Small Business Economics (2005) 25: 489–504
DOI 10.1007/s11187-004-2277-5

Still Searching (Systematically)[1] for Entrepreneurial Discoveries

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ABSTRACT. We examine how entrepreneurs can search deliberately for discoveries. We use consideration sets to impose constraints on how and where they search. A *consideration set* is a promising set of information channels, which entrepreneurs can select and search based on prior knowledge. To decide how to search the channels in a consideration set, we apply existing mathematical formalism to illustrate a maximal search sequence. Because there is some probability that a search sequence could continue indefinitely, we determine stopping rules. We argue that entrepreneurial search is more feasible within a consideration set than it is in the rest of the world.

KEY WORDS: search, learning, information, knowledge.

JEL CLASSIFICATIONS: D83, M13.

1. Introduction

Entrepreneurs launch ventures in the face of uncertain or incomplete information, sometimes regarding markets that do not yet exist. They may attempt to clarify uncertainty regarding the search for opportunities and their exploitation by finding more information. If the outcome of entrepreneurs' searching were known or predictable, they could manage the search process using the most efficient form of governance. However, in many entrepreneurial settings the distribution of outcomes is simply unknowable, which raises the question of whether their searching for information is a manageable process (Knight, 1933). One way to avoid some uncertainty may be to match their search efforts to markets where an entrepreneur already possesses prior knowledge. This article examines how entrepreneurs can improve their odds of successfully making discoveries by focusing on known information markets, which does not necessarily describe average search behavior. We discuss problems incurred by using search paradigms from three different schools and illustrate an alternative, which we view as more promising.

We begin this article by discussing the role of information in entrepreneurial discovery and how one can search for it in different markets. This discussion is followed by an examination of received search theories. Next, we examine a new theory of systematic search, which postulates that entrepreneurs may be able to search more effectively by restricting their inquiry to known markets. We will see that the problems of calculating a maximal solution for both *unconstrained search* and *searching for what is unknown* occur only if we do not specify how and where entrepreneurs can search for exploitable venture ideas. Next, we model how to search by applying mathematical formalism. Finally, we identify the conceptual parameters of a theory about how entrepreneurs can discover exploitable venture ideas, not necessarily how they typically do search.

2. The role of information

Information is required to discover and exploit venture ideas (Fiet, 1996; Kaish and Gilad, 1991; Shane, 2000). It consists of any element in a system, usually from an entrepreneur's prior experience, which provides meaningful ideas about an observed relationship. Because information can be rare and costly to acquire, we address how to decide how to search for venture ideas that entrepreneurs can exploit to create new wealth. The object of such a search would be to identify a

Final version accepted on June 20, 2004

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discovery, which is a valuable economic opportunity, such as the founding of a new firm, the creation of a new product line, the development of an innovative technology, the satisfaction of an ephemeral market need through arbitrage, or the like (Fiet, 1996). The *exploitation* of a discovery requires the assembly of complementary resources available either internally or in markets. Because search is a precursor to exploitation, this article focuses on the search for discoveries. In focusing on search, we acknowledge that the successful commercialization of a venture idea requires both its discovery and exploitation.

Informational economics suggests that there should be a maximal combination of the quantity and specificity of information upon which the discovery and exploitation of venture ideas depends (Fiet, 1996; Marschak, 1971; Stigler, 1961). However, many theorists have noted that it is impossible to conduct a maximal search if we assume that a search domain is the whole world, which effectively makes it *unconstrained* (Baumol, 1993; Kaish and Gilad, 1991; Kirzner, 1997; Shane, 2000; Shane and Venkatraman, 2000). Thus, Kirzner (1997) argues that we are only left with one search option – to remain alert, in effect being in a reactive mode. The purpose of this article is to introduce constrained, systematic search as a viable option. By searching systematically entrepreneurs can focus on search domains in which they are already knowledgeable and hence increase the probability of finding a discovery.

3. Received search theories

To understand how searching is conducted, it is necessary to understand an entrepreneur's epistemic structure. An *epistemic structure* is the manner in which our minds catalogue information for recall, which can be used to guide searching. There are two primary epistemic structures based on general and specific information. *General information* is widely available in public domains and can be very easily assimilated. Because general information is widely available, entrepreneurs cannot use it to create a competitive advantage. On the other hand, *specific information* is time and sequence dependent, and hence, more difficult for others to appropriate than general information. An entrepreneur can assimilate specific information into his or her epistemic structure and use it to search related information domains. In contrast, if an entrepreneur relies solely on general information, profitable venture ideas may not be found because competing market agents would vie for any above average profits. By focusing on search domains that correspond to an entrepreneur's specific knowledge it may be possible to reduce the number of competing economic agents and increase the possibility of finding a valuable venture idea. Hence, for entrepreneurs to earn an economic profit, they must rely on an epistemic structure consisting of specific information.

The information search literature contains numerous schools of thought, including the Neo-Classical school, the Austrian school and organizational behavior's satisfying and effectuation theories.

3.1. *Neo-classical perspective on search*

Neo-classical economics is an approach for analyzing economic phenomena that assumes optimizing behavior by economic agents, has a predilection for equilibrium analysis and excludes chronic information problems (Cournot, 1960; Pareto, 1906; Smith 1776; Walras 1874). Entrepreneurs operate in information markets that either do not exist or they exist in situations where the information is dispersed so widely that the cost of searching for information is enormous. Although, the neo-classical approach argues that market agents equilibrate markets through fine adjustments in their profit maximizing behavior, entrepreneurs cannot optimize their search functions due to limited information and computational capacity. Under these conditions, entrepreneurs cannot search for opportunities using optimization techniques.

