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Inventor Perseverance after Being Told to Quit: The Role of Cognitive Biases

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ABSTRACT

We find that approximately one third (29%) of independent inventors continue to spend money and 51% continue to spend time on projects after receiving highly diagnostic advice to cease effort. Using survey data from actual inventors, this paper studies the role of overconfidence, optimism, and the sunk-cost bias in these decisions. We find that inventors are more overconfident and optimistic than the general population. We also find that optimism and past expenditures increased perseverance after being told to quit, while overconfidence in judgment ability had no effect. After being told to quit, optimists spend 166% more than pessimists and those having already spent, for example, \$10 000 spend another \$10 000. Copyright © 2007 John Wiley & Sons, Ltd.

KEY WORDS inventor behavior; sunk-cost bias; optimism; overconfidence; decision biases

INTRODUCTION

The expected internal rate of return to invention by independent inventors is negative and switching to self-employment reduces lifetime earnings by 35% (Åstebro, 2003; Hamilton, 2000). Even in the face of these statistics, inventors still invent and entrepreneurs still start new businesses. For example, in 2003 in the United States, independent inventors represented approximately 15% of the creators of patented inventions (USPTO, 2004).[1] If these activities have lower expected returns than the next best alternative, why do inventors invent and entrepreneurs start new businesses?

One reason that has been offered is that entrepreneurs are unrealistic optimists and that they greatly overestimate their abilities and likelihood of success (Arabsheibani, de Meza, Maloney, & Pearson, 2000).

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[1]In Canada, evidence points to an even more significant proportion of independent inventors. By the end of the 1970s approximately 42% of patented inventions of Canadian origin originated with individuals, a finding at least partially explained by Canada's reliance on firms in resource-intensive sectors that have low R&D activity (Amesse *et al.*, 1991.)

Others conclude that entrepreneurs are strongly motivated by non-pecuniary benefits (Blanchflower & Oswald, 1998; Frey & Benz, 2002; Hamilton, 2000), others raise the possibility that inventors are ''skewness lovers'' who are holding out for the small chance to ''strike it rich'' (Åstebro, 2003). Rather than look at entrepreneurs, we examine independent inventors' decision-making and why a significant number of these inventors continue spending time and money on projects after obtaining highly diagnostic advice to terminate their efforts.

This population provides an excellent quasi-experimental design where we can study the effect of decision biases ''in the wild'' on a unique pool of decision makers under relatively controlled conditions. In order to explain why many inventors continue to throw good money after bad, we evaluate three of the most robust of decision-making biases pointed out in previous research: overconfidence, optimism, and the sunk-cost bias. We examine how these three biases affect two real and economically important decisions: how much money and time to spend on further development after obtaining advice to stop. We also examine differences between the inventor population and a matched sample drawn from the general population with respect to their degree of overconfidence and optimism.

THREE COMMON DECISION-MAKING BIASES

Overconfidence, optimism, and the sunk-cost bias have been shown to be important predictors of decision-making errors in a number of experimental studies and across various contexts. Some of these common biases have also been offered as the reasons for why people enter into entrepreneurship. For instance, Camerer and Lovallo (1999) show that students in an experiment forecasted below zero profits due to excess entry, but entered anyway and were more likely to enter when they performed well on a skills test. They explain this as an optimistic bias coupled with a neglect of the behavioral intent of others. In a similar experiment Moore and Cain (2004) show that entrants are greater optimists when the skill test is easy, thereby inducing greater rates of entry and lower post-entry profits. These authors go on to propose that the excess entry and low returns in industries such as restaurants and convenience stores are caused by excess optimism coupled with perceived task simplicity. For this study, we hypothesize that optimism will play a role when an inventor is estimating the expected return from his or her invention, while overconfidence will play a role when he or she is evaluating his or her skill at being able to successfully develop an invention.

We also predict that previous expenditures on an invention will drive an irrational escalation of commitment to a project. This is particularly damaging to inventors who receive advice to terminate development. This is not related to optimism over the payoffs to the invention, or overconfidence in judging the probability of success, rather it is simply a function of past expenditures. Each of these effects on the decision to continue will be expanded on below.

Optimism

Many people display a consistent belief that they are less likely than others to suffer from bad events and more likely to experience positive events (Weinstein, 1980). Such beliefs lead people to overestimate positive outcomes and underestimate negative outcomes. This optimistic bias has been shown across many domains, cultures, and age groups (Weinstein & Klein, 1995). Research has shown that entrepreneurs (who often start out as inventors) are more optimistic than employees about their future earnings, even though they actually realize lower earnings (Arabsheibani et al., 2000). We believe that inventors will suffer from a similar decision-making bias as entrepreneurs and that inventors will be more optimistic than a cross-section of similar people selected from the general population.

Our argument is one of self-selection and follows that made by de Meza and Southey (1996): because of the inherent unpredictability of returns from invention, only the extremely optimistic will choose to exert

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effort on such activities. In addition, we rely on Weinstein (1980) who argues that two conditions must be fulfilled for an optimistic bias to arise: (a) the event is perceived as controllable and (b) people have some degree of commitment or emotional investment in the outcome. Both conditions are likely to occur for inventors. Our hypotheses also build on research by Taylor and her colleagues (Taylor & Lobel, 1989) who find less realistic expectations about events the individual believes they can control, versus less optimistic expectations about events the individual cannot affect. We believe that since inventors themselves put in most of the efforts and resources to commercialize their ideas, inventors will believe that they have control of the innovation process.

Hypothesis 1: Independent inventors are more optimistic than the general population.

An optimistic bias would raise the perceived expected return on an invention, either by an increased perceived probability of success and/or by an increased subjective expected return conditional on succeeding to commercialize the invention. This would raise the subjective expected value of continuing with the project and tend to make inventors spend more on their projects. In line with this hypothesis, Cooper *et al*. (1988) found that 81% of all entrepreneurs believe their chance of success to be 70% or above, while in actuality 2/3 of businesses fail within the first 4 years.

