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Holding on for too long? An experimental study on inertia in entrepreneurs' and non-entrepreneurs' disinvestment choices

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Holding on for too long? An experimental study on inertia in entrepreneurs' and non-entrepreneurs' disinvestment choices

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Abstract

Disinvestment, in the sense of project termination and liquidation of assets including the cession of a venture, is an important realm of entrepreneurial decision-making. This study presents the results of an experimental investigation modeling the choice to disinvest as a dynamic problem of optimal stopping in which the patterns of decisions are analyzed with entrepreneurs and non-entrepreneurs. Our experimental results reject the standard net present value approach as an account of observed behavior. Instead, most individuals seem to understand the value of waiting. Their choices are weakly related to the disinvestment triggers derived from a formal optimal stopping benchmark consistent with real options reasoning. We also observe a pronounced 'psychological inertia', i.e., most individuals hold on to a losing project for even longer than real options reasoning would predict. The study provides evidence for entrepreneurs and non-entrepreneurs being quite similar in their behavior.

Keywords: Real-Options, Disinvestment, Exit Behavior, Experimental Economics

Zusammenfassung

Desinvestitionsentscheidungen, im Sinne von Projektabbruch und Liquidation, stellen einen sehr wichtigen Aspekt der unternehmerischen Praxis dar, für den nach wie vor ein erheblicher Untersuchungsbedarf besteht. Diese Studie präsentiert die Ergebnisse einer experimentellen Untersuchung bei der eine Desinvestitionsentscheidung als dynamisches Optimal-Stopping-Problem mit unterschiedlichen Volatilitäten modelliert wird. Darüber hinaus werden die Entscheidungen von Unternehmern denen von Nicht-Unternehmern gegenübergestellt. Die experimentellen Resultate werden mit den normativen Vorhersagen der traditionellen und der neuen Investitionstheorie (am Beispiel des finanztheoretischen Gegenwartskonzeptes bzw. des Realoptionenansatzes) konfrontiert. Die experimentelle Ergebnisse lehnen die deskriptive Validität des finanztheoretischen Gegenwartskonzeptes ab und deuten auf die signifikante Korrelation zwischen dem Verhalten im Experiment und den Vorhersagen des Realoptionen-ansatzes hin. Die Befunde liefern darüber hinaus Evidenz für psychologische Inertia, die mit dem Status-Quo-Phänomen in Verbindung gebracht werden kann. Die Studie zeigt weiterhin die leichte Tendenz von Unternehmern auf, eher als Nicht-Unternehmer an einem laufenden Projekt festzuhalten.

Schlüsselwörter: Realoptionen, Desinvestition, Exit-Entscheidungen, experimentelle Ökonomie

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1. Introduction

This study investigates the disinvestment behavior of entrepreneurs when choices are irreversible.[1] In spite of the importance of such disinvestment decisions, including termination of projects and entrepreneurial exit, this topic still received insufficient attention in entrepreneurship research (DeTienne, 2008; McGrath, 1999; O'Brien and Folta, 2009). This study aims at deepening our understanding of this choice situation by investigating, via an experiment on asset liquidation, the timing of abandoning a project with risky returns.

Concerning entrepreneurial disinvestment choices, there is mostly anecdotal evidence of founders "dying in the saddle" rather than selling their venture "under price" as well as of young entrepreneurs developing their project by burning their own and the aunt's bank account instead of terminating their business idea. There is only one example of an empirical study providing results on the reasons why entrepreneurs hold on with an under-performing business, the study by DeTienne, Sheperd, and Castro (2008).

With the main aim of further understanding the reluctance to "pull the plug" on a business, perhaps sticking to it for too long and postponing its termination and selling of underlying assets, this study empirically tests whether an optimal stopping approach consistent with *real options reasoning* provides a suitable theoretical framework according to which the tendency to postpone exit and termination choices can be *rationalized*. Indeed, real options theory provides a microeconomic explanation of the reluctance to leave a losing activity such as an under-performing firm. Specifically, real options theory exploits the analogy between a financial option and a real (dis)investment. It asserts that a firm may increase its profit by deferring an irreversible disinvestment even if the expected present value of the firm's cash flow falls below the liquidation value. The intuitive reason is that in cases of irreversible decisions waiting has a positive value since new information about the expected cash flow arrives in subsequent periods. As long as the disinvestment has not been realized – the "plug has not been pulled" – a decision maker has the flexibility to continue with an ongoing project that could prove to be valuable in case the cash flow increases again. Termination of the project (the firm) 'kills" this option and reduces the decision maker's flexibility. The loss of this flexibility must be covered by the liquidation value, too, before a disinvestment becomes optimal.

This mechanism described by real options theory results in a kind of inertia, which has been called a "tyranny of the status quo" (Dixit 1992). It is a tyranny based on rational considerations, however. We are experimentally testing this explanation against behavioral accounts for waiting with a disinvestment for *too* long. Hence, our contribution over and above the study

[1] An irreversible decision can be defined as a decision which "shrinks the space of available options" (Ramani and Richard, 1993), or in other words a decision evoking an outcome that cannot be reversed at least in the short term (Henry, 1974) and / or for free (Pyndick, 1991).

of DeTienne et al. (2008) is that we empirically disentangle a 'rational' from a 'psychological' component of such a postponement.

In the same experimental setting we test both disinvestment behavior of high-tech entrepreneurs and non-entrepreneurs, relying thus on the experimental method as a way of analyzing entrepreneurial behavior (for an overview of such attempts, see Schade and Burmeister-Lamp, 2009). Testing not only the responses of non-entrepreneurs might be considered important as professionals could be expected to be more acquainted than non-entrepreneurs with investment tasks and to rely on different decision heuristics and strategies (Busenitz and Lau, 1996; Busenitz and Barney, 1997; Parlich and Bagby, 1995; Olson, 1986; Forbes, 2005; Koellinger et al., 2007; Cooper et al. 1988; Burmeister and Schade, 2007).

So far, in order to explain inertia in investment decisions, research has often focused on biased decision-making of managers mostly discussing psychological drivers of this behavior, such as sunk-cost fallacy (Ross and Staw, 1993) and escalation of commitment (Staw, 1981) (see also DeTienne et al., 2008). In a similar vein, Burmeister and Schade (2007) postulate and experimentally demonstrate that entrepreneurs and managers fall prey to a status quo bias (Burmeister and Schade, 2007). Only few recent theoretical contributions in entrepreneurship have tried to develop a rational account for inertia in investment decisions by evaluating the value of waiting for incoming information in tune with real options reasoning (e.g. O'Brien et al., 2003, for entry and O'Brien and Folta, 2009, for exit decisions).

Again, this study tackles the problem of empirically disentangling the two very different perspectives on inertia in entrepreneurial disinvestment decisions: an 'options-based' inertia consistent with real options reasoning, i.e., rationally considering the value of waiting, and a 'psychological inertia' in the sense of a potential bias. We pursue this research aim by running experiments on irreversible project termination, observing also whether individuals behave differently under the conditions of different volatilities. The high volatility case is also tested with high-tech entrepreneurs. Our experimental setting further permits to test the effect of risk propensity on disinvestment timing in a framework that explicitly models the tradeoff between the risks associated with staying in the running project and that associated with terminating it too early.

The experimental examination of 'options-like' situations is still in its beginning, so that also in this regard the present research moves on a relatively unexplored terrain. To the best of our knowledge, the present study is the first experimental contribution dealing with disinvestment behavior in an optimal stopping framework. It is also the first study that additionally measures risk propensity in either an investment or disinvestment experiment. From a theoretical perspective, risk propensity is important in both situations. When rationally considering investment choices, risk aversion should induce the postponement of entry time so that potential effects of 'psychological inertia' and risk propensity overlap. Considering the choice to disinvest, risk aversion works in the opposite direction as will be shown in the theory section.

The motivation of this study is that disinvestment encompasses a broad and important spectrum of entrepreneurial choices, ranging from the decision to terminate a project, to liquidate assets in order to reorganize the business, up to the cession of a venture. In spite of its relevance, empirical research is scarce concerning the dynamics and the drivers which inspire, at the entrepreneurial level, the decision to disinvest as well as its timing. The already mentioned exception is the contribution of DeTienne et al. (2008) which explores, relying on conjoint analysis, factors explaining the decision to keep on an unprofitable business depending on entrepreneurs' individual thresholds. However, this study does not allow to empirically disentangling rational from psychological explanations for inertia in disinvestment choices.