Numerous search experiments conducted by neo-classical economists focus on the risk associated with information search (i.e., a distribution is known) and not its uncertainty (i.e., a distribution is not known). When a distribution is assumed to be known, markets can converge to a competitive equilibrium (Arthur, 1988; Stigler, 1961). However, assuming that a distribution is known may distract our attention from another problem – market agents are incapable of efficiently procuring information or optimizing

their gains (Arrow, 1988; Zeira, 1994). Obviously, such sub-optimal behavior leads to sub-optimal decisions about how to search. Although numerous neo-classical economists have created search models based on subjective probability calculus, such approaches have focused on objects that are already known such as the spare price of a product (Hirshleifer, 1970, 1978; Stigler, 1961). However, it may be possible for entrepreneurs to maximize the value of a search, given the information known to them at a particular time, even if the information is incomplete. Thus, we direct our attention in this article to maximization processes, rather than optimization processes.

3.2. *Austrian perspective on search*

An alternative to deliberate search is alertness. Austrian economists argue that because the object of search is not known it is impossible to conduct a deliberate search (Kaish and Gilad, 1991; Kirzner, 1997; Shane, 2000; Shane and Venkatraman, 2000). Alertness requires constant monitoring of the environment and is largely dependent on being lucky (Demsetz, 1983). Luck plays a major role in alertness because the outcomes of such efforts are more than risky; they are uncertain.

Austrian economists point out that subjective probability approaches do not play any role in simplifying *radical ignorance* involving the environment (Langlois, 1994), which would leave some residual uncertainty. Essentially, radical ignorance occurs when actors do not realize what it is that they do not know. Austrians assume that the very construction of probabilistic expectations is based on knowledge of the world, which is impossible to attain given radical ignorance. Hence, due to bounded rationality an entrepreneur would not be able to define such probabilistic outcomes for the world.

3.3. *Organizational behavior perspectives on search*

Organizational behavior theory identifies two additional perspectives on search viz., satisficing and effectuation. Simon's (1976) *satisficing theory* suggests that individuals search for a solution to a problem and rather than considering all the alternatives in a total solution set, they simply accept the first satisfactory alternative. Simon's (1976) logic is quite complete and convincing. However, although such behavior may be cost-minimizing it is not necessarily optimal or even sub-optimal (or, maximal) because all humanly possible search possibilities, given a budget constraint, might not have been explored.

A maximal search is one that makes the best use of limited resources and capabilities. However, a maximal search is not one that is satisficing because it seeks to find the best available outcome. Also, a maximal search focuses on information assimilation, and the updating one's epistemic structure as new information is available. Hence, compared to satisficing a maximizing search is a dynamic process in which information procurement specifications may change temporally.

Effectuation theory assumes that an entrepreneur, guided by prior knowledge, while looking for valuable venture ideas is able to control future outcomes. If an entrepreneur possessed such a capability, then effectuating a search could work. Controlling the future, an entrepreneur could transform a marginally profitable idea into a successful idea. Hence, a logical implication would be that all entrepreneurs with the ability to effectuate would be successful.

On closer examination, the ability to control future events may only be possible in limited problem space domains, if at all. Markets for information and resources are influenced by numerous factors that are beyond an entrepreneur's control. In large problem spaces, it would be extremely difficult, if not impossible, to control the future and effectuate a discovery.

3.4. *Summary of current perspectives on search*

Theoretical research suggests that markets for information are risky, complex, and dynamic in nature (Hey, 1993; James, 1994; Reinganum, 1979; Stigler, 1961; Zeira, 1994). In addition, these factors are subject to continual change – structurally and temporally. Given the neo-classical route, an entrepreneur will only find an idea in simple, relatively known situations. If an entrepreneur takes the Austrian path, he or she might as well not search because it is precluded by the paradigm. Alertness is the only available Austrian alterative. In the realm of behavioral theory, an entrepreneur stands only a slim chance

at finding a venture idea. Hence, paradigms from these schools can only offer limited advantages for entrepreneurial search.

We argue that the only signals to which an entrepreneur could be receptive are related to his epistemic structure. As a corollary, the set of possible ideas that could match an entrepreneur's pre-existing epistemic structure is determined in advance, which makes it unnecessary to search the entire world for a discovery. Instead, an entrepreneur could guide his or her search toward sources of possible matches with what is already known. We argue that this matching approach could effectively increase an entrepreneur's probability of success. We propose solving the problem of radical ignorance by suggesting that entrepreneurs avoid defining subjective probabilities for problems about which they do not already possess prior knowledge – knowledge that is stored in their epistemic structures.

4. A new theory of systematic search

The complexity of information markets, endogenous epistemic structures, and limited resources dictate that successful entrepreneurs focus on specific search channels if they wish to leverage their epistemic structures. Thus, Fiet et al. (2004) found in a recent study that entrepreneurs who had started at least three successful ventures focused their searching on known information channels – channels that provided access to maximum possible sub-maximality for discovering a wealth creating venture idea.

We use Bayesian logic to understand how knowledge of prior events can limit these risks found in channel searching. Bayes' theorem defines a rule for factoring in additional evidence to reduce uncertainty, thereby leading to an estimate of the probability that a hypothesis is true (Bayes, 1763; Cox 1946). A potential venture idea, V, is an unknown variable and E is an entrepreneur's epistemic structure. As mentioned before, an epistemic structure is a result of past learning and may change structurally and temporally as more information is available. Hence, ex ante, the probability of finding an idea in a channel is $P(V)$, and $P(V|E)$ the posterior probability of V (after conducting the search). Therefore, V is the driving variable, or the cause, and E is the driven variable, or effect. By knowing the causal relationship between E and V, we can infer V from E.