Furthermore, optimism has been found to be quite resistant to many debiasing interventions such as making people aware of the risks, changing the presentation mode of the risks, changing the intensity of the risks, and generating reasons why these risks might occur (see Weinstein & Klein, 1995, for a review of these studies). Consistent with the idea that debiasing optimists is difficult, we propose that optimistic inventors would pay little attention to advice that asks them to break their behavior and stop spending more. Since we are only interested in the decision to continue in the face of receiving advice to cease efforts, we do not make any prediction about the effect of optimism on those who receive advice to continue, since in this case continuing is the correct decision. We extend previous research by not simply measuring beliefs, but by measuring actual behavior.

Hypothesis 2: Inventors with higher levels of optimism will be more likely to continue spending time and money after receiving advice to stop activity.

Overconfidence

Overconfidence is considered one of the most robust of all decision-making biases (DeBondt & Thaler, 1995). Individuals display overconfidence in two ways, both representing an inflated sense of accuracy or ability in a specific domain. The first display of overconfidence is the use of too narrow a credible interval when making predictions. For example, when asked to create an interval such that there is a 90% chance that they are correct, people often set intervals that contain the correct value only 50% of the time (Lichtenstein, Fischhoff, & Phillips, 1982). Overconfident individuals are also shown to overestimate their accuracy on a general knowledge test. These same researchers found that individuals, who thought they were right 80% of the time were, on average, only correct 60% of the time. It is also interesting to note that experience does not necessarily make people more accurate, but it does make them more confident in their ability (Camerer & Johnson, 1991). Overconfident forecasts have been documented across a variety of decision-making situations and decision-makers (Griffin & Tversky, 1992), and we expect that inventors forecasting the success of their invention would also display overconfidence.

Overconfidence may be such a robust phenomenon because of the many potential causes for it found in the decision-making literature. Early work on overconfidence hypothesized that a lack of meta-knowledge was the reason for overconfidence (Oskamp, 1965). Another source of overconfidence arises from a phenomenon known as the confirmation bias (Jonas, Schulz-Hardt, Frey, & Thelen, 2001; Klayman, 1995; Klayman & Ha, 1987; Koriat, Lichtenstein, & Fischhoff, 1980). A third source of overconfidence comes from ease of recall

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biases (Kahneman & Tversky, 1973). We expect that all of these potential sources of overconfidence will be present in the population of inventors.

If an inventor has inappropriately high beliefs in his or her ability to bring a product to market, this will raise the subjective expected value of continuing with the project. There are two hypotheses originating from this prediction. First, because of the inflated subjective expected value to invention held by overconfident individuals we expect a self-selection effect introducing higher levels of overconfidence among inventors compared to a cross-section of similar people selected from the general population.

Second, we expect that the inflated expected value to invent held by overconfident individuals will make an overconfident inventor more likely to spend additional time or money on developing the invention, even when they are advised to stop. Even while the overconfident inventors may use Bayesian updating taking into account advice to stop, which will then reduce the subjective expected value, those with greater overconfidence will have stronger priors that will weigh more favorably in terms of continuing with development efforts. As with optimism, we are making no prediction for those who receive positive advice since continuing in this case is the correct decision.

Hypothesis 3: Independent inventors are more overconfident than the general population.

Hypothesis 4: Inventors with higher levels of overconfidence will be more likely to continue spending time and money after receiving advice to stop activity.

It should be noted that we believe that overconfidence and optimism are different, even though many have claimed that they are at least highly correlated, while others have even questioned whether they are different constructs. In this research, we believe that optimism is a more global construct, in other words, a general feeling that good things will happen to a person. Overconfidence on the other hand would apply to an inventor's perceived ability rather than an overall measure of belief in the expected occurrence of positive outcomes. Furthermore, we posit that optimism has a direct effect inflating the subjective expected value of inventing, while the effect of overconfidence is indirect by first affecting the inventor's sense of beliefs that he or she is able to bring the product to the market. Since the second effect is more indirect it may be more difficult to detect in this study.

Sunk-costs

One final decision making bias that we predict has an effect on inventors' investment behavior is that of commitment to sunk-costs. Inventors who increase commitment to the project after being told the marginal costs will exceed the marginal benefits are influenced by an irrational escalation of commitment, often called the sunk-cost bias. One argument advanced to explain the escalation phenomenon is the concept of self-justification; where an individual stays committed to justify a past decision (Brockner & Rubin, 1985; Staw, 1976). Another argument is based on the psychology of sunk-costs, which argues that people are more likely to spend money on a project simply because money has been spent on it in the past (Arkes & Blummer, 1985).

Some researchers have challenged studies on sunk-costs arguing that information about sunk-costs was confounded with information about level of project completion (Boehne & Paese, 2000; Conlon & Garland, 1993; Keil, Mann, & Rai, 2000; Moon, 2001). Nevertheless, the sunk-costs bias has been shown to be persistent. For example, Tan and Yates (2002) show that escalation effects occur among experienced participants even when explicit future costs and benefits are provided to them.

Our quasi-experimental design takes advantage of the fact that a recommendation to terminate indicates that the marginal benefits of continuing are expected to be very low. We would thus expect low invention quality to lead to no post-advice investments, unless the decision-maker is biased. High-quality inventions that are recommended to go forward, on the other hand, should rationally have both higher pre- and

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post-advice investments. For those who receive advice to continue it is likely that pre- and post-advice investments are positively correlated, simply because these are good inventions to invest in. We therefore only formulate a hypothesis regarding the sunk-cost bias for those who receive advice to terminate their projects. For this subset we interpret any remaining effect of pre-advice investment on post-advice investments as an indication of sunk-costs.

Hypothesis 5: Higher levels of pre-advice investment will lead to higher levels of post-advice investments for inventors advised to terminate their projects.

DATA SOURCE

We gathered information from actual inventors who had sought advice from the Inventors' Assistance Program (IAP) at the Canadian Innovation Centre (CIC). This center was initially established in 1976 at the University of Waterloo in Waterloo, Ontario, Canada to help evaluate early stage inventions and the likelihood of market success (Åstebro & Bernhardt, 1999; Åstebro & Gerchak, 2001). By 1994 the Canadian IAP had a very strong presence as a trustworthy and dominating supplier of unbiased invention evaluation in Canada. The system they used to evaluate inventions was developed by Professor Gerald Udell at the Oregon Innovation Center in 1974 as critical for the success of inventions and was based on accumulated innovation research at that time (Udell, 1989).