As already pointed out, one example for irreversible disinvestment decisions of entrepreneurs is exit.[2] As other disinvestment choices, exit choices are no deterministic decisions and they do not only relate to the business profitability but also to the options available to the entrepreneur.[3] A considerable amount of resources are reallocated as a consequence of entrepreneurial exit, firm disappearance, and / or transfer having profound implications for the industry and the economy (DeTienne, 2008; Holmberg, 1991). It is important for policy makers to better understand business exit and transfer.[4]

Even if we interpret disinvestment in the more conventional sense of a decision on whether or not to terminate a specific project, these decisions are often momentous. Stopping a project too early might imply large foregone chances, stopping it too late might imply depleting the oftentimes scarce monetary resources of the entrepreneur. Hence, disinvestment decisions with respect to specific projects are critical for the success of a business venture as well as important for the development of a specific industry. Managerial and policy implications, however, largely depend on whether most of the inertia in disinvestment and exit decisions has to be attributed to an economically rational form of waiting or to waiting as a bias. A bias should be cured (if possible), rational waiting should not.

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[2] Entrepreneurial exit can be defined as "the process by which founders of privately held firms leave the firm they helped to create; thereby removing themselves, under varying degrees, from the primary ownership and decision-making structure of the firm" (DeTienne, 2008, p. 2). In particular, there are different exit strategies, different reasons for exit and (within a certain interval) flexibility with respect to the exit time. Furthermore, each of these aspects might be differently characterized in the context of the various phases of the entrepreneurial process (DeTienne, 2008). It is thus clear that only "a greater understanding of the entrepreneur will provide insights into the process of entrepreneurial exit" (DeTienne, 2008, p. 2) and that it won't be possible to gain a deeper and more realistic view on this process without explicitly focussing on decisions of the individual entrepreneur as the unit of analysis.

[3] The decision to exit a business has been argued to emerge from a highly context dependent and subjective mixture of motivations (for more on entrepreneurial motivation see Shane et al., 2003), intentions (Krueger et al., 2000), opportunity costs, options (McGrath, 1996), aspirations and goals (Sarasvathy, 2004).

[4] For the example of Europe, it is estimated that approximately one third of the entrepreneurs will leave their business within the next ten years and that while transferring a business within the family is still the most frequent case, the number of sales to third parties is increasing (European Commission, 2006).

The analysis is articulated as follows: First, the benchmark model to which the study refers and the propositions that can be derived on its basis are presented. A discussion of the behavioral hypotheses of psychological inertia and salience of high volatility situations as well as the characterization of the experimental setting then follow. The experimental findings for both entrepreneurs and non-entrepreneurs are then presented and confronted with the benchmark propositions as well as the behavioral hypotheses. This inspires some concluding remarks and implications of the study, also exploring potential reasons as to why entrepreneurs might perhaps benefit from behaving the observed way outside the laboratory. Limitations of the present investigation and perspectives for further research conclude.

2. Benchmark model and propositions

A value of waiting is present in various decision problems that are characterized by irreversibility, risk, and flexibility. In this paper we describe the value of waiting in the context of a simple disinvestment problem. Without a loss in generality[5], we consider an already existing project with a finite lifetime of three periods that currently earns an annual cash flow X_0. The cash flow follows a binomial tree, i.e., in period 1 the cash flow will either increase by a value $h > 0$ with probability *p* or decrease by *h* with probability 1-*p*. In period 2 the cash flow can take the values $X_0 + 2h$ with probability p^2, $X_0 - 2h$ with probability $(1-p)^2$ and X_0 with probability $2p(1-p)$.[6] We first assume a risk neutral decision maker who has to decide whether to continue or to abandon the project. Termination of the project yields a salvage value *L* in addition to the cash flow of the current period. The project cannot be restarted once it has been terminated, that means the decision is irreversible. Traditional investment theory asserts that the project should be terminated if the liquidation value $L + X_0$ exceeds the continuation value $\hat{C}$. Hence the decision rule is:
$D_1 : \max(\hat{C}; L + X_0) = \hat{F}_0$,

where

$$\begin{aligned}\hat{C} = X_0 &+ (p \cdot (X_0 + h) + (1-p) \cdot (X_0 - h)) \cdot q^{-1} \\ &+ \left(p^2 \cdot (X_0 + 2h) + 2 \cdot (p \cdot (1-p) \cdot X_0) + (1-p)^2 \cdot (X_0 - 2h) + L\right) \cdot q^{-2}\end{aligned} \tag{1}$$

Herein $q^{-1} = \frac{1}{(1+r)}$ is a discount factor and r denotes an interest rate. Decision rule D_1 essentially means that stopping the project is preferable if the salvage value *L* exceeds the

5 Qualitatively identical results can be derived for an infinite time horizon.

6 In contrast to standard options models we assume an additive model of risk instead of a multiplicative one. The additive model has been chosen for the subsequent experiments because it is easier to handle for the respondents in a multiperiod framework. The hypotheses that we derive are valid for an additive as well as for a multiplicative model of risk.

expected value of the discounted cash flows, where the expectation is build on information available in period 0. The decision is simply a comparison between the two alternatives "continuation of the project" and "termination of the project in period 0".

The situation is different if the decision on the termination of the project can be deferred to period 1. Using financial wording the decision maker now has an abandonment option in period 0 that he / she can either exercise or keep alive until maturity (period 1 in this case). Deferring the decision has the potential advantage that it allows to take into account information arriving in period 1. Of particular interest is the situation where $X_0 - h < L \cdot r < X_0 + h$, which implies that continuation (termination) is the favorable decision if the cash flow in period 1 increases (decreases). In this case the optimal stopping rule becomes:

(2) $$D_2 : \max\left(\widetilde{C}; L + X_0\right) = \widetilde{F}_0,$$

with a continuation value

(3) $$\begin{aligned} \widetilde{C} = X_0 &+ \left(p \cdot (X_0 + h) + (1-p) \cdot (X_0 - h + L)\right) \cdot q^{-1} \\ &+ \left(p^2 \cdot (X_0 + 2h + L) + p \cdot (1-p) \cdot (X_0 + L)\right) \cdot q^{-2} \end{aligned}$$

Note that in contrast to the previous decision rule, the second term on the right hand side of (3) addresses the continuation and the termination of the project, respectively, depending on whether an upward or downward movement of the cash flow occurs in period 1. Thus, the myopic decision rule D_1 differs from the optimal stopping rule D_2, in general. First of all, the classical net present value of the project, $\hat{F}_0$, is less than or at most equal to $\widetilde{F}_0$, which is sometimes called the strategic (expanded) net present value (Trigeorgis, 1996). Moreover, decisions built on theses strategies may deviate. This becomes obvious by comparing the respective disinvestment triggers. A disinvestment trigger marks the threshold level of the cash flow where it becomes optimal to disinvest. In each period the decision maker compares this normative threshold with the realization of the random cash flow. As long as the actual cash flow is larger than the disinvestment trigger, the project should be continued. The disinvestment triggers can be derived by equating the continuation value and the termination value and solving for X_0. (A numerical example for the application of a disinvestment trigger is given in section 5 below in the context of our experiment.) According to D_1, the project should be terminated if the current cash flow falls below

(4) $$\hat{X}_0 = L \cdot r - h \cdot (2p - 1) \cdot \left(1 + \frac{1}{1+q}\right).$$

The optimal disinvestment trigger referring to D_2 is:

(5) $$\widetilde{X}_0 = L \cdot r - h \cdot \left(2p - \frac{q}{p+q}\right)$$

The difference between the two triggers amounts to

(6) $$\hat{X}_0 - \tilde{X}_0 = \frac{h \cdot (1-p) \cdot (2p+q)}{(1+q) \cdot (p+q)} > 0 .$$

Apparently $\tilde{X}_0$ is smaller than $\hat{X}_0$ as long as $p > 0$. The above reasoning leads us to the following two propositions:

> *P1: Rational disinvestment behavior is determined by decision rule D_2 and the according disinvestment trigger given in (5).*