There are several risks associated with channel search. First, an entrepreneur may not select the right channel in which to find an idea. Second, the costs associated with a search may have been improperly estimated. To limit these risks, entrepreneurs can focus on channels with maximum potential based on their prior knowledge and change their search preferences as they learn while searching. Finally, the signals from information channels are subject to dynamic change. Constrained by bounded rationality and facing channel dynamism, entrepreneurs must update their expectations, search objectives and actions on a continual basis.

Entrepreneurs can earn economic profits by discovering valuable specific information that is compatible with their epistemic structures, and not with those of other agents. However, the probability of finding opportunities that are highly exclusive to an entrepreneur's epistemic structure is quite low. On the other hand, risk taking entrepreneurs can trade their uncertainty (alertness) for a comparatively lower risk (deliberate search). Hence, we argue that entrepreneurs can systematically discover ideas despite uncertainties and resource constraints. As entrepreneurs gain experience, they become more knowledgeable about venture ideas and their sources.

4.1. *Information channels*

To the extent that certain sources, or *information channels*, provide access to discoveries, they may also represent an entrepreneur's best chance of conducting a maximal search, despite the possibility that they may also propagate noise that is of little value (Marschak, 1971).

The selection of an attractive information channel depends on the following function:

$$\begin{aligned}&\text{Information Channel Attractiveness}\\&= f\,(\text{Epistemic Structure, Environment,}\\&\quad\text{Cost of Search}).\end{aligned}\tag{1}$$

In order for an information channel to be attractive, it should satisfy each of the criteria in function (1). As an example, suppose an

entrepreneur is trying to develop a market for machinery that can cultivate asparagus in Guadalajara, Mexico. A possible information channel could be a trade emissary at a Mexican consulate in Washington, DC. To succeed in the Guadalajara market, an entrepreneur should possess prior specific knowledge about doing business in Guadalajara, preferably in an industry related to asparagus cultivation. Even if an entrepreneur can draw on an appropriate epistemic structure, the Guadalajara market would still need to be attractive to conduct a maximal search. Finally, the cost of such a search should be within an entrepreneur's budget for searching. Hence the information channel choice is a multiplicative function. Other examples of possible information channels that could inform an entrepreneur's epistemic structure for entering the Guadalajara asparagus equipment market are an entrepreneur's inner circle of friends and confidants, business associates, the U.S. Patent Office, a Mexican trade delegation, weekly trade publications, trade shows, golfing buddies at the country club, and the like.

An advantage of analyzing how entrepreneurs could search information channels, rather than studying how entrepreneurs may be alert to particular venture ideas, is that it becomes mathematically possible to maximize the search of a finite number of channels. Thus, we resolve concerns about optimization or maximization by replacing *the scanning for unknown venture ideas* (i.e., being alert for them) with *the search of known information channels*. The selection of information channels presupposes where future discoveries will lie. It does not precisely specify what they will be. However, we do assume that entrepreneurs who search for them within their known information channels will be more successful than otherwise, due to previously acquired knowledge, which has guided the search.

Another advantage of restricting entrepreneurial search to information channels is that it is consistent with the expectation that entrepreneurs would update their on-going search patterns as they interpret environmental signals. In fact, many studies, in addition to the Fiet et al. (2004) study, indicate that repeat entrepreneurs actually narrow their search efforts to particular areas of interests in anticipation of making discoveries (Baumol, 1993; Bar-Hillel and Falk, 1982; Gaglio, 1997; Gilad, et al. 1988; Hughes, 1978; Keren, 1984; Kaish and Gilad, 1991). The empirical contradiction with received theory that is posed by these studies suggests that it is important to clarify the conditions that would allow search outcomes to be *maximized* – conditions to which repeat entrepreneurs may be able to adapt. Otherwise, we are left with the alternative hypothesis that conducting an optimal search is impossible and largely dependent on luck (Demsetz, 1983).

4.2. *Consideration sets*

A new feature of the current research is the suggestion that entrepreneurs can maximize their searching of information channels by grouping them into consideration sets. A *consideration set* is a promising group of information channels, which entrepreneurs can select and search based on their prior knowledge (Fiet, 1996; Hirshleifer and Riley, 1979; Johnson and Dark, 1986; Keren, 1984; Lopes, 1994). Not only could the selected channels be sources of discoveries, but they could also be sources of information for updating the selection of the channels themselves within a consideration set. An entrepreneur's consideration set would probably be unique based on idiosyncratic, prior knowledge and ongoing feedback signals from previously selected channels.

Someone could protest that limiting entrepreneurial search to known channels is too high a price to pay in missed discoveries that could lie outside a consideration set. Such criticism assumes that entrepreneurs are equally qualified to exploit all venture ideas when we suppose that they vary in their competence, depending on their experience-based prior knowledge (Shane, 2000). Entrepreneurs do not forego discoveries that are not a reflection of their prior knowledge because they are not qualified to exploit them. Nor can rapid preparation substitute very often for prior knowledge due to the ephemeral value of many venture ideas, which is what creates windows of opportunity.

The primary benefit to aspiring entrepreneurs of a consideration set-based approach is that it offers them a choice – they can either exploit a venture idea with their current knowledge or

they can continue searching for more related, informative signals (Fiet, 1996; Hayek, 1945; Hirschleifer, 1970). Because searching for information within a consideration set surely would be less costly (due to economies of scope) and risky than actually launching a venture, this recognition offers them a chance to leverage their resources even if they are minimal. Using this approach, entrepreneurs with fewer resources may be able to compete with those who are more richly endowed.