The Canadian IAP evaluates potential entrepreneurs and their projects on 37 different cues and provides advice on how and whether to continue. To have a project evaluated, the entrepreneur fills out a questionnaire and pays a moderate fee ($250 USD in 1994, $750 USD by 2001). In addition to background information about the entrepreneur, the questionnaire asks for a brief description of the idea and supplementary documentation such as patent applications, sketches, and test reports. An in-house analyst compares the project with other similar projects in their library of previous reviews and other various databases. Personal contact with the entrepreneur beyond the provided documentation is avoided by the analyst to ensure that these discussions do not bias the evaluation. In addition to scores on the 37 cues, the analyst also derives an overall score for the project using intuitive judgment and assigns one of five possible scores shown in Table 1.

Columns 2 and 3 of Table 1 report the frequency distribution of the IAP's overall rating from a survey conducted prior to this study (Åstebro, 2003). A majority of ventures (75% with rating "D" or "E") were advised to terminate efforts, 2% received the most favorable overall score "A," 4% were given an intermediate positive recommendation "B," and 19% were advised that the project is suitable to launch as a limited (i.e., part-time) effort "C." Column 6 reports similar frequencies found in our study, with 1% receiving an "A" rating, 7% receiving "B," 15% receiving "C," 74% receiving a "D," and 3% receiving an "E." We code "D" and "E" as 'cease activity' ratings.

Table 1 also reports the probability of commercialization for each of the different overall scores (column 4). As seen, the probability of commercialization is strongly correlated with the IAP advice, with a clear difference between those rated D and E (advised to stop) and those rated A, B or C. These data provide evidence of the high diagnosticity of the advice. Other research has shown that both positive and negative advice have similar prediction accuracy rates. In a survey of 559 projects the IAP correctly forecasted 75.0% of the successes and 79.4% of the failures (Åstebro & Koehler, forthcoming). This means that both types of advice (continue and cease) are approximately equally reliable. Column 5 shows that the advice is highly diagnostic of the financial returns conditional on commercializing the invention. None of those rated E reached the market so returns for those cannot be calculated and the return among those rated D was negative 28.5%. Given this high level of diagnosticity, inventors who receive negative advice (e.g., a "D" or an "E") should cease developmental efforts and move on to other activities rather than spending additional time and money on an unlikely success.

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Table 1. Base rates and diagnosticity of invention reviews by the Canadian IAP, 1976-1993

Rating (1)	Sample total (2)	Percent of all (3)	Probability of commercialization (4)	Median return among commercial* (5)	Distribution of 1994–2001 sample (6)
A—recommended for development.	24	2%	50%	26.0%	1%
B—may go forward, but need to collect more data.	45	4%	16%	26.0%	7%
C—recommended to go forward, returns likely modest.	204	19%	16%	−13.2%	15%
D—doubtful, further development not recommended.	657	60%	4%	−28.5%	74%
E—strongly recommend to stop further development.	163	15%	0%	N/A	3%
Weighted average			7%	−7.3%	
Total	1091	100%			

N/A: No inventions succeeded. Return on investment is not applicable, or alternatively, negative infinity.
Data for columns 2–5 obtained from Åstebro, (2003.) Data for this survey reported in column 6.
*Data for inventions rated A and B not possible to compute separately. Numbers on returns are for A and B combined.

Table 2. Fraction of inventors spending a certain percentage of total resources after receiving a negative evaluation

Percentage of total resources expended after receiving advice to stop efforts	Fraction of inventors spending that amount of money	Fraction of inventors spending that amount of time
0%	71%	49%
1%–20%	3%	26%
21%–40%	6%	9%
41%–60%	8%	6%
61%–80%	4%	5%
81%–100%	9%	5%

The table describes the fraction of inventors spending a certain percentage of all resources on the invention after obtaining negative advice. For example, 9% of all inventors spent between 81% and 100% of their total money after being told to quit.

While the inventors did not know the base rate accuracy of the IAP during the study period, we believe that inventors would not willingly pay a fee of up to $1000 if they did not believe in the value of the advice. This payment is large in relation to the total amount of money they have put into the invention's development up to that point (on average Cdn. $6755). Outlays of such a large amount for the advice signifies that inventors must have held some *ex ante* belief of its value.

The phenomenon we are studying can be seen in Table 2, which shows the spending of resources for inventors who were given advice to cease effort (rating D or E). The first column shows the ranges of percentages that inventors spent after obtaining the advice to cease development. The next two columns show the fraction of inventors who spend that percentage of resources. Even though most inventors who receive the advice to terminate their efforts follow that advice (71% and 49% for money and time, respectively), a significant proportion of inventors continue to invest time and money in these endeavors. That is, *ex post*, some pay no or little attention to the advice to stop. We expect that differences in overconfidence, optimism, and the sunk-cost bias across inventors can at least partially explain these behaviors.

Survey population

Using records from the Canadian Innovation Center, we developed a list of 5008 inventors who had submitted ideas for IAP review between 1994 and 2001. Of this number, we were able to trace 1352 current addresses. Of these, 1272 addresses led to actual contacts. The Survey Research Centre at the University of Waterloo was able to interview 830 respondents, 780 of which fully completed the survey for an overall adjusted response rate of 61%. The adjusted response rate is calculated as the contact rate (1272/1352) multiplied by the cooperation rate (830/1272).[2]

To examine whether inventors have greater decision-making biases than the general population, we also obtained telephone survey data from a comparison pool of 300 Canadians. The sample frame was a set of random household telephone numbers, stratified by province. The sample was selected to approximate the distribution of gender, age, and work experience obtained in the inventor sample. Sample quotas were set to mirror the distribution of the inventor sample obtained approximately halfway through the survey of inventors. There was some drift in the population of inventors as the inventor survey was completed making the matched sample somewhat younger and more tilted towards males than the final inventor sample. Data are displayed in the upper panel of Table 3.