> *P2: A rational decision maker, obeying D_2 will tolerate lower cash flows before immediately terminating a running project compared with a myopic decision maker who follows D_1 and thus ignores the value of waiting.*

So far the myopic and the optimal decision rules have been derived assuming a risk neutral decision maker. In the context of financial options this assumption is not restrictive as the resulting prices and exercise strategies are independent of the risk preference of the decision maker[7]. However, in the context of real options risk preferences come into play at least if it is impossible to set up a replicating portfolio of traded assets that duplicates the stochastic outcome of the (dis)investment project under consideration (see Dixit and Pindyck, 1994). Such a duplication is difficult in most real-life decisions on non-financial options and it is also (made) impossible in our experiments. The valuation of the risky prospects can then be conducted, for example, in an expected utility framework either by replacing uncertain outcomes by their certainty equivalent or by using risk-adjusted discount rates. Let $r^* > r$ denote the risk adjusted discount rate and $q^* = 1 + r^*$. Then the modified disinvestment triggers for the myopic decision maker and the rational decision maker read as:

(7) $$\hat{X}_0^* = L \cdot r^* - h \cdot (2p-1) \cdot \left(1 + \frac{1}{1+q^*}\right)$$

(8) $$\tilde{X}_0^* = L \cdot r^* - h \cdot \left(2p - \frac{q^*}{p+q^*}\right),$$

respectively. A comparison of (4) and (5) with (7) and (8) shows that risk aversion increases the disinvestment trigger of both decision rules.

Even though this change has no impact on the validity of our propositions, the effects of risk propensity can be taken into account as explicated in Proposition 3:

> *P3: The larger an individual's risk aversion, the earlier the disinvestment occurs.*

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7 Note that the calculation of arbitrage-free option prices is based on 'risk-neutral' probabilities instead of actual probabilities as in our model (see Hull, 2006).

In other words, the more risk averse the individual, the higher his / her disinvestment trigger, meaning that he / she would consider disinvestment when investment returns are, for a risk-neutral individual, still too high to leave the ongoing investment.

Our optimal stopping problem has been formulated in the spirit of real options reasoning whilst keeping the decision situation somewhat realistic and the degree of complexity at a level that can still be implemented in the laboratory. Real options reasoning applies whenever there is risk concerning future developments, when costs are at least partially irreversible, and when there is flexibility with respect to time. It has been applied to a variety of economic settings[8] and some authors have also discussed the applicability of real options reasoning to entrepreneurial decision-making.[9] Real options reasoning has also been used to capture the strategic nature of entrepreneurial creation of wealth (McGrath, 1996) and postulated as a way of managing the costs of entrepreneurial failure (McGrath, 1999). In particular, if applied to entrepreneurial exit decisions, real options reasoning provides a framework in which (part of) the effect of sunk costs on future decisions can be interpreted as rationally considering the potential to recover them (O'Brien and Folta, 2009).

Several studies (e.g. Ingersoll and Ross, 1992; Paddock et al., 1988) postulate the advantages of new investment theory, which in essence relies on emphasizing the role of risk and irreversibility for investment behavior.[10] In spite of its interesting practical implications, direct empirical testing of real options reasoning is still lacking (for an overview see, e.g., Hinrichs et al., 2008). It is difficult to collect proper data, partly because of the complexity of the model (which admits analytical solutions only for certain specifications of the underlying stochastic processes), partly because most of the model's components either emerge from subjective valuations or are represented by variables that cannot be directly observed (Odening et al., 2004).

Some authors argue that the above limitations also "make (…) [real options] impractical as a general decision-making aid for most business managers" (Busby and Pitts, 1997, p. 170). Those and additional reasons why real options reasoning might not be applied in management decisions are also discussed by Adner and Levinthal (2004). Our position is far less radical. We believe that the value of waiting makes sense for most individuals also intuitively, and we are interested in how close such intuitive behavior of entrepreneurs and non-entrepreneurs can be approximated by a rational model capturing the value of waiting in the sense of an 'options-based' inertia or whether waiting is more in tune with 'psychological inertia' as explicated in the next section.

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8 Real options reasoning has been, e.g., applied to environmental and agricultural economics (Arrow and Fisher, 1974; Pietola and Myers, 2000; Purvis et al., 1996; Richards and Patterson, 2004), to land conversion and conservation intervention (Titman, 1985; Quigg, 1993), as well as to the economic policy of reforms (Dewatripont and Roland, 1995).

9 It has been, e.g., applied to business incubation (Hackett and Dilts, 2004), organizational resource investment (Bowman and Hurry, 1993), and intergenerational transfer (Miljkovic, 2000).

10 There is also empirical evidence supporting the similarity between patterns of firms' entry and real options dynamics (Caves, 1998).

Our experimental approach allows implementing all features of our benchmark model and all parameter values chosen, hence encompassing measurement problems and deviations from model assumptions in decisions outside the laboratory. From our perspective, the research aim of disentangling 'options-based' and 'psychological' components of inertia can only be tackled relying on the experimental method, as it permits to obtain data under controlled conditions and to disentangle the different origins of inertia from the potential effects of risk preferences.

As mentioned in the introduction, the experimental investigation of the real options approach is still at an early stage: Closest to the spirit of our investigation is a recent paper by Oprea et al. (2009) that analyses whether individual behavior in an investment setting might, by learning, approximate the optimal exercise frontier for available options. Further, Rauchs and Willinger (1996), focusing on how increased expected information affects subjects' choices, provide evidence for an irreversibility effect, while Sirmans and Yavas (2005) try to elicit, in a very simple setting, subjective valuations for an option by asking the participants to submit a bid for it. Another options-related design is discussed in Barner et al. (2005) that focus on information arrival and aggregation in an experimental asset market.

3. Behavioral Hypotheses

The benchmark propositions stated in Section 2 rely on the interpretation of human decision making as fully rational and are based on Bayesian optimization, which is rather consistent with an axiomatic characterization of human behavior than with its direct empirical observation (Selten, 1999). This type of approach has been severely challenged as an empirical account of behavior. Important critiques stem from interdisciplinary studies which integrate economics with findings from psychology, neurology, research on artificial intelligence and cognitive disciplines in general.[11] Looking from the perspective of bounded rationality implies refraining from the assumption of perfect computational abilities and describing a decision process via simple dynamics and heuristics (Simon, 1955). By doing that, it challenges the benchmarks of perfect rationality by formulating behaviorally motivated hypotheses.

Concerning the task of terminating a risky project of the type characterized in Section 3, individuals can be expected not to perfectly adjust their behavior to the degree of risk (as this would require fairly sophisticated computations) but rather to intuitively determine the time of disinvestment. Moreover, in addition to the already mentioned sunk cost fallacy (Ross and Staw, 1993) and escalation of commitment (Staw, 1981), there are numerous other behavioral phenomena that might influence the intuitive choice of a disinvestment trigger *towards postponement* of this irreversible decision such as status-quo bias (Samuelson and Zeckhauser, 1988;

[11] For a critical approach to perfect rationality assumptions see, e.g., Kahneman (2002), Gigerenzer and Selten (2001), Güth and Kliemt (2004b), March (1994), Simon (1990) and (1955). A more philosophical approach is discussed in, e.g., Kliemt (2001).

Kahneman et al., 1991), resistance to change (Grabitz, 1971), inaction inertia (Tykocinski and Pitman, 1998), inaction or omission bias (Ritov and Baron, 1992), decision avoidance (Anderson, 2003), and procrastination (O'Donogue and Rabin, 1999; 2001; Ferrari et al., 1995).

The behavioral literature also describes tendencies that might point in the opposite direction: tendencies *against* keeping a status quo, such as variety seeking and action bias, but their occurrence has only been demonstrated in situations quite different from a disinvestment task: Burmeister and Schade (2005) experimentally demonstrate that a status quo bias might be overcompensated by variety-seeking tendencies only for 'sensual' objects such as perfume and Bar-Eli et al. (2007) demonstrate an action bias in a strategic situation in soccer games: reactions of goalkeepers in penalty kicks.

Hence, our reasoning unambiguously leads to the formulation of the following behavioral hypothesis; note that to discriminate our behavioral from the normative propositions, we chose to label them differently starting with H1:

> *H1: In a disinvestment task, individuals are waiting longer than optimal to terminate a project.*

In the present study, we call this behavior 'psychological inertia' to contrast this type of inertia with the 'options-based' type of inertia postulated in Propositions 1-3.