5. Modeling how to search

Understanding how entrepreneurs could search most efficiently depends on several assumptions. Given that entrepreneurs can develop expectations about the value of a discovery, based on their prior knowledge, we assume that they can search information channels according to their perception of the chances of a venture idea being in a particular channel. In our view, they would not search where they did not expect to find a discovery. We assume that they can assign a probability to an exploitable venture idea actually being in a particular information channel. While searching, we assume that they update their estimate of the cost-effectiveness of each of their search decisions at each stage of the process. The higher the probability of making a discovery and the lower the cost of acquiring information, the more efficient a search would be in its utilization of time and resources.

It is an empirical question as to whether or not entrepreneurs can accurately estimate the probabilities and costs for searching. Fortunately, there is provisional empirical support for the assumption that entrepreneurial behavior approaches a maximum as the information available to a searcher increases (Schotter and Heiner, 1983; Braunstein, 1981). Hey (1987) used laboratory investigations to demonstrate this intuitively appealing result. Conversely, he also found that that behavior becomes increasingly subject to arbitrary "rules of thumb" as information decreases. Because entrepreneurs could select and search information channels based on what they know best, we expect that their selection and searching would approach a maximum.

The modeling of a search depends on the following additional assumptions: First, the prospects for making a discovery in a particular channel can vary. Second, entrepreneurs can adjust the regularity with which they search channels based on their expectations for making a discovery. Third, even within a consideration set, entrepreneurs face some uncertainty about whether they will find a venture idea that they are competent to exploit. Fourth, entrepreneurs can only search one information channel at a time. Fifth, we assume that one or more valuable venture ideas actually exist in one of the channels of an entrepreneur's consideration set.

Even if a venture idea can be found, and is likely to be found, in a particular information channel, there is some remaining uncertainty that an entrepreneur will be lucky enough to discover it. We assume that the probability of overlooking a venture idea would depend on its channel, and would be the same for all searches of that channel, indicating that search outcomes are independent. The probability of identifying an actual discovery would be influenced by an entrepreneur's epistemic structure and the attractiveness of the channels being searched, regardless of how much he or she searches.

5.1. *A formal model for determining a maximal search sequence*

In this section, we determine a maximal search sequence. We base this research on stochastic models developed by Matula (1964), Kadane (1968), Chew (1967), and summarized by DeGroot (1970). An advantage of using a mathematical approach is that it introduces formalism into the analysis, which can provide a basis for identifying the assumptions necessary to conduct a systematic search.

The Matula–Kadane–Chew–DeGroot (MKCD) approach employs very simple semantics: a person searches n boxes for an object. We substitute n information channels for n boxes in order to simulate searching within a consideration set. By making this substitution, we demonstrate how a consideration set-based search can pay off, versus unconstrained, stochastic search, by limiting

inquiry to select information channels. To proceed with this demonstration, we reproduce parts of the analysis presented by DeGroot (1970). We also describe DeGroot's (1970) *optimal* search algorithm because some of its intermediate results can be reasonably interpreted as entrepreneurial search, which provides evidence for the adequacy of the model.

Let $p_i > 0$ $(i = 1, \ldots, r), p_1 + p_2 + \cdots + p_r = 1$ be the *prior probability* (the probability before a search begins) that a discovery is in the *ith* of r information channels. Equating the expression to one means that a valuable venture idea actually exists in one of r channels of a consideration set. Thus, we are assuming channel attractiveness, based on an entrepreneur's prior knowledge. We are also assuming that entrepreneurs can assign probabilities based on prior knowledge. Entrepreneurs do not have to specify the probability of finding an unknown idea from all sources, only the probabilities for familiar, known channels. Nor do entrepreneurs have to specify an exact idea, merely the probability of an idea from a familiar class of ideas being in one of r information channels within their consideration set.

Let $\alpha_i (0 \leqslant \alpha_i \leqslant 1)$ represent the probability that an entrepreneur will overlook a venture idea if it is in an information channel $i (i = 1, \ldots, r)$. Let $c_i > 0$ represent the cost of searching channel $i, i = 1, \ldots, r$.

Our criterion for determining a maximal search sequence for r information channels is to minimize an entrepreneur's expected total search costs. Because the probability of finding a discovery in a particular channel influences search costs, we will now examine these probabilities.

Even if entrepreneurs were to search a channel, j, and fail to make a discovery, despite the failure, they would have acquired information that changes the future probability of a discovery being in one of the channels. Based on Bayes theorem, they can select the next channel to be searched using a revised set of probabilities – the *posterior probability* of a venture idea, being in one of information channels. The posterior probability of a valuable venture idea being in a channel is:

$$p_j^* = \frac{p_j \alpha_j}{p_j \alpha_j + 1 - p_j},$$

$$p_i^* = \frac{p_i}{p_j \alpha_j + 1 - p_j}, \quad i \neq j. \tag{2}$$

Let the expected total cost of searching be $L(p_1, p_2, \ldots, p_r)$, when p_i is the probability that the discovery is in channel $i (i = 1, \ldots, r)$. It consists of the cost of searching one of the channels c_j and the expected cost $L(p_1^*, p_2^*, \ldots, p_r^*)$ for the remainder of a search, assuming that an entrepreneur follows a maximal search routine. That is, the expected total cost of a maximal search routine must satisfy the following recurrence relation (DeGroot, 1970):

$$L(p_1, \ldots, p_r) = \min_{j=1,\ldots,r} \{c_j + (p_j \alpha_j + 1 - p_j) \times L(p_1^*, \ldots, p_r^*)\}. \tag{3}$$

DeGroot's (1970) work demonstrated that arranging the following terms in descending order of magnitude provides the sequence that minimizes the total cost of searching within a consideration set:

$$\frac{\Pi_{ij}}{c_i} = \frac{p_i \alpha_i^{j-1} (1 - \alpha_i)}{c_i}. \tag{4}$$

This result corresponds to the jth search of the ith channel. Furthermore, if a particular ratio Π_{ij}/c_i is the nth highest value in an ordering of information channels, an entrepreneur can minimize his or her search costs by conducting the jth search of channel i at the nth stage. If, at any stage, two or more values of the ratio Π_{ij}/c_i are equal, an entrepreneur would be indifferent about their order. Equation (4) can be considered as the cost-effectiveness of the jth search of channel i.