[2]The Centre follows the statistical methods and best practices of the American Association of Public Opinion Research,

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Table 3. Descriptive statistics

	Inventors		General population		
	Mean	std.dev	mean	std.dev	t-test
Work experience: <9 years	0.02	0.12	0.05	0.22	-2.48^{**}
Work experience: 10–19 years	0.13	0.33	0.13	0.34	-0.06
Work experience: 20 years or more	0.85	0.35	0.82	0.38	1.24
Male[a]	0.85	0.35	0.92	0.28	-2.83^{**}
Optimism	1.06	0.55	0.96	0.60	2.48^{**}
Confidence	0.14	0.11	0.12	0.11	1.97^{*}

Inventor sub sample	mean	std.dev	Skewness[b]	z-test[c]
Log(post R&D$)	3.26	4.14	0.70	2.04^{*}
Log(post time)	2.46	2.71	0.63	4.67^{***}
Optimism	1.06	0.55	-0.64	5.15^{***}
Confidence	0.14	0.11	0.03	1.63
Sunk-costs: log(prior R&D$)	5.09	3.27	-0.25	2.29^{*}
Sunk-time: log(prior time)	4.30	1.71	-0.06	2.72^{**}
Experience inventing[d]	0.74	0.44	n/a	
Positive advice	0.23	0.42	n/a	

	Positive Advice		Negative Advice		
Inventor subsample	mean	std.dev	mean	std.dev	t-test
Log(post R&D$)	6.44	4.33	2.28	3.53	11.43^{***}
Log(post time)	4.41	2.66	1.84	2.41	10.97^{***}
Optimism	1.15	0.47	1.03	0.57	2.77^{**}
Confidence	0.13	0.10	0.14	0.11	0.81
Sunk-costs: log(prior R&D$)	7.16	3.17	4.49	3.03	9.82^{***}
Sunk-time: log(prior time)	5.33	1.60	3.98	1.63	9.35^{***}
Experience inventing[d]	0.82	0.39	0.71	0.46	3.21^{**}

N/A—not meaningful to measure skewness on a binary indicator.
$^{*}p < 0.05$.
$^{**}p < 0.01$.
$^{***}p < 0.001$.
[a]Dummy variable, 1 = male, 0 = female.
[b]Skewness measure generated only for non-zero values of expenditure and time.
[c]Shapiro-Francia W' test for normal data (similar to Shapiro–Wilk test).
[d]Dummy variable, 1 = 3 or more years of experience, 0 = less than 3 years experience.

Dependent measures

We measure the money personally spent by inventors after receiving the IAP report by their own self-reported R&D cash outlays. We asked for all costs for product development, marketing research, making of prototypes, etc. We further asked respondents to anchor these expenditures in time to the year in which they spent the majority of the development costs, in order to normalize all of these expenses to 2003 dollars using the Canadian CPI. To measure time investment, we ask the inventor ''What percentage of that time was spent after the invention was evaluated by the IAP'' where the time refers to that '' . . . spent actually working on the invention'' as opposed to calendar time. As can be seen in Table 2, inventors are more likely to continue spending time than money after being advised to cease efforts. We speculate that if inventors are employed, as

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most in this sample are when inventing, the time spent on inventive pursuits outside of working hours carries low or no opportunity cost. Furthermore, the inventor is operating in an environment where he or she is not likely to be able to sell his or her inventive abilities on a spot market.

Since the effort may well have a low opportunity cost, the time spent, as opposed to the money spent, may reflect many other decision making biases or non-monetary factors, such as the intrinsic value of inventing. Research has further shown that individuals find it difficult to accurately account for sunk-time (Soman, 2001). Time may be a noisy measure for both these reasons.

To reduce heteroskedasticity we transformed the raw data on expenditures and time using the natural logarithm as the base. The distribution functions for the log of expenditures and time spent, even without considering the large mass points at zero, are still skew after these transformations, as indicated in Table 3, middle panel.

The dependent variables log(post-advice R&D) and log(time) are positively skew with long upper (right) tails, while the measures of sunk-costs [log(pre-advice R&D) and log(time)] are negatively skew, with long lower (left) tails. All distributions with the log transform have heavier tails than the standard normal. We therefore also tried more advanced transformations of the expenditure and time distributions. We performed regressions where the expenditure and time distributions were brought to zero skewness using the Box–Cox power transformation. Results were qualitatively similar as those reported and we chose to report results with the lognormal transformation for ease of interpretation and clarity.

Independent measures

Optimism

To measure optimism we chose six optimism items from the 10-item International Personality Item Pool personal attributes survey (Oregon Research Institute, 2001; Scheier, Carver, & Bridges, 1994).[3] Two example statements are "I just know that I will be a success" and "I am often in a bad mood." For each item the respondents were asked the extent to which they agree/disagree on a five-point scale, with 1 representing strongly disagree and 5 representing strongly agree. The order of the five items was randomized across subjects and items for this variable were mixed randomly with all other items used. We averaged the item scores for this variable obtaining a Cronbach's alpha of 0.67 (inventor and general population pooled).

Overconfidence

Consistent with previous research (Busenitz & Barney, 1997; Griffin & Tversky, 1992) we measured overconfidence as the degree to which an individual expects that they have made a correct judgment on a judgment task divided by the average degree of correct judgments in the population. We ask respondents to judge which one of two cities that has the larger population and to indicate the confidence in their judgment being correct on a half-range probability scale (50–100% certain). Five city comparisons were elicited; three pairs of cities were Canadian, while two pairs were foreign. The order of the five comparisons was randomized across subjects. The overconfidence measure was constructed as:

$$\textit{overconfidence} = \sum_k (a_{ik} - \overline{b}_k)/5,$$

where, a_{ik} is respondent i's estimated confidence of being right on judgment k and $\overline{b}_k$ is the average per cent correct choice of judgment k in the population. Cronbach's alpha for this scale across the five city size judgments was 0.70 (inventor and general population pooled).