A second behavioral effect we were interested in was to evaluate whether different volatility regimes drive different behaviors. It can be easily shown that an increase in the volatility of the project returns lowers the optimal disinvestment trigger. However, in our experiments we observe the disinvestment time. Increasing the volatility has two opposite effects on the optimal disinvestment time. On the one hand, the optimal disinvestment trigger decreases and on the other hand, the amplitude of the up and down movements of the random returns increases. Both effects have opposite consequences for the disinvestment time and hence, in our experimental setting the optimal disinvestment time in the low volatility treatment is, on average, only slightly smaller on average compared with the high volatility treatment (period 4.14 in the high volatility scenario versus period 4.06 in the low volatility scenario). Thus from the real options perspective we expect similar disinvestment timings under both high and low volatility.

On the other hand, individuals are known to be loss averse; a loss of the same magnitude has a much larger consequence on the evaluation of a risky option than a gain (Kahneman and Tversky, 1979; Tversky and Kahneman, 1992). Since potential losses from waiting one period longer are larger under conditions of high volatility, we expect individuals to pay more attention to the fact that they are facing a random process, to consider the disinvestment problem more intensively and hence, to act closer to the real options prediction under conditions of high volatility. This leads to our second behavioral hypothesis:

> *H2: Individuals acting under high volatility regime are more consistent with the real options benchmark than those under a low volatility regime.*

Table 1 provides an overview of the benchmark propositions (P) and the behavioral hypotheses (H) that have been tested and also foreshadows the results to be reported in Section 6. To simplify the notation, it is henceforth referred to Real options as "RO" and net present value as "NPV." The net present value theory becomes our null hypothesis (P0).

Table 1. Benchmark propositions, behavioral hypotheses, and overview of findings

Propositions and hypotheses:	1st study low volatility	1st study high volatility	2nd study high volatility
P0: Disinvestment behavior is consistent with classical investment theory	Not supported	Not supported	Not supported
P1: Disinvestment behavior is consistent with real options theory	Supported	Supported	Supported
P2: Decision makers consistent with the real options theory tolerate lower cash flows before terminating a project compared to classical investment theory	Supported	Supported	Supported
P3: The larger the individual risk aversion, the higher the disinvestment trigger, i.e. the more risk averse an individual, the earlier is disinvestment	Not supported	Not supported	Not supported
H1: Individuals are waiting too long to terminate a project, i.e., they are susceptible to psychological inertia	Supported	Supported	Supported
H2: Individuals acting under high volatility regime are more consistent with the RO benchmark	Not supported	Not supported	n.a.

It is evident that for numerous reasons it is by far easier to motivate non-entrepreneurs (many of them students) rather than entrepreneurs to participate in a laboratory study so that the larger study using both volatility treatments and a larger number of respondents facilitating statistical significance is run with non-entrepreneurs. We then carry out a laboratory experiment on a small sample of high-tech entrepreneurs to better motivate external validity of our results. There is much experimental evidence showing that entrepreneurs are biased or even more biased than other decision-makers (Busenitz and Barney, 1997; Olson, 1986; Forbes, 2005; Koellinger et al., 2007) and that there is already support for the idea of entrepreneurs persisting in an under-performing business and being prone to self-justification and escalation of commitment (DeTienne et al., 2008).

4. Experimental Setting

In each round, the experimental task consisted of a problem of optimal stopping, stylizing a context-free choice to abandon a project for a constant termination value. Within each round, respondents could decide to stop in one of ten *periods*; and this task was repeated over *multiple rounds*. Relying on this design, we ran two different studies: in the first large scale experiment we compared the effects of different volatilities, while in the second small scale experiment we replicated the high volatility treatment with entrepreneurs.

Both experiments were followed by a session of Holt and Laury (2002) lotteries with real payments in order to elicit risk attitudes of the participants. Lottery comparisons have been preferred over a certainty equivalent method because they permit avoiding possible distortions by a certainty effect (Levy and Levy, 2002). This method has also been favoured over psychometric scales (e.g., Zuckerman, 1971), as lottery comparisons are consistent with the experimental disinvestment task, being based on monetary choices under risk with real payoffs at stake. Returns from the existing project followed a binomial distribution with p=0.50 and no underlying drift in each round. First period revenues were always 1.000 points. To simplify matters for the participants, the risk-free interest rate was fixed at 10 %. Abandoning the project yielded constant revenue of 11.000 points, was allowed in each of 10 periods and made compulsory in the last period. Note that there was an interest rate of 10 % applied to the disinvestment revenue of 11,000 in all periods after disinvestment, so that there was an opportunity cost of not disinvesting.

The first experiment was carried out in two treatments (between subjects), differing in the size of potential gains and losses (referred to as volatility). Specifically, the potential gains and losses were 200 points in the low volatility and 500 points in the high-volatility treatment. The participants were informed about all parameters and assumptions underlying the experimental setting. The binomial tree of potential revenues together with the associated probabilities of occurrence was displayed on their screen. Respondents learned the development of payoffs (the outcome of the random process) from period to period. The tree was updated after each period based on the random outcome of this period and before the decision whether or not to disinvest had to be made. Choice was not time constrained.

For each of the 20 rounds, the entire binomial tree was newly determined via a random mechanism. Hence, over the course of the entire experiment each respondent was confronted with 20 different, randomly determined paths of the binomial tree. The respondents did not receive immediate payoff feedback, except in the trial period. The random developments were separately determined for each individual. With no immediate payoff feedback and randomly determined paths of revenues, we limited reinforcement learning from outcomes.

The final payoff was based on one of the 20 rounds (randomly chosen). The trial round gave the participants the opportunity to become acquainted with the experiment and to ask questions and was excluded from the determination of the payoff. The experiment was neutrally framed and presented as a problem of optimal stopping to isolate project termination from other individual drivers and motives that may affect disinvestment and exit choices (for a translation of the instructions see the Appendix).

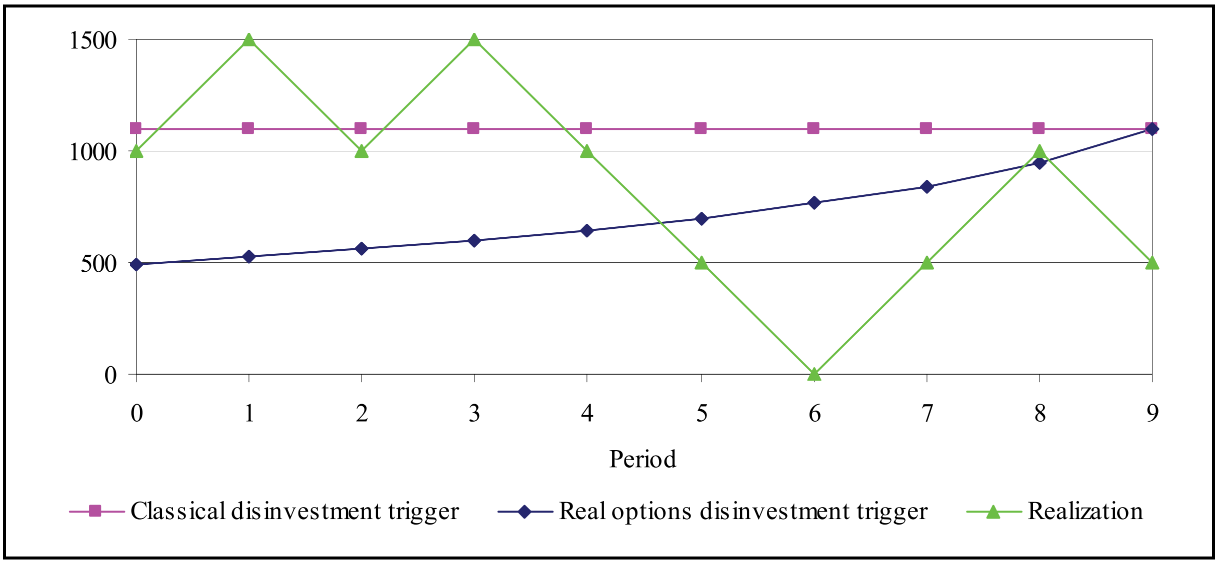
The experiment was programmed in Z-tree (Fischbacher, 2007) and was run in August 2008 in the stationary laboratory of a major German University. A total of 84 respondents (39 undergraduate students of different schools and 37 non-students) participated in the experiment, i.e. 42 per treatment. Average earnings were 11.78 €.