In summary, to determine the maximal sequence of channels to search within a consideration set, let $p_1^*, \ldots, p_r^*$ be the current posterior probability that a discovery may still be in each of r possible channels, which an entrepreneur can reevaluate after each search, according to Bayes rule. The most cost-effective or maximal channel to search of those in a consideration set will be

the one for which the value of $p_i^*(1-\alpha_i)/c_i$ is the greatest.

5.2. *An example to illustrate a maximal search sequence*

As an example of how entrepreneurs could apply these algorithms, consider the following six hypothetical channels: (1) inner circles of friends and confidants, (2) business associates, (3) U.S patent office, (4) weekly trade publications, (5) trade shows, and (6) golfing buddies at the country club. For each of these channels, Table I contains hypothetical values for p_i, α_i and c_i. Because they chose channels to search that are known to them, we can assume their estimation of α_i, and c_i approaches a maximum (Hey, 1987).

Table II contains values in each cell that represent the cost-effectiveness of a search of the hypothetical information channels. The boxed cells identify a maximal search sequence, given the data listed in Table I. We computed the values for each of the first six stages of the search by using equations (2) and (4). The search actually continues past these six stages, however we deemed six stages to be sufficient to illustrate how to apply these equations.

5.3. *Options for terminating a search*

The rules for terminating a search are the following: (1) exhaust the search budget or (2) find a venture idea, whichever prevails. Ideally, we could terminate a search by optimizing its value. However given the risky, complex, and dynamic nature of information markets it would be simply impossible to rely on optimization techniques as we have suggested earlier. Thus, we are left with these two rules.

At the beginning of any search, entrepreneurs would do well to acknowledge that they might never terminate a search by making a discovery. This could occur for two reasons. First, even in the case that we just considered in which the channels to be searched actually contain exploitable venture ideas $(p_1, +p_2, + \cdots + p_r = 1)$, there is always a small probability that a discovery will not be made in one of the channels. The probability of not finding a discovery can only asymptotically approach zero and will never completely disappear.

A second reason is that entrepreneurs cannot know whether a valuable venture idea of the type they seek really exists within a particular consideration set. Thus, the sum of the probabilities of finding one or more discoveries in one of the channels in their consideration set may be less than one: $p_1, +p_2, + \cdots + p_r < 1$. In this case, even an entrepreneur who is willing to invest any amount of resources in searching may never discover an exploitable venture idea. Entrepreneurs are free to assume that a discovery is in one of $r+1$channels. However this is not helpful to them because channel $(r+1)$ represents the rest of the world. Under conditions of limited resources, they can only search among the first r channels.

We do not see their search budget as being a serious limitation for them because they have a higher probability of discovering an exploitable venture idea in a known information channel than they do of discovering one in the rest of the world. If a search algorithm minimizing the expected cost of searching would indicate that the next channel to be searched would be $(r+1)$,

TABLE I
Hypothetical Information Channels

NO.	Information channels	p_i	α_i	c_i
1	Inner circle friends and confidants	0.05	0.2	5
2	Business assoiates	0.1	0.4	8
3	U.S. patent office	0.35	0.7	10
4	Weekly trade publication	0.05	0.1	2
5	Trade shows	0.25	0.6	6
6	Golfing buddies at the country Club	0.2	0.8	15

p_i is the prior probability that entrepreneurs will discover a valuable venture idea in a given information channel, α_I is the probability that entrepreneurs will overlook a valuable idea in a given information channel within their consideration set and c_i the cost for a one-time search of an information channel within a given information channel.

TABLE II
Optimal search sequence for hypothetical information channels

No.	Information channels	Search stages					
		1	2	3	4	5	6
1	Inner circle of friends and confidants	0.0080	0.0084	0.0094	0.0107	0.0116	0.0025
2	Business associates	0.0075	0.0079	0.0088	0.0100	0.0109	0.0115
3	U.S. Patent office	0.0105	0.0110	0.0123	0.0098	0.0107	0.0113
4	Weekly trade publications	0.0225	0.0024	0.0026	0.0030	0.0033	0.0035
5	Trade shows	0.0167	0.0175	0.0117	0.0133	0.0087	0.0092
6	Golfing buddies at the country club	0.0027	0.0028	0.0031	0.0036	0.0039	0.0041

which is unavailable to them, then the channel with the second largest value of $p_i^*(1-\alpha_i)/c_i$ should be searched next. The fact that a discovery may be in a channel that cannot be searched increases the probability that a particular search will never terminate.

In either of these two cases, a search to find a discovery would have a positive probability of never terminating, making it necessary to determine criteria for stopping. Most stopping problem formulations assume that searchers have two choices: (1) they can stop searching and pay an exit fee or (2) they can continue to pay the cost of further searching (e.g., Chew, 1967).

We propose replacing an exit fee as the terminating constraint with a search budget. A *search budget* consists of an entrepreneur's available resources such as, money, time and effort. Entrepreneurs cannot search indefinitely. Sooner or later they will exhaust their resources for searching, even within the more limited domain of a consideration set. How and when should an entrepreneur decide to stop searching? Without search theory, possibly derived using a mathematical model, entrepreneurs would have to decide intuitively when to terminate a search. They would stop searching when they reached a predetermined budget constraint or when in their view their chances of discovering an exploitable venture idea were very small.