[3]Pretests results indicated respondents' difficulty with the items "I feel blue" and "I dislike myself." After careful deliberations on the possible effects of the two items on the survey response and reliability, we decided to exclude these items and two other items that are matched with them.

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Sunk-costs

As a proxy measure we use the natural log of the amount of personal expenditures (cash or time) before obtaining the advice.

Control variables

A number of other variables could, potentially, be associated with our outcome variables and were thus examined. These variables have been raised in previous literature as possible explanations for why certain individuals become entrepreneurs. The next four variables were all obtained by asking respondents to agree or disagree with a set of statements on a five-point scale. The scores were then averaged to come up with a common factor.

Risk attitudes

People with higher risk tolerance might be more likely to continue spending time and money on the inventions. We used seven items of risk taking aspects from the Jackson Personality Inventory (Jackson, 1977) that were most germane to the domain of inventing (Begley & Boyd, 1987; Busenitz & Barney, 1997). We obtained a Cronbach's alpha of 0.60 (inventor and general population pooled).

Self-efficacy

During the invention process inventors may develop perceptions of competence and beliefs in their capacity to perform the specific tasks they face. A self-efficacious inventor is more likely to perceive the feasibility of his invention's success (Bandura, 1986; 1997). We used the self-efficacy items from Markman, Balkin, and Baron (2002); Cronbach's alpha = 0.82 (inventor and general population pooled).

Opportunity recognition

Our final personality variable was adapted from work on opportunity recognition (Gaglio & Katz, 2001). These authors hypothesized that entrepreneurs would be better than the general population at recognizing new ideas or ways in which existing items could be improved. A four-item scale with statements such as "I often find products that I think can be improved upon" produced a scale with Cronbach's alpha = 0.68 (inventor and general population pooled).

Intrinsic motivation

We had reason to believe that some people may invent because they enjoy it. Therefore, we created a 7-item scale regarding the intrinsic motivation to invent after reviewing the work of Deci, Koestner, and Ryan (1999). This scale had a Cronbach's alpha = 0.80 and was only obtained for inventors.

Personal/demographic characteristics

Following Camerer and Johnson (1991) we considered that more experienced inventors may be more confident in their estimation of the success of their inventions. Information was collected on the number of years the inventor had been working on developing inventions and the total number of inventions that the inventor had worked on in his/her lifetime. We also measured education, being concerned that education could proxy for the availability of outside job options that could pay more (i.e., more educated people have more job opportunities) and thus be less likely to persist when recommended to stop. Descriptive statistics on

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Table 4. Correlation matrix

	log(post R&D$)	log(post time)	optimism	confidence	sunk costs	sunk time	experience	positive advice
Log(post R&D$)	1.00							
Log(post time)	0.78***	1.00						
Optimism	0.12***	0.09*	1.00					
Confidence	0.01	0.00	0.12**	1.00				
Sunk-costs: log(prior R&D$)	0.50***	0.48***	0.08*	0.01	1.00			
sunk-time: log(prior time)	0.48***	0.60***	0.08*	0.03	0.55***	1.00		
Experience inventing	0.27***	0.33***	0.04	0.00	0.26***	0.34***	1.00	
Positive advice	0.42***	0.40***	0.09*	−0.03	0.34***	0.33***	0.10**	1.00

*$p < 0.05$; **$p < 0.01$; ***$p < 0.001$.

dependent and the independent variables found to be of statistical relevance are displayed in Table 3 and Table 4 contains a correlation matrix.

RESULTS

We first report tests on differences between the general and inventor populations ($n = 1130$). The inventors reported to have higher degree of optimism, $t(1128) = 2.48$, $p < 0.01$, and overconfidence, $t(1128) = 1.97$, $p < 0.05$, than the general population, supporting our hypotheses regarding inventor personality. Furthermore, inventors reported to have much greater risk seeking propensity, $t(1128) = 5.76$, $p < 0.001$, higher self-efficacy, $t(1128) = 2.85$, $p < 0.01$, and greater opportunity seeking tendency, $t(1128) = 7.52$, $p < 0.001$, than the general population. Data on optimism and overconfidence are reported in the upper panel of Table 3.

We also analyzed differences in cognitive biases between inventors receiving positive and negative advice ($n = 758$). Inventors with a positive evaluation were more optimistic, $t(756) = 2.77$, $p < 0.01$, and risk seeking, $t(756) = 3.17$, $p < 0.01$, but were neither more nor less confident, self-efficacious, opportunity seeking, or intrinsically motivated (all *p*'s ns). Data on optimism and overconfidence for inventors are reported in the lower panel of Table 3. While many of the differences reported above are significant, they may not be economically relevant. We therefore continue analyzing how these established biases might affect real decisions. First, we report some univariate analysis on the decision variables of interest.

Inventors personally spent an average of $39 694 (*SD* $256 900, maximum $5 million) on their inventions, showing that these inventions involved substantial development efforts.[4] The inventions in the sample appear typical of independent inventions. A plurality of the inventions was consumer-oriented, including inventions for household and general consumer use (33%) and sports and leisure applications (27%). Successful consumer-oriented inventions included a new milk container design, a washable sanitary pad, and a home security light timer that imitates typical use. Other inventions had business applications, including some that involved high technology (8%) or industrial equipment (14%). These inventions included an aligner and printer for photographic proofs, a tractor-trailer fairing that enhances fuel efficiency, a re-usable plug to insert in wooden hydroelectric poles after testing for rot, and a computerized and mechanically integrated tree harvester. Thus the inventions varied substantially in market potential. Those who were advised to terminate

[4]Unless otherwise specified, all dollar figures reported in this paper represent 2003 dollars Canadian.

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development efforts reported spending less ($M = \$3587$, $SD = \$55\,418$) after receiving their advice than those who were advised to continue ($M = \$28\,523$, $SD = \$94\,856$), $t(756) = 5.58$, $p < 0.001$, confirming the fact that on average inventors follow the advice to stop.