The second experiment was a replication of the high volatility treatment with high-tech entrepreneurs. The only differences were that, because of the higher opportunity cost of entrepreneurs, this group of respondents played only 10 instead of 20 rounds, i.e., were only confronted with 10 randomly chosen paths of the binomial tree, and that the incentives were upgraded for the same reason (700 points /€ instead of 3500 points /€). The experiment was run making use of a mobile laboratory in March 2009 with entrepreneurs from a business incubator in a major German city. The subject pool consisted of 15 founders of high-tech enterprises.

As was the case in the study with non-entrepreneurs, we again presented the decision problem in abstract terms for the sake of comparability. At the end of the game-playing sessions, however, entrepreneurs were asked to state whether they have associated the experiment with some real-life situations.

To illustrate the type of decision situation a participant was facing and to further motivate real options reasoning, Fig. 1 now depicts the two theoretical disinvestment triggers as well as a sample path of the random variable (an example for how such a development might have occurred) for the parameters chosen in our experiment. The first disinvestment trigger reflects the simple net present value criterion which amounts to a constant value of 1100 (red line). The second disinvestment trigger is based on the real options model (blue line).

Fig. 1. Disinvestment triggers and sample path of the random variable (high volatility scenario)



This graph, which is called an exercise frontier, starts at a value of about 500 and converges to the classical net present value trigger. According to the net present value criterion one should immediately disinvest in period zero, because the cash flow is 1000 < 1100. This decision deviates from the real options prediction. A decision maker who is consistent with the real options theory should disinvest in period five, because this is the first time where the cash flow falls below the exercise frontier. In other words, the two models come up with different predictions concerning the optimal disinvestment timing. A 'psychological' inertia would imply waiting even longer with the disinvestment than until period five.

5. Experimental results

The analysis of experimental results aimed at testing the benchmark propositions and the behavioral hypotheses stated above. The benchmark propositions and the behavioral hypotheses are labeled as in Table 1.

5.1 Approach to data analysis

Part of the data analysis is based on rank correlations (Kendall's Tau) between *observed* and *predicted* choices, i.e., observed disinvestment times in the experiment and results from calculating the optimal disinvestment trigger via D_2 for the respective random development of the binomial tree, across all rounds per individual. We interpret these correlations as *indicators* for *general consistency* between experimentally observed and theoretically predicted choices. The rank correlations indicate whether someone disinvests earlier if he/she should and later if he/she should according to the benchmark predictions in the different random developments of the project in the different rounds he/she is facing.

We calculate another individual measure that reveals a different type of consistency with the real options benchmark, the general tendency of an individual towards psychological inertia in the sense of having a bias towards low or late disinvestment. We ran an analysis of variance with all individuals as factors (without intercepts) and with the inertia revealed by the disinvestment choices as dependent variables, i.e., observing whether disinvestment in the different rounds was consistent with the real options prediction (0), later than that (1), or earlier (-1). By this means, we obtain a measure of the individual propensity to hold on to a running investment for too long or in other words, a measure of the individual-level inertia over and above that part of waiting predicted by the real options approach. This indicator has values between -1 and 1 and will henceforth be labelled 'predicted individual inertia'. The choice to rely on this measure instead of simply analyzing metric deviations from the theoretical benchmark is inspired by the asymmetric nature of the experimental data: Deviations from the real options benchmark can only be interpreted as a distance in case of late or consistent disinvestment. In case of early disinvestment this does not make much sense, as future developments of the random path (after the disinvestment decision has been made) are unknown to the subjects (see Fig. 1).

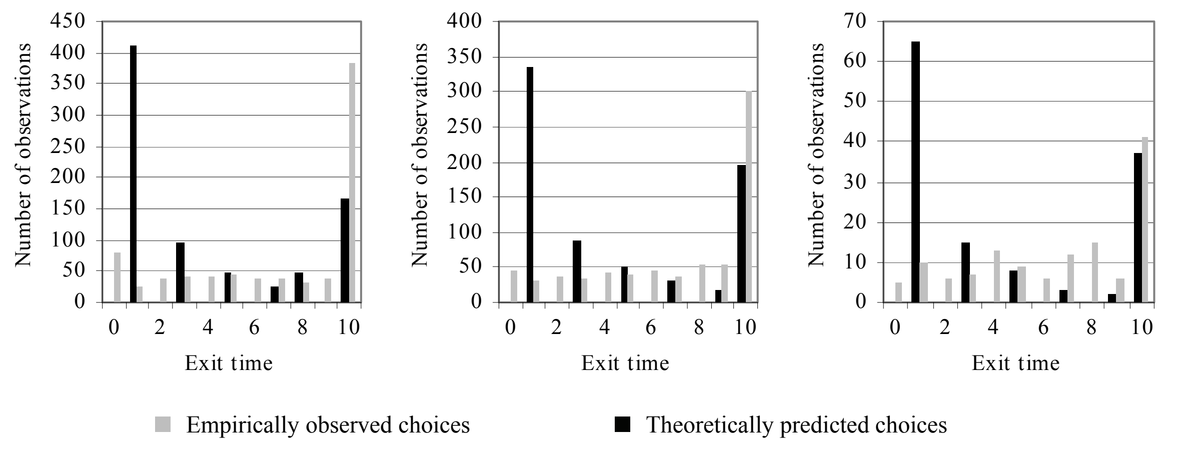
5.2 Laboratory experiment with non-entrepreneurs

For the study with non-entrepreneur participants, the choices of 6 participants have been excluded from data evaluation, as they stated risk preferences that were inconsistent with a monotonicity requirement. Specifically, data analysis refers to 40 independent observations for the low-volatility treatment and 36 for the high-volatility treatment. Slightly more females than males participated in the experiment (23 vs. 17 in the low-volatility and 20 vs. 16 in the high-volatility treatment). The average age was, in both treatments, 29 years, ranging from 19 to 67.

Test of P0 and P2

According to net present value, people should have disinvested right away; since the opportunity cost of not disinvesting was 1,100 and the expected value of revenues was only 1,000 points per round. Overall, the results corroborate the hypothesis of late disinvestment (cf. Fig. 2) and provide evidence for the unsuitability of the net present value benchmark (P0, based on D1) as an account of actual behavior in our disinvestment scenario.

Fig. 2. Exit times for non-entrepreneurs/low volatility (left side), non-entrepreneurs/high volatility (middle) and entrepreneurs/high volatility (right)



Average disinvestment times per subject over the 20 games equal, on average, 6.92 in the low and 6.99 in the high volatility treatment. These values are significantly different from zero (t-test, $p < 0.001$, for both treatments). Hence, respondents do not disinvest as soon as the liquidation value exceeds the project's expected value in the sense of classical investment theory.

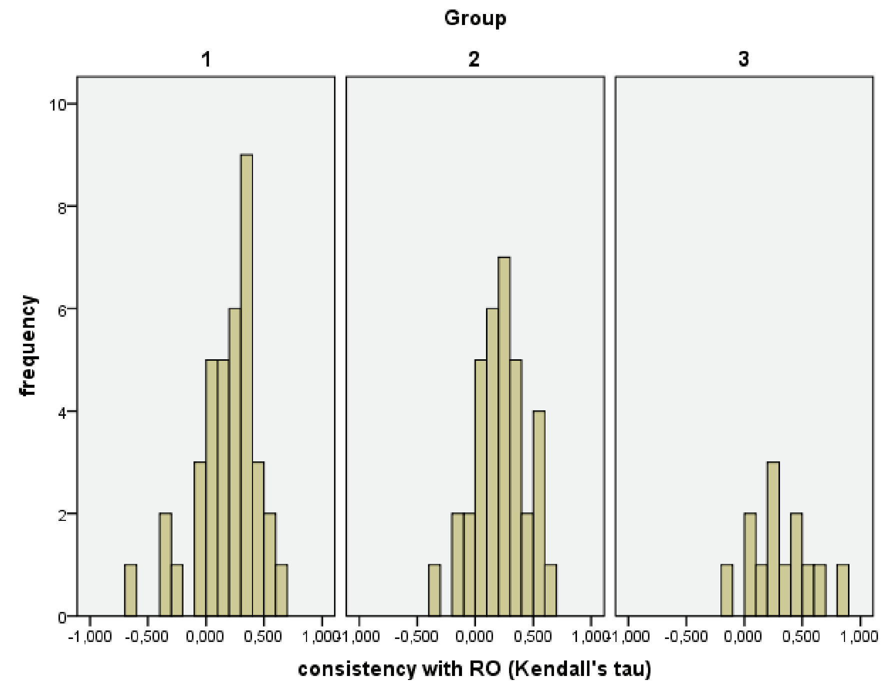
The null hypothesis constituted by the NPV prediction is rejected for both treatments. At the same time, respondents' late disinvestment offers support for P2.