The idea of using a budget to terminate a search seems to contradict the neoclassical ideal of the profit-maximizing entrepreneur who pursues any positive net present value opportunities. The difference in our formulation is that we assume that entrepreneurs face uncertainty about how to actually maximize their search investments. Instead of possessing perfect information about possible outcomes, we expect that our entrepreneurs will encounter some search failures and that it would not be prudent to spend more than they have budgeted, even if they were to be successful searching.

6. Modeling how to stop searching

Modeling when to stop searching requires that entrepreneurs estimate the probability a discovery being in a particular information channel and the cost of searching for it.

6.1. *The probability of making a discovery*

Entrepreneurs can divide their searching into stages. A *stage* represents the one-time search of a single channel within a consideration set. After each stage, an entrepreneur can reevaluate the probabilities of discoveries being in each channel as indicated by equation (1). Thus, we can conceive of entrepreneurial search as a multi-stage process, when at each stage k, there are corresponding probabilities of making discoveries $\{p_{kj}\}, j = 1, \ldots, t_r;\ k = 1, 2, \ldots$ If p_{kj} is a probability of a discovery being in a channel j searched at stage k, the probability of not making a discovery is $p_{kj}\alpha_j + 1 - p_{kj}$. Entrepreneurs may continue searching if they fail to make a discovery at a particular stage. Eventually they reach a stage, m, if they have failed previously, yet continued to search. The probability of not making a discovery until the current stage m is a product of all the probabilities of not making discoveries at previous stages. At the same time this probability

can be considered as the probability that an entrepreneur would continue a search if he or she has not already given up without making a discovery. Thus, the probability q_m of continuing to search at stage m is:

$$q_m = \prod_{\substack{k=1 \\ j \in S}}^{m-1} (p_{kj}\alpha_j + 1 - p_{kj}), \tag{5}$$

where S is a sequence of channels searched.

6.2. *Search costs*

Because there is no way of reducing equation (2) to a closed form, instead of using the expected cost, we will use the cumulative expected cost or build-up function of the expected cost of searching, which takes the following form:

$$L(n) = \sum_{k=1}^{n} q_k c_k, \qquad n = 1, 2, \ldots \tag{6}$$

We will use equation (6) as an aid in deciding when to terminate a search. Such a decision could occur in three different situations.

6.3. *Unlimited resources with no budget constraints*

Given unlimited resources and no budget constraints, only the probability of making a discovery matters, which means that a level of *confidence* Q (the level of probable success that an entrepreneur is willing to accept) can be used as a criterion for stopping. In this case he or she should continue searching until reaching stage m_q which is the smallest value of m for which the following inequality holds:

$$\prod_{\substack{k=1 \\ j \in S}}^{m} (p_{kj}\alpha_j + 1 - p_{kj}) \leqslant 1 - Q, \tag{7}$$

where S is a sequence of search channels and m_q corresponds to the first stage when the probability of making a discovery exceeds Q, which can be determined in advance.

6.4. *Limited resources with a budget constraint*

An entrepreneur can determine using a budget B how many search stages m_b he or she can afford, where m_b is the largest integer m satisfying the following inequality:

$$\sum_{j \in S}^{m} c_j \leqslant B. \tag{8}$$

After m_b stages, the search budget B has been spent and the search must be terminated. The probability of making a discovery within m_b searches is

$$q_{m_b} = \prod_{\substack{k=1 \\ j \in S}}^{m_b} (p_{kj}\alpha_j + 1 - p_{kj}) \tag{9}$$

and can be used to justify whether a search budget could provide sufficient chances for making a discovery. According to DeGroot (1970), *the expected total cost of a maximal search* $L(p_1, p_2, \ldots, p_r)$

$$L(p_1, \ldots, p_r) \leq (c_1 + \cdots + c_r) \sum_{i=1}^{r} \frac{p_i}{1 - \alpha_i} \tag{10}$$

satisfies the following inequality:

This inequality provides a rough upper bound for expected search costs and can also be used while determining a search budget.

6.5. *Both a budget and probability constraint*

When entrepreneurs commence a search, they are presumably interested in more than just having an adventure. Their objective is to make a discovery. Nevertheless, they must acknowledge the stochastic nature of search, even within a consideration set. They can pre-select a level of confidence Q that reflects their desired probability of making a discovery. This is a probability that must be less than 1; otherwise a search could continue indefinitely. However, to locate a discovery while searching a particular channel with confidence level Q, an entrepreneur must still possess all of the resources specified in his or her search budget. In addition, the

confidence level Q of making a discovery limits the number of stages m_q that an entrepreneur can afford to search. To conduct mq stages of search requires $C_{m_q} = \sum_{j \in S}^{m_q} c_j$, resources, where S is. a sequence of searched channels. If a search budget B were set at this value, it would indicate that an entrepreneur was pessimistic about dismissing the adverse role of luck. He or she would demonstrate more optimism by budgeting a smaller amount, such as $C^*_{m_q} = \sum_{j \in S}^{m_q} q_j c_j$, representing the expected cost of searching the first mq stages of a maximal sequence. With these resources, an entrepreneur can conduct m^*_q stages of search with probability $Q_m < Q$ of making a discovery. Even after carefully considering their level of confidence in making a discovery and their search budget B, entrepreneurs may still fail in their search for an exploitable venture idea.