It is illustrative to examine the distribution of spending: 50% of all inventors spend less than $234 before the review, indicating that a majority of inventors have not done much development work before approaching the IAP. This also supports that these inventors believe *ex ante* that the evaluation has value. As indicated earlier 71% spent $0 after a negative review, indicating a majority of inventors stop development efforts on the advice of the IAP. Considering time spent developing their ideas, inventors spend on average 16% of the development time after receiving a negative review, and 49% spend 1% or less of their time on the inventions after a negative review.

Multivariate analysis of the decisions to spend time and money

The distribution functions for expenditures and time spent both contain large densities at zero (Table 2.) This indicates that there may be two decisions involved: a decision to continue, and a decision on how much time and money to spend conditional on deciding to continue. However, a likelihood-ratio test marginally rejected that the two equations were independent $F(1, N = 758) = 3.63$, $p = 0.06$, suggesting that it might not be useful to estimate two equations jointly. An alternative approach is to estimate a censored latent-variable model of expenditures (time) with the dependent variable censored at the value 0 (Tobin, 1958). We settled on the second modeling alternative as it turned out to produce estimates that were more robust to alternative specifications.

For this analysis we had complete data from 669 (81%) of the respondents with respect to R&D expenditures and 677 respondents with respect to time.[5] We include measures of optimism, overconfidence, sunk-costs, and experience with inventing to examine the tendency to spend money and time after receiving feedback. Non-significant control variables were dropped (risk attitudes, self-efficacy, opportunity seeking, intrinsic motivation, education).

Results in Table 5 are presented in two panels. The top panel reports coefficient estimates for those receiving negative advice; column 1 reports effects on the amount of post-advice R&D expenditures, column 2 is the same regression with time spent as the dependent variable. Panel 2 contains the same regressions for those receiving positive advice.

We found no effects for overconfidence, while optimism had one economically meaningful and significant effect in the regressions. Above-average optimists who receive negative advice have posterior expenditures 166% higher than below-average optimists (column 1). Optimism did not affect expenditures when obtaining positive advice and did not affect time spent after advice. That is, those who are optimistic tend to continue spending money after being advised to stop, while those advised to continue are not affected by optimism, supporting our hypotheses regarding optimism. One could argue that optimism would have an effect on people obtaining positive advice, as research has shown that pessimists tend to discount positive information. However, our findings suggest that optimism only seems to kick in when inventors face large adversities such as receiving advice to stop.

Sunk-costs had the effects anticipated, both for time and for money, as observed in panel 1 of Table 5. There was approximately a one-to-one correspondence between previous resource commitments and those committed after obtaining a negative evaluation. That is, when advised to stop, those who already had spent for example $10 000, spent another $10 000. The only exception was the effect of money spent before advice on the time spent afterwards. This coefficient was approximately one fourth the size of the other effects.

[5]There were missing archival data on the ratings for about 100 observations. Respondents answering "don't know" on the amount of post-advice R&D and time spent were dropped from the analysis. Respondents answering "don't know" on independent variables had these data imputed assuming data missing at random.

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Table 5. Tobit regressions: Impacts of decision biases on post-advice expenditures and time

	Expenditures		Time	
Panel 1: Observations with negative advice	coeff (1)	std.err	coeff (2)	std.err
High optimism[a]	1.66*	0.83	0.38	0.33
High confidence[a]	0.38	0.84	−0.05	0.33
Sunk-costs: log(prior R&D$)	1.03***	0.18	0.25***	0.06
Sunk-time: log(prior time)	1.00***	0.30	0.96***	0.12
Experience inventing[b]	3.01**	1.04	1.75***	0.40
N	517		523	
LR Chi-2	114.02***		174.03***	
pseudo-R2	0.07		0.09	

	Expenditures		Time	
Panel 2: Observations with positive advice	coeff. (3)	std.err.	coeff. (4)	std.err.
high optimism[a]	−0.05	0.76	−0.01	0.38
high confidence[a]	0.70	0.75	0.09	0.38
Sunk-costs: log(prior R&D$)	0.71***	0.15	0.14†	0.07
Sunk-time: log(prior time)	1.04***	0.30	0.89***	0.15
experience inventing[b]	1.52	1.00	0.91†	0.50
N	152		154	
LR Chi-2	73.38***		78.62***	
pseudo-R2	0.09		0.11	

Logged prior- and post-advice R&D and time as the distributions of R&D and time are skewed.
High = dummy variable taking unity if observation is above the mean.
Coefficients are marginal effects estimated as dy/dx.
$p < 0.10$, two-tailed tests.
*$p < 0.05$, two-tailed tests.
**$p < 0.01$, two-tailed tests.
***$p < 0.001$, two-tailed tests.
[a]Coefficient is for a discrete change of dummy variable from 0 to 1.
[b]Dummy variable, 1 = 3 or more years of experience, 0 = less than 3 years experience.

One control variable that had important effects was experience with inventing. Inventors with 3 or more years of experience developing inventions spent 301% more money and 175% more time after being advised to stop than those inventors with less than 3 years of experience. The effects of prior experience were not significant when obtaining positive advice. These results did not change qualitatively when we used the total number of inventions worked on by the inventor instead of the number of years of experience inventing.

It is possible that the effect of past spending on future spending indicates a project completion effect. According to some studies, as projects get closer to completion expenditures and efforts increases and the propensity to continue due to escalation of commitment also increases (Boehne & Paese, 2000; Conlon & Garland, 1993; Keil et al., 2000; Moon, 2001). These studies apparently do not argue for a different psychological mechanism, but rather that there is, potentially, mis-measurement using dollars (or efforts) expended. For example, a project with a small absolute budget might still experience large escalation of commitment as the project nears completion. We investigated this argument by adding several control variables indicating the degree to which the invention project had progressed at the time when it was assessed by the IAP. The inventor was required to provide information on the degree to which there was

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documentation, the degree to which the inventor had developed a prototype, and the degree to which the product had been tested. We were able to collect such data from 328 of the 517 inventions with negative advice using administrative records on file at the IAP. Results are displayed in Table 6.