Test of P1 and H2

In order to test benchmark prediction P1 as well behavioral hypothesis H2, we focus on individual rank correlation coefficients between optimal disinvestment triggers and observed behaviors that provide an indicator for consistency between choice and real options benchmark.

As Fig. 3 (left and middle distribution) shows, individuals' behavior in the experiment results in a majority of positive correlations between the benchmark prediction applying D2 and observed behavior. The null hypothesis of non-correlation could be rejected for both volatilities (t-test, $p<0.001$), proving thus that the individual rank correlation coefficients are on average positive and significantly different from zero. Mean correlation coefficients are slightly higher under high volatility (0.22 vs. 0.18) but do not differ significantly (t-test; $p>0.05$). Since they are not significantly higher in the high-volatility treatment, H2 is not supported.

Fig. 3. Kendalls' Tau correlations between RO-benchmark and choices per individual



Caption: *Group 1="Non-Entrepreneurs; Low Volatility", Group 2="Non-Entrepreneurs; High Volatility", Group 3="Entrepreneurs; High Volatility"*

Test of P3 and H1

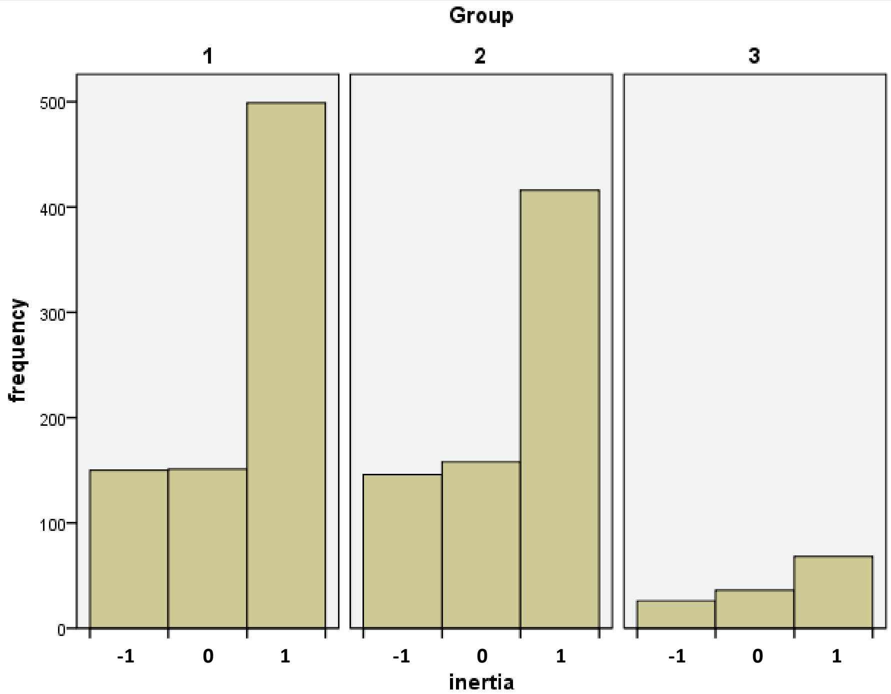
With non-entrepreneurs, the Holt and Laury lotteries reveal the predominance of risk aversion, which is consistent with previous experimental findings (see, e.g., Holt and Laury, 2002). Out of the 76 individuals whose choices did not violate monotonicity, 9.2% were risk seeking, 17.1% risk neutral, and 73.7% risk averse.

As posited by P3, the more risk averse an individual, the earlier (in comparison to the decision rule D_2) should he / she disinvest. This tendency would have to show up in the individual's deviation of actual disinvestment from the benchmark triggers. Specifically, the more risk averse an individual, the more should he / she tend to early disinvestment compared to the risk neutral triggers calculated using D2.

Looking again at Fig. 4 and Fig. 5 (left and middle diagrams), the experimental results provide strong evidence for psychological inertia going beyond what can be rationalized via an 'options-based' reasoning. Referring to Fig. 4, a tendency to late disinvestment is prevalent and there is a similar percentage of early and theory consistent disinvestment both under low and high volatility (respectively 18.8 % versus 18.9 % in the low-volatility treatment and 20.3 % versus 21.9 % in the high-volatility treatment). This already gives a first indication of risk aversion not having an overall effect in the predicted direction.

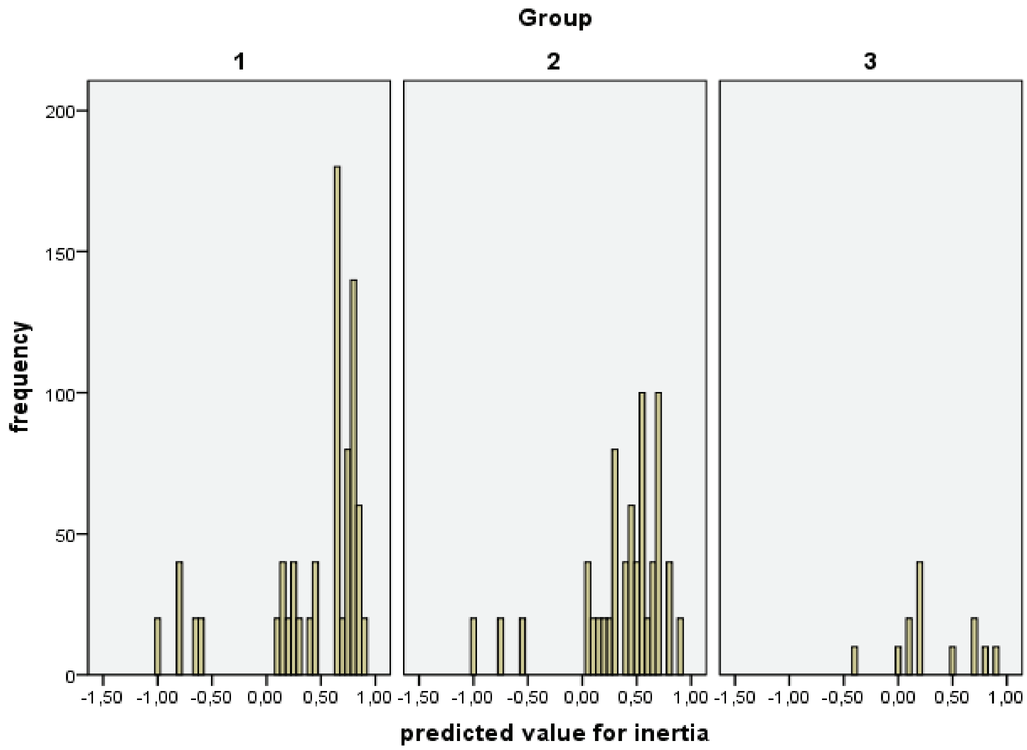
H1 stated that individuals tend to wait with the disinvestment for too long, i.e., wait more than indicated by an 'options-based' inertia. Looking at Fig. 4, late disinvestment (1) is much more prevalent than early (-1) or theory consistent disinvestment (0). This provides strong evidence for disinvestment inertia going beyond the real options benchmark.

Fig. 4. Inertia per group



Caption: *Group 1="Non-Entrepreneurs; Low Volatility", Group 2="Non-Entrepreneurs; High Volatility", Group 3="Entrepreneurs; High Volatility"*

Fig. 5. Predicted value for individual inertia



Caption: *Group 1="Non-Entrepreneurs; Low Volatility", Group 2="Non-Entrepreneurs; High Volatility", Group 3="Entrepreneurs; High Volatility"*

The fact that late disinvestment occurs in 62.4 % of cases under low volatility and in 57.8 % of the cases under high volatility clearly speak for a strong tendency towards psychological inertia.