When both a budget and a probability constraint matter, an entrepreneur specifies both Q and B. The confidence of making a discovery, Q. limits the number of searched stages m_q according to equation (7). A search budget B must be sufficient to provide for at least m_q searches. That is, the corresponding B should be such that $m_b > m_q$. In this case we would apply a different constraint for terminating a search. It would require that each time an entrepreneur begins to search a new channel, say $m + 1$, that he or she evaluate the cost of searching, which includes the cost of the first m stages (C_m) of failed searches, together with the expected cost of further search (L_{m+1}):

$$E_m = C_m + L_{m+1} = \sum_{j \in S} c_j + \sum_{\substack{k=m+1 \\ j \in S}}^{\infty} q_k c_j. \qquad (11)$$

Let n_s be the largest value of n such that

$$\sum_{j \in S} c_j + \sum_{\substack{k=m+1 \\ j \in S}}^{n} q_k c_j \leqslant B, \quad n = m+1, \ldots \qquad (12)$$

If $n_s > m_q$ an entrepreneur may continue searching because when cumulative, expected search costs exceed the budget, the respective probability would be larger than the confidence level Q. If $n_s \leqslant m_q$, an entrepreneur would stop searching because the budgeted resources would be spent even though the confidence level Q had not been reached. Note that the value of ns can be determined in advance using the model.

6.6. *An example to illustrate criteria for terminating a search*

Let us consider in more detail the search problem presented previously in of Table I. We will demonstrate how a consideration set-based search could be analyzed and the decision support that a formal model could provide while searching. By decision support we are referring to the fact that it would not actually be necessary to conduct a search in order to determine a maximal search sequence.

Table III illustrates a truncated search sequence, which contains a complete 18-stage search. The row labeled *search channel* lists the same channels by numbers that are detailed in Table I. Recall that these were the same channels indicated for searching by the maximal search sequence procedures that we derived earlier. The first six stages in Table II correspond to the stages in Table I.

In Table III, the row labeled *probability of not making a discovery* contains the probabilities q_m of not making a discovery until the current stage m, which are also the probabilities of continuing the search. For example, after 18 stages, there is a probability of 21.5% that the plan would not have detected a valuable venture idea.

As a review, we have considered three different constraints that impact stopping a search: (1) unlimited resources, (2) budget constraints, (3) specified budget and confidence levels. We will review each of these cases in the same order. First, suppose that an entrepreneur with unlimited resources wants to make a discovery with a confidence level of 0.75. According to inequality (5) and the example in Table I, it may require as many as $m_q = 17$ stages to reach Q. If an entrepreneur were to search 17 stages without making a discovery, he or she would have to decide whether to search further. It might be safer to terminate the focal search because it is possible that the assigned probabilities could be inade-

TABLE III
A multi-stage search plan using a truncated search sequence

	Stage of search																	
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Search channel	4	5	3	5	1	2	3	5	3	3	5	2	6	3	4	5	6	3
Search costs ($ in hundreds)	2	6	10	6	5	8	10	6	10	10	6	8	15	10	2	6	15	10
Probability of not making discovery at previous stages (%)	95.5	85.5	75	69	65	59	51.6	48	42.9	39.3	37.1	34.7	30.7	28.2	27.8	26.5	23.3	21.5
Expected total costs at stage 1 ($ in hundreds)	7.73	16.3	20.8	24.2	29.4	35.3	38.4	43.2	47.5	49.9	52.9	58.1	61.1	61.7	62.4	67.3	69.7	72.9
Cumulative expected cost estimated at stage 10 ($ in hund.)	2	8	18	24	29	37	47	53	63	75.4	78.3	83.5	86.6	87.2	88.8	92.8	95.1	98.4

quate to preclude a discovery being found in the rest of the world.

Second, if only a budget were to matter to an entrepreneur, then he or she could specify an amount and then use inequality (6). If B were = \$9,000, then according to inequality (7), it would only allow $m_q = 12$ search stages. Table III could be helpful in establishing a budget. It contains the cumulative, expected cost (the last two rows), estimated at the first stage ($m = 1$) for different $N = 1, \ldots, 36$. Using the data in Table III, entrepreneurs can budget \$9,000, lmowing that this level of investment would guarantee them a discovery with a probability larger than 65%.

Third, when both a budget and a confidence level matter, consider the case of an entrepreneur desiring to make a discovery with a 75% probability of success. This would correspond to $m_q = 17$ search stages. Refer to inequality (7) or the 3rd row of Table II, which contains the probability of not making a discovery before each stage. The probability of making a discovery within 17 stages is 76.5%. Using inequality (10), we deduce that $m = 9$ is the first stage for which $n_s \leqslant m_q = 17$. This result means that after nine unsuccessful search stages and spending \$6,300, an entrepreneur would understand that the expected cost of searching until $Q = 0.75$ (or until $m_q = 17$) is greater than the remaining resources still budgeted for searching. In this case an entrepreneur should stop searching because his or her search budget would be exceeded after 16 stages and would corresponds to a probability of making discovery that is less than 75% (see the last row of Table III). Therefore, if an entrepreneur's desired level of confidence in making a discovery were 75%, he or she would stop searching after failing at the first nine stages.

7. Discussion

This paper has discussed how uncertainty and incomplete information serve as obstacles to entrepreneurs searching for discoveries, which are partially a requirement for their earning above average profits. These obstacles exist because markets for information are risky, complex, and dynamic in nature (Hey, 1993; James, 1994; Reinganum, 1979; Stigler, 1961; Zeira, 1994). In

addition, the factors underlying the operation of these markets are subject to continual change – structurally and temporally.

We have examined the limited guidance offered by received theory to assist entrepreneurs with their searching. Using neo-classical economics, an entrepreneur will only find an idea in simple, relatively known situations. Using Austrian economics, an entrepreneur would do well not to search because it is precluded by the paradigm. Alertness is the only available Austrian alterative. Using satisficing or effectuation theory, an entrepreneur stands only a slim chance at finding a discovery. Hence, paradigms from these schools can only offer limited advantages for entrepreneurial search.