The seven control variables were not jointly significant, $F(7, 316) = 1.53$, $p = 0.16$. When the control variables were added the coefficient for sunk-costs did not diminish appreciably, it was reduced from 1.31 to 1.29 (1.6%), and was in both cases significant at $p < 0.001$. The coefficient for sunk-time dropped more, from 0.73 to 0.64, but to start with it was not statistically significant at conventional levels. Any variation in the coefficient might therefore simply be random. We therefore conclude that the estimated coefficient using R&D dollars indicates the effects of sunk-costs rather than project completion. A summary of the hypotheses and their results are shown in Table 7.

GENERAL DISCUSSION

One key finding is that as many have speculated, independent inventors are ‘‘different’’ than other people. We found that inventors are more optimistic and overconfident than the general population. These effects are consistent with our belief that only extremely optimistic and/or overconfident individuals self-select into inventing because of the low expected returns. Our position is that inventors will be optimistic about future returns and overconfident about their abilities to ensure success. They are also more risk seeking, opportunity seeking, and have higher levels of self-efficacy than the general population.

We also found a significant and positive effect of optimism on spending for those who had received credible advice to cease activities. For optimism, there is a possible signal effect where optimism may attract outside financing, in-kind efforts, and other resources that are useful to a venture. If convincing others to contribute by signaling high abilities is beneficial to the venture, then self-deceptive optimism may be the key to most effectively produce such signals (Arabsheibani et al., 2000). However, we do not believe that this is the mechanism at work. If this were the case then all inventors would have expenditures a function of optimism, which is not the case in our data. We observe that only those obtaining negative advice are affected by optimism in their spending behavior. We interpret these findings to show that a high level of optimism may act to keep inventors going in the face of adversity (Armor and Taylor, 1998, 2002). Our interpretation is consistent with findings from Coelho, de Meza and Reyniers (2004). In their experiments they found that optimistic subjects ignored bad news rather than over reacted to good news.

Our results also indicate inventors to be strongly affected by the self-justification/sunk-cost bias. The more money and time spent on the invention before the advice from the IAP, the more time and money spent after the evaluation. While this is not technically a bias for those receiving positive advice, those who receive advice to stop should be spending no additional resources. For these inventors, a positive coefficient on sunk-cost and sunk-time demonstrates a sunk-cost bias.

That we found no effects for overconfidence on the decision to continue and on the amount of resources allocated was somewhat surprising in view of the large and robust effects often reported in the literature. One potential explanation for this deals with the possible existence of two general ‘‘types’’ of overconfidence: confidence in judgment versus confidence in abilities (Burson, Larrick, & Klayman, 2006; Kruger, 1999; Kruger & Dunning, 1999; Yates, 1990). Our measure using city pair comparisons likely captured the former, and therefore was able to distinguish between inventors and the general population. However, it may be the second type of overconfidence that causes inventors to move forward with their inventions after being advised to stop. If this is the case, our measure would not capture it.

One indication that overconfidence in ability does affect expenditure is the observed effect of inventive experience. Those with greater inventive experience had greater expenditures after obtaining advice to stop, which is consistent with our hypothesis. The results suggest that similar to being optimistic, experience makes inventors more likely to disregard outside expert advice and place more weight on their own

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Table 6. Tobit regressions: Controlling for project completion, sub-sample of records

	Expenditures	
Panel 1: Observations with negative advice	coeff (1)	Std.err
High optimism[a]	2.22*	1.09
High confidence[a]	0.73	1.09
Sunk-costs: log(prior R&D$)	1.31***	0.25
Sunk-time: log(prior time)	0.73†	0.41
Experience inventing[b]	4.78***	1.44
N	328	
LR Chi-2	89.82***	
Pseudo-R2	0.10	

	Expenditures	
Panel 2: Observations with negative advice, controls added	coeff. (2)	std.err.
High optimism[a]	2.20*	1.08
High confidence[a]	0.90	1.08
Sunk-costs: log(prior R&D$)	1.29***	0.26
Sunk-time: log(prior time)	0.64	0.41
Experience inventing[b]	4.79***	1.43
Documentation available:		
Rough sketches	1.58	1.40
Final working drawings	3.47*	1.58
Prototype status:		
Rough working model	−1.24	1.39
Fully tested model	−1.85	1.91
Product testing:		
Function testing	2.25	1.59
Normal user testing	2.87†	1.48
Market testing	−4.11	4.33
N	328	
LR Chi-2	101.31***	
Pseudo-R2	0.11	

Logged prior- and post-advice R&D and time as the distributions of R&D and time are skewed.
High = dummy variable taking unity if observation is above the mean.
Coefficients are marginal effects estimated as dy/dx.
All control variables are dummy [0/1] variables. The intercept contains those with "no documentation," "no prototype," and "no product testing."
Sub-sample contains records where we were able to obtain data on completion degree using information submitted by the inventors to the IAP at the time of invention review.
$p < 0.10$, two-tailed tests.
*$p < 0.05$, two-tailed tests.
†$p < 0.01$, two-tailed tests.
***$p < 0.001$, two-tailed tests.
[a]Coefficient is for a discrete change of dummy variable from 0 to 1.
[b]Dummy variable, 1 = 3 or more years of experience, 0 = less than 3 years experience.

assessment of the quality of their inventions. We interpret this similarly to Camerer and Johnson (1991) in that greater experience makes inventors more confident in their abilities, but no better at evaluating the promise of their invention.

A second potential explanation of the zero correlation between the overconfidence measure and expenditures is that extremely overconfident inventors may not approach the IAP since they believe

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Table 7. Summary of hypotheses tests

	General	Expenditures	Time
H1: Inventors are more optimistic than the general population	Supported		
H2: Inventors with higher levels of optimism will be more likely to continue spending more time and money after receiving advice to stop		Supported	Not supported
H3: Independent inventors are more overconfident than the general population	Supported		
H4: Inventors with higher levels of overconfidence will be more likely to continue spending time and money after receiving advice to stop		Not supported	Not supported
H5: Higher levels of pre-advice investment will lead to higher levels of post-advice investments for inventors advised to terminate their projects.		Supported	Supported

(incorrectly) that their inventions will be successful, and thus additional information is of little value. This could reduce the range of overconfidence in our sample and lower the chance of finding an effect.

