of changing the searcher's state of knowledge about the underlying distribution of wage offers by making two

separate comparisons of the behavior of our subjects. For the first comparison both groups tested were actually searching from the same symmetric triangular distribution of wage offers, but only one of the groups, Group I, Trial 1 (referred to as "informed"), knew this to be the case. The other group (the "uninformed") were told that they might be searching from any one of four different distributions (Group III, Trial 7). The results show there were no significant differences in the average reservation wages, accepted wages, or highest rejected wages between these two groups (see Table 11).

The second comparison was between two groups searching from right triangular distributions, with one group having been incorrectly told that they were searching from a uniform distribution of wage offers--Group I, Trial 6 (this group is called the "misinformed" group), and the other properly informed (Group III, Trial 6). Here we find significant differences in search behavior; the misinformed group had significantly higher average reservation wages, highest rejected wages, and accepted wages. From these results we draw the conclusion that the effects of having incorrect information are much greater than those of having incomplete information. The consequences that this result holds for labor market policy will be

TABLE 11

TESTS OF H^{11} (UNKNOWN DISTRIBUTIONS

Comparison and Parameter Tested[a]	Knowledge of Distribution: Uninformed	Informed	Difference
Uninformed vs. Informed[a]:			
Reservation Wage	135.87	134.50	-1.37
Highest rejected wage	111.07	123.17	12.10
Accepted Wage	138.22	146.45	8.23
	Misinformed	Correctly Informed	Difference
Misinformed vs. Correctly Informed[b]:			
Reservation Wage	155.00	102.73	-52.27*
Highest Rejected Wage	109.37	66.66	-42.71*
Accepted Wage	134.33	116.14	-18.19*

Note: [a]Comparison of the behavior of Group I, Trial 1 and Group III, Trial 1.

[b]Comparison of the behavior of Group I, Trial 6 and Group III, Trial 6.

*Significant at the 99% level.

explored in a follow-up paper to this one.

Hypothesis 12: Unknown Distribution. Searchers searching in the basic searched paradigm when the distribution of wages they face is unknown tend to search longer than the same searchers when they know with certainly the distribution from which they are searching.

In addition to the predicted change in reservation wage, there is a corresponding predicted change in the number of searches before the subject accepts a wage offer. Our tests of this hypothesis provide results that are complementary to those described (Table 11). Both the uninformed and misinformed groups searched longer than did the corresponding informed groups. For the misinformed-informed comparison, however, this difference was large and statistically significant (8.8 versus 3.08, respectively). In fact, misinformed searchers searched on the average of 8.8 times compared to informed searchers who, when searching from the same distribution, tended to search only 3.08 times. This result is consistent with the theoretical results of Gastwirth (1976), who demonstrates that "optimal sequential search rules" are not robust

TABLE 12

TESTS OF H^{12} (UNKNOWN DISTRIBUTIONS)

EFFECT ON NUMBER OF SEARCHERS

Comparison	Knowledge of Distribution: Uninformed or Misinformed	Informed	Difference
Uninformed vs. Informed	3.40	2.70	0.70
Misinformed vs. Informed	8.80	3.08	5.73*

Note: Comparison of the behavior of Group III, Trial 1 and Group I, Trial 1 (uninformed vs. informed), and Group I, Trial 6 and Group III, Trial 6 (misinformed vs. informed).

*Significant at the 99% level.

rules and run into problems when the searchers are misinformed about the distribution they are searching from. Searchers seemed slow to realize that the distribution they thought they were searching from was incorrect.

Section V

Conclusions

The overall impression that one gets from the results of our experiment is that on average the subjects in our experiment did tend to search in a fashion that was consistent with the search behavior predicted by the reservation wage hypothesis. For what we have called "risk neutral" searchers, this is especially true, since they seem able to set approximately optimal reservation wages and react to changes in the basic search paradigm in the predicted way with statistical significance. What we have called risk averse searchers seemed less able to make the appropriate calculations but, given the calculations they made, they seemed to act as if they had set an optimal reservation wage. Both groups reacted as we would expect them to when the search costs were changed, when the distribution from which they searched became more risky,

the recall option was removed, etc., yet the statistical significance of these results varied.

Our results, like all experimental results, cannot be taken as absolute proof of any hypothesis. In fact, there may be many different theories that could explain the same observed behavior (i.e., see Stigler's seminal articles, 1961 and 1962 , in which a different theory is presented which would predict generally equivalent qualitative results). We made no attempt to compare these theories. However, we can make some comments on the way in which our subjects searched by analyzing their written responses to our questions asking them how they searched in the experiment. Most subjects, when answering this question, stated that they would never accept a wage below a certain minimum amount but also would never search more than 4 or 5 times. (The theoretically expected number of searches in Group I, Trial 1 was 4.5). This type of behavior is actually a combination of the behavior suggested by Stigler (1961, 1962) and the "optimal search strategy" presented in Section II. Consequently, while our data does support the hypothesis that people search according to the reservation wage hypothesis, their behavior may be explained by other theories as well. We leave it to other investigators to construct and test these theories.

References

DeGroot, Morris H. Optimal Statistical Decision. New York: McGraw-Hill, 1970.

Gastwirth, Joseph. "On Probabilistic Models of Consumer Search for Information." Quarterly Journal of of Economics (February 1976), 38-50.

Karni, Edi and Abd Schwartz. "Search Theory: The Case of Search with Uncertain Recall." Journal of Economic Theory, Vol. 16 (1977), 35-52.

Kasper, Hirschel. "The Asking Price of Labor and the Duration of Unemployment." Review of Economics and Statistics (May 1967), 165-72.

Kohn, Meir and Steven Shavell. "The Theory of Search." Journal of Economic Theory, Vol. 9 (1974), 93-123.

Lippman, Steven and John McCall. "The Economics of Job Search: A Survey. Part I," Economic Inquiry, Vol. XIV, No. 2 (June 1976), 155-90.

------- and McCall. "The Economics of Job Search. A Survey.

Part II," Economic Inquiry, Vol. XIV, No. 3 (September 1976), 347-69.

McCall, John. "The Economics of Information and Optimal Stopping Rules." Journal of Business (July 1965), 300-17.

------. "Economics of Information and Job Search." Quarterly Journal of Economics, Vol. 84 (February 1974), 113-25.

Mortensen, Dale. "Job Search, the Duration of Unemployment and the Phillips Curve." American Economic Review, Vol. 60 (December 1970), 847-62.

Nachman, David. "On Risk Aversion and Optimal Stopping." Unpublished paper, Northwestern University (November 1972).

Rothschild, Michael. "Models of Market Organization with Imperfect Information: A Survey." Journal of Political Economy, Vol. 81 (November-December 1973), 1283-308.

----------. "Searching for the Lowest Price When the Distribution of Prices is Unknown." Journal of Political Economy (July-August 1974), 82, 689-711.

---------- and Joseph Stiglitz. "Increasing Risk I: A Definition." Journal of Economic Theory, Vol. 2 (1970), 225-43.

Sakaguchi, M. "Dynamic Programming of Some Sequential Sampling Design." Journal of Mathematical Analysis and Application, Vol. 2 (1961), 446-66.

Salop, Steven C. "Systematic Job Search and Unemployment." Review of Economic Studies, Vol. 40 (1973), 191-201.

Stigler, George J. "The Economics of Information." Journal of Political Economy, Vol. 69 (June 1961), 213-25.

-------. "Information in the Labor Market." Journal of Political Economy, Vol. 70 (October 1962), 94-104.

Telser, Lester. "Searching for the Lowest Price." American Economic Review, Vol. 63 (May 1973), 40-49.