We argued that the only signals to which an entrepreneur could be receptive are related to his epistemic structure. As a corollary, the set of possible ideas that could match an entrepreneur's pre-existing epistemic structure is determined in advance, which makes it unnecessary to search the entire world for a discovery. Instead, an entrepreneur could guide his or her search toward sources of possible matches with what is already known. We argue that this matching approach could effectively increase an entrepreneur's probability of success. We propose solving the problem of radical ignorance by suggesting that entrepreneurs avoid defining subjective probabilities for problems about which they do not already possess prior knowledge – knowledge that is stored in their epistemic structures.

We have demonstrated that entrepreneurs may determine a maximal search sequence for discoveries, as well as an effective termination criterion. If we are correct, we have effectively explained how to help entrepreneurs to decide how to search for discoveries. Our demonstration was based on searching within a consideration set of known information channels, which increases the odds of entrepreneurs effectively assigning probabilities and costs for maximal searching. We have argued that the assignment of these probabilities and costs is more feasible within a consideration set because of their prior knowledge of the information channels than it is in the rest of the world. We have not demonstrated that entrepreneurs actually can conduct such a search because it is an empirical question as to how effectively they can estimate prior probabilities and costs. However, we have extended the intuitively appealing work of Hey (1987) to demonstrate how entrepreneurial search could reach a maximum level. We have noted that repeat entrepreneurs tend to narrow their search domains.

We based this research on an informal search model, which was an application of existing mathematical formalism. We draw several inferences from this application, which are important to students, aspiring entrepreneurs and scholars. First, entrepreneurs can replace *the search for unknown discoveries with the search of known information channels*, which removes the suspected obstacles from conducting a maximal or optimal search. Second, entrepreneurs can systematically search the channels in their consideration set, which may lead to a maximal solution. Third, signals leading to the discovery of exploitable venture ideas are not equally valuable, nor widely available. Fourth, differences in signals create both acquisition risks and opportunities. Fifth, an entrepreneur's primary task is to maximize his or her investment in the acquisition of specific signals. Sixth, one way to 'minimize the risk of signal acquisition is to search known information channels, which we have grouped into a consideration set. Seventh, signals must be exploited in order to be valuable. Eighth, aspiring entrepreneurs can use consideration sets to estimate a search budget with a given level of confidence of discovering an exploitable venture idea. Ninth, assuming that entrepreneurs can reliably estimate a search budget, this would provide them with an effective tool for evaluating their options – either (1) exploiting immediately a known discovery or (2) searching more to refine it or discover another.

7.1. *Empirical testing*

It is an empirical question as to whether aspiring entrepreneurs can estimate prior probabilities and search costs. Thus, the next step would be to conduct a test by comparing the performance of randomly selected groups – one that was trained in the use consideration sets, based on a careful assessment of their prior knowledge, and the other, a control group that would attempt to be alert to potential discoveries.

A precursor to controlled tests is to develop assessment techniques to assist aspiring entrepreneurs to understand their prior knowledge as expressed in the form of idiosyncratic competencies. An underlying premise of this research is that aspiring entrepreneurs are most competent to discover exploitable venture ideas that are related to their prior knowledge. In fact, the selection of information channels that constitute a consideration set depends crucially on an entrepreneur understanding his or her own prior knowledge. It is not enough to say that searching consideration sets leads to the discovery of exploitable venture ideas; it is important to show that it leads to more discoveries than an unsystematic approach, could generate because many discoveries may result from being lucky (Demsetz, 1983).

One of the obvious difficulties with conducting a comparative test is convincing a control group that it is really the treatment group. Consider- how difficult it would be telling subjects to go forth and be lucky and then report back the results of how many discoveries that they made. If it were possible to teach subjects to be lucky, it would not be viewed as such a rare commodity. Thus, one necessary step in testing a consideration set-based approach is to develop a convincing cover story to be used while training subjects.

7.2. *Implications*

This research has implications for students and aspiring entrepreneurs. Here are a few of these implications. First, the chances for entrepreneurs of making discoveries are greater within a consideration set than in the rest of the world. Second, entrepreneurs would have different consideration sets based on their prior knowledge. Third, entrepreneurs are not equally equipped to discover or exploit venture ideas. Fourth, if entrepreneurs can evaluate their prior experience, they can use it to select their own, probably unique consideration sets, which could endow them with a competitive advantage. Fifth, entrepreneurs can update their consideration sets as they process information. Sixth, searching using consideration sets may make it affordable for more people to make their own discoveries, which suggests that more people could be entrepreneurs.

This research is important for scholars because it offers evidence that a maximal search is possible, given the constraints that we have placed on the search problem. As Schumpeter expressed it, "... [as] innovation itself is being reduced to routine. ... so many more things can be strictly calculated that had of old to be visualized in a flash of genius" (1947, p. 132). One way to view the use of consideration sets is as the routinization of the discovery process, which does not diminish their idiosyncratic nature nor potential for discovering ideas for wealth creation (Baumol,1993). Although making discoveries will never be routine, we look forward to the greater routinization of the discovery process that Schumpeter (1947) anticipated.

Notes

[1] In 1987, John Hey published a seminal article titled, Still Searching. The present research is an application and extension of his work. He provided laboratory evidence that as an entrepreneur obtains information, his search behavior approximates optimality, which is very intuitively appealing result.

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[3] Professor Alexandre Piskounov died unexpectedly in July 2004. This article is published posthumously in his honour. He leaves a devoted wife and a son who is studying to be mathematician.

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