H1 can be further analyzed by relying on the indicator of 'predicted individual inertia' described in 5.1 whose distribution is represented in Fig. 5 (left and middle distribution).

It clearly emerges that both in the high- and in the low-volatility treatment, only few respondents tend to early disinvestment (see the negative range in Fig. 5), while the large majority exhibits a tendency towards late disinvestment. Mean values of the indicator 'predicted individual inertia' are 0.44 for the low- and 0.38 for the high-volatility treatment. Both coefficients are significantly positive ($p < 0.001$) and do not significantly differ from each other ($p > 0.05$).

Hence, H1 is strongly supported and P3 positing the opposite direction for our majority of risk averse individuals is rejected.

Robustness checks

A linear regression with the individual correlation coefficients as dependent and volatility, age, gender, and risk propensity (in the form of the number of safe choices in the Holt and Laury test) as independent variables yields no significant effects for any of the tested variables ($p>0.10$) showing that the general degree of consistency with the real options benchmark does not depend on either individual characteristics or volatility. The same result emerges based on regressions with the 'predicted individual inertia' coefficients as dependent and the same variables as independent variables. Hence, inertia is also independent of those factors. This underlines our above decision with respect to P3. It indicates that the tendency to disinvest too late or too early is independent of risk propensity.

5.3 Small-scale laboratory experiment with high-tech entrepreneurs

The second study investigates the behaviour of 15 high-tech entrepreneurs. Because of inconsistencies with the monotonicity requirement in the Holt and Laury session, the choices of 2 participants have not been considered in the data evaluation. The data analysis thus refers to a subject pool of 3 female and 10 male entrepreneurs, having made 10 decisions each yielding in 130 decisions. The average age was 43.7, ranging from 22 to 66. Four of the participants declared to have a second job. On average, they have been in business for 6.7 years, with a minimum of 1 year to a maximum of 17 years of entrepreneurial activity. Average earnings amounted to 56.67 €.

Test of P0 and P2

Also among entrepreneurs, P0 is not supported by the experimental evidence (cf. Fig. 2, right distribution), as the average disinvestment occurs in period 6.91. Average disinvestment times of the entrepreneurs are significantly different from zero (t-test, $p<0.001$). Even though this was expected from a theoretical perspective, net present value is still a very common and easy to implement method to evaluate investments. Therefore, assuming entrepreneurs to be acquainted with investment and disinvestment decisions, it would not have been surprising to observe more consistency with P0 in the choice of some individuals. This was not the case, as disinvestment in the very first period only occurred 5 times, and none of the participants always disinvested in $t=0$. This also lends support for P2 within the group of entrepreneurs.

Test of P1, P3, and H1[12,13]

With a mean correlation of 0.31, which is slightly higher than among non-entrepreneurs (a marginal significant difference in a one-sided test; t-test: $p<0.10$), entrepreneurs' behavior

[12] As explained in the experimental design section, entrepreneurs played only 10 instead of 20 games, so that entrepreneurs' correlation coefficients and average deviation measures have been calculated on the basis of 10 instead of 20 observations.

[13] As entrepreneurs only played under high-volatility regime, H2 does not apply and ´could not be tested.

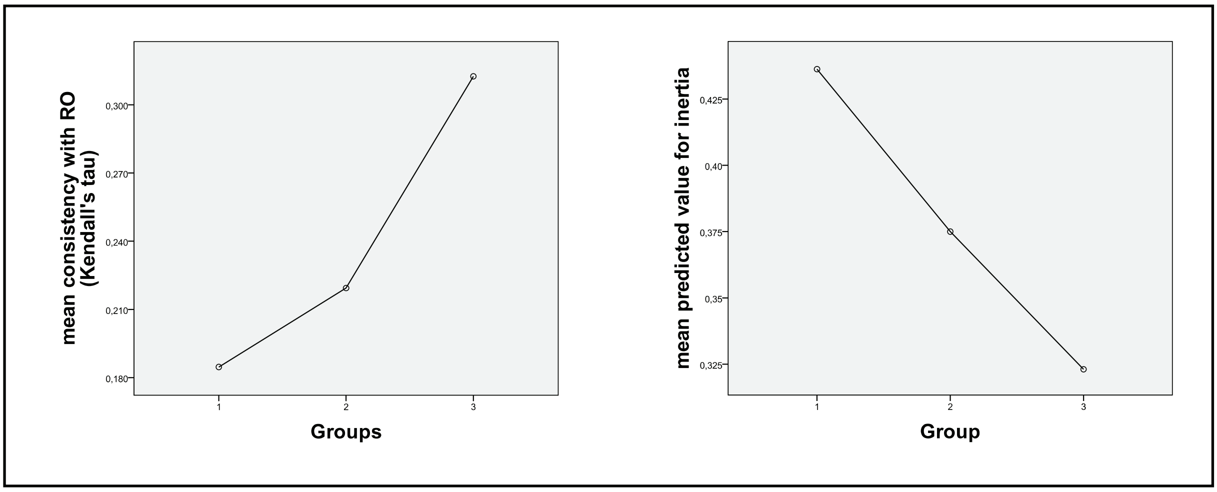
exhibits a subtle tendency to be more consistent with real options reasoning (cf. Fig. 3). The null hypothesis of zero correlation can be rejected even in this small sample (t-test, p<0.01) lending further support to P1. Nevertheless, entrepreneurs are also prone to inertia going beyond benchmark predictions (52.3 % versus 57.8 % of non-entrepreneurs with high volatility) and similarly susceptible to early disinvestment (20.0 % versus 20.3 %, as represented in Fig. 4, middle and left diagrams). 'Predicted individual inertia' is significantly larger than zero (p<0.01) but does not significantly differ from that of the non-entrepreneurs (p>0.10).

None of the entrepreneurs is a risk taker, 23.1% are risk neutral, and 76.9% are risk averse, according to the Holt and Laury test. The number of safe choices in this test is not significantly different between entrepreneurs and non-entrepreneurs (t-test, p>0.10). Hence, risk propensity seems not to differ between these two groups of individuals. A linear regression with entrepreneurs' 'predicted individual inertia' coefficients as the dependent and age, gender, and risk propensity (number of safe choices in Holt and Laury test) as independent variables demonstrates none of these parameters to be statistically significant (p>0.10). Hence, risk propensity is again irrelevant for disinvestment timing lending no support to P3.

Joint test of entrepreneurs' and non-entrepreneurs' consistency with the benchmark

Figures 2, 3, 4, 5, and 6 reveal a consistent pattern. Entrepreneurs are always slightly *more* consistent with the real options benchmark. They exhibit a smaller tendency to wait until the last period (Fig. 2), they show a smaller fraction of negative or zero rank correlations (Fig. 3), as a population, they exhibit a smaller fraction of late disinvestment choices (Fig. 3), and only one entrepreneur clearly tends to early disinvestment (Fig. 5). Figure 6 allows for a comparison of average responses across all three groups. Entrepreneurs are more consistent with the real options framework and 'predicted individual inertia' coefficients are smaller with entrepreneurs.

Fig. 6. Means of Kendalls' tau and predicted value for inertia per group



Given the small number of entrepreneurs, it is actually quite difficult to achieve a clear statistical significance for those differences. However, and consistent with the above t-test results, the entrepreneur dummy variable (entrepreneur vs. non-entrepreneur) achieves marginal significance (one-sided) in an overall regression with individual rank correlations as dependent and risk propensity, gender, and volatility as independent variables. None of the other tested variables has a significant effect on the individual correlation coefficients ($p>0.10$). Although a marginal significance can be seen as indicating a tendency, a conservative interpretation of our findings dictates not to base our discussion and implications on this. But our results clearly offer no support to an idea of entrepreneurs being more biased or having a tendency to hold on with a losing activity than other individuals.

Some entrepreneurs stated to have associated the experimental problem with a real-life situation. Specifically, they related it to technology marketing, customers' willingness to pay, investment strategy, and profitability of continuation of an ongoing project.