There is a common thread that the effects of the decision-making biases of optimism and escalation of commitment play in conditioning the behavior by inventors who obtain the advice to stop. There is also a parallel effect of inventive experience, which may indicate overconfidence in judgment. The three biases all seem to induce a coping mechanism which is to put little or no weight on the review, and instead greater belief in their own judgment. Therefore, there is an interesting change between the *ex ante* and *ex post* value of the IAP advice if it is negative. *Ex-ante* it is valued (since they pay for it), ex post it is not (or at least heavily discounted.) All three decision-making biases (optimism, escalated commitment, and experience induced overconfidence) seem to lead to higher distrust in the review if it is negative.

There is an alternative way to interpret some of the results. Inventors may be ''rationally'' overoptimistic by holding too high and strong a prior belief in the success of their inventions. Those who receive positive advice—implying a high likelihood of success—revise their priors little and continue. Those who receive negative advice also revise their priors but not enough to change their behavior (van den Steen, 2004.) The more optimistic and thus the larger the prior, the less likely the inventor is to stop when given negative advice. And the more confident the inventor, the tighter the credible interval around the prior and the less likely it is that for any given prior the inventor revises his prior much and changes behavior.[6] A rational model may also explain why we obtain a positive effect of inventive experience on continuing when advised to stop. Increases in skills over time may lead to an increase in optimism and/or overconfidence (Santos-Pinto & Sobel, 2005).

There is, however, some information that speaks against this interpretation. First, the inventors are submitting their ideas for external scrutiny and opinion, implying they are not sure they have winning ideas. This should be reflected in lower prior beliefs of success and they should, according to the rational model, be more prone to stop given negative advice. Further, the definition of overconfidence that we use captures their credible intervals in general and would be expected also to reflect their credible intervals on the focal inventions' priors. Either we have measurement problems or the credible intervals do not matter. The latter interpretation questions the rational updating model of van den Steen (2004). Finally, the rational model of

[6]For example, for the Beta family of distributions, Bayesian updating takes the form $p^* = \frac{\gamma p}{\gamma+\xi} + \frac{\xi s}{\gamma+\xi}$ where p is the prior probability, p^* the posterior, γ the precision attached to the prior, s the risk implied by the new information and ξ the precision of the new information. The posterior is a weighted average of the information that the inventor has and the information the IAP provides.

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Santos-Pinto and Sobel (2005) does not explain why experience only matters when receiving negative advice. On balance we therefore subscribe to ''coping with setbacks'' as the best general explanation for the observed behavior.

Limitations and future research

One potential drawback of our methodology is that we relied on self-reports of past activities. This may have created a hindsight bias in recall, which might depend on the outcome of any additional money spent. For example, those who continued to spend money and later succeeded although advised to stop may have become generally more optimistic at survey time because they succeeded with their invention—causing a spurious correlation between optimism and post-advice expenditures. We do not believe this to be a significant problem. First, only a small percentage of those advised to stop who continued actually did succeed in commercializing their inventions (6.9%). Second, if there was such a recall bias it should appear more clearly among those advised to continue since a larger fraction among those individuals actually succeed. But we do not find a correlation between optimism and expenditures for these.

Some form of socially desirable response may have occurred as well, since inventors may not want to admit that they spent additional time and money on an invention that eventually failed. We believe that if this were the case, it would simply depress the number reported after receiving negative advice. This would make it harder rather than easier to find an effect, so we are not as concerned about this.

We believe that this sample is representative of serious inventors who are looking to commercialize their inventions. Informal surveys by the CIC suggest that nine of ten inventors who approach the Canadian IAP abort the submission process after considering the examination fee to be too high, suggesting that inventions with low prospects are excluded from the sample. This is a positive way to trim the sample, as it likely limits our sample population to only serious inventors. There may, however, be some additional uncontrolled sampling biases. For example, inventors who are already well informed about the commercial prospects of their inventions may consider the additional information from the IAP to be of marginal value. This could imply that the quality of inventions in our sample is biased, although it could be mis-stated in either direction. While both effects are a possibility, we do not feel that it damages the results we find within those inventors being advised to cease effort.

Another limitation of our study is that we are drawing conclusions about inventors who are at an early stage of their development process. They are a subset of all inventors and technological entrepreneurs, where the subjective expected value of their invention is at least that of the examination fee, which was approximately US \$250 in 1994 and US \$750 in 2001. We make no claims that the sample is representative of the general population of inventors. However, there is no alternative efficient method of obtaining a representative sample of inventors and our method allows us to efficiently obtain a reasonably large sample that is likely to represent a fairly broad cross-section of independent inventors.

CONCLUSION

This paper is important because it provides some plausible reasons for the excess entry and concomitant observed negative expected rate of return for inventors. Excess entry has been observed in several experimental studies. Some have argued that overconfidence in one's own skills and the neglect of others' skills and decisions cause excess entry (Camerer & Lovallo, 1999; Moore & Cain, 2004). While we do not find any evidence of this, it may be due to the two suggestions made earlier regarding the measure of overconfidence used and the population studied. Other researchers argue that excessive optimism is the main culprit Arabsheibani et al. (2000; de Meza & Southey, 1996), and our findings are consistent with this claim. The magnitude of the optimistic bias is quite large and on the same order as that obtained by (Arabsheibani

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et al., 2000). We also find that the sunk-cost bias is an important explanation of additional spending when spending should be curtailed.

This paper contributes to the decision-making literature by adding more evidence of a pervasive sunk-cost bias, even among experienced inventors. In addition, it shows that while optimism can be healthy for the psyche, it may lead people to spend money on losing propositions. This paper contributes to innovation research by showing the effects of optimism and the sunk-cost bias on inventor effort. As inventive activity creates a net benefit to society, understanding the factors that lead to the decision to continue on less than promising inventions could provide a positive step in the better utilization of inventor efforts. Finally, this paper could contribute to policies regarding how to more efficiently allocate inventive activities.

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