Final remark on learning

As explicitly pursued by providing no direct payoff feedback after the disinvestment choices, no significant learning effects seem to have occurred in any of the treatments and / or studies. Exploring the occurrence of theory consistent choices in the different periods, we found no monotonic trend supporting the occurrence of learning.

6. Discussion and implications

Disinvestment and, in particular, entrepreneurial exit represent crucial decisions for business practice that involve substantial risk. Two alternative explanations are possible as to why individuals might postpone disinvestments: a rational account in line with real options reasoning as well as a behavioral account in line with a status quo bias, inaction inertia, and other psychological phenomena leading individuals to generally postpone or even avoid action. Since the implications of these two explanations for judging the adequacy of entrepreneurs' disinvestment choices are quite different, the experiments carried out in the present contribution aimed at disentangling an 'options-based' from a 'psychological' inertia.

The main findings from this experimental study are first that individuals do postpone taking an irreversible decision such as project termination even if the net present value is negative to start with, hence rejecting traditional investment theory and its myopic property as an account of actual human behavior. We also do not expect individuals to carry out the computations necessary to make disinvestment choices fully consistent with real options reasoning. However, we have evidence for many of them at least intuitively understanding the value of waiting and applying decision rules that result in choices somewhat consistent with those that would have resulted if they had applied such reasoning.

However, even though (intuitive) real options reasoning seems to be more appropriate to account for individuals' behavior than the net present value approach, an 'options-based' inertia appears not to be the entire story. 'Psychological inertia' plays a central role in as a driver of disinvestment behavior and is not moderated by factors such as gender, age, and risk propensity.

Although entrepreneurs' behavior seems not to differ substantially from that of non-entrepreneurs, a subtle tendency of the entrepreneurs to exhibit more options-like reasoning than non-entrepreneurs could be demonstrated. This is clearly opposed to any argument along the lines that entrepreneurs are *especially prone* to go on with a losing investment for too long. This result is fully consistent with the much simpler questionnaire experiments – not looking at disinvestment choices and not employing a multi-period framework – reported in Burmeister and Schade (2007) demonstrating that entrepreneurs are not more status quo biased than students, and that they are actually less status biased than bankers.

In a real options framework, entrepreneurs' behavior could also be consistent with risk taking. However, a tendency towards risk taking could neither be demonstrated by Elston et al. (2006) nor in our sample. Furthermore, risk propensity could be demonstrated to be simply not related to disinvestment choices with either high or low volatility or with entrepreneurs or non-entrepreneurs in our experiments. We admit that our measurement of risk propensity is not reflective of most risks outside the laboratory. However, it is consistent with our experimental task. This is necessary to give the measurement a fair chance to be predictive for behavior in our disinvestment task.

Although entrepreneurs revealed slightly more consistency with real-options reasoning than non-entrepreneurs, they are still characterized by pronounced psychological inertia. Could there be anything reasonable with respect to this 'irrational' tendency? This question should be answered before suggesting potential 'cures' for this problem. Taking into account that our results refer to a sample of successful high-tech entrepreneurs, it might be argued that they have learned that it makes sense to pursue a project even in difficult times, i.e., that it might make sense to tolerate lower cash flows and wait before taking the irreversible decision of a disinvestment. The point is that people tend to bring their experience into the lab (Burns, 1985) and perseverance is commonly considered to be not only a key to entrepreneurial success, but rather a virtue for mankind in general: Where would astronomy be without Copernicus' and Galileo's stubbornness against all evidence and state of the art?

The latter argument has a lot in common with an 'ecological rationality' argument (Gigerenzer and Goldstein, 1996; 2002): Could it be a smart heuristic to wait a bit longer before an irreversible choice is made than it appears to be rational at first sight? Besides our reasoning in favor of perseverance, there is another aspect favoring such behavior outside the laboratory. Uncertainty or ambiguity, surely a more accurate characterization of most entrepreneurial decision situations than risk with known probabilities, could make waiting more valuable than with known probabilities.[14]

Another aspect that is relevant for the implications we can draw from our study is the relatively low consistency between disinvestment choices and benchmark triggers with both entrepreneurs and non-entrepreneurs. One the one hand, significant correlations indicate that individuals somehow apply an 'options-based' intuition or reasoning. On the other hand, average coefficients below 0.50 are still quite low under conditions of high volatility given the importance of disinvestment choices for the financial success of this group of individuals. Hence, we believe that teaching 'options-based' reasoning to entrepreneurs as well as non-entrepreneurs could lead to an improvement of their decision making.

But is it actually possible to improve or even induce 'options-based' reasoning? As research on theory recursivity argues, it is important for effective consulting and advising to take into consideration the boundedly rational processing of knowledge and information when teaching theories (Güth and Kliemt, 2004a; 2004b; Sandri, 2009). It is especially hard to equip, e.g., individuals with counterintuitive concepts such as mixed strategies and one has to come up with smart ideas how to translate such concepts into practical advice. In this regard, however, our experiment is quite encouraging since, even though for some individuals the correlations between options benchmark and choices are quite low or even negative, it provides some evidence of an existing affinity between a real options perspective and individuals' intuitive reasoning one could build up upon.

7. Limitations and Future Research

As already pointed out, the experimental examination and testing of real options settings is in its beginning and experimental evidence on behavior with abandonment options other than the present study is, to the best of our knowledge, lacking. Moving on a rather unexplored terrain, we consider our study a small but important first step on the way towards a better understanding and rationalizing of termination choices. A lot of work remains to be done in order to better understand what kinds of heuristics might exactly drive different individuals' decision making in disinvestment situations.

Among the limitations of the current experimental setting (which we were aware of and whose potential disadvantages we carefully pondered in advance), are the discrete modeling of returns from the existing project and the identity of the myopic NPV prediction with an extreme (period 0). While continuous returns would have enriched our understanding of behavior (in particular concerning the heuristics applied), discrete returns have been adopted in order to keep the setting as clear and easy to understand as possible. The location of the NPV prediction was inspired by the necessity to separate this prediction enough from the

[14] We are grateful to Gerd Gigerenzer for suggesting this explanation.

options benchmarks whilst keeping volatility within a moderate range. However, results revealed this potential frailty of the chosen design not to matter much as most choices fell wide apart from the NPV predictions.

Concerning the experiment with entrepreneurs, the main limitation is the small sample size. Only larger sample sizes would help substantiating the differences between entrepreneurs and non-entrepreneurs towards a clear level of significance. It is however quite difficult to motivate successful high-tech entrepreneurs to take part in a controlled experimental study despite the availability of a mobile laboratory. Nevertheless, we were able to collect 10 disinvestment choices with each entrepreneur participating in our study, resulting in 130 usable entrepreneurial decisions.

Further research in the vein of this study should investigate the effect of framing on disinvestment choices: Will individuals be more ‘attached’ to a project that is framed in realistic terms? Another interesting path to be taken is testing the disinvestment behavior of other groups of individuals. An exciting endeavor, e.g., is testing the behavior of farmers, as they have been alleged to be particularly conservative and averse to changes (Jose and Crumly, 1993; Odening et al., 2005). The experimental results also signal the need to disentangle the effects of the different potential drivers of ‘psychological inertia’, i.e., status quo bias, reluctance to change, escalation of commitment etc., in further studies. The study by DeTienne et al. (2008) is already an important contribution along this path. However, we could like to see the results that would emerge keeping our incentive compatible experimentation methodology. Finally, it is clearly worth pursuing the ecological rationality interpretation of late disinvestment. Experiments implementing uncertainty or ambiguity might be an appropriate step towards a better understanding of the relevance of this explanation and helping to weigh this perspective against the occurrence of ‘psychological inertia’ as a bias in a scenario closer to the characteristics of the actual business world.

8. Conclusion

This study provides experimental evidence for entrepreneurs as well as non-entrepreneurs understanding the value of waiting in disinvestment decisions and for being partially in tune with an ‘options-based’ reasoning. But we have also strong evidence for a ‘psychological inertia’ occurring, individuals tend to postpone disinvestment for longer than ‘options-based’ reasoning would advise them to do.

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Appendix: Experimental instructions

Translation from German, instructions for study with non-entrepreneurs, high-volatility treatment

General information

[…] Please read all instructions carefully as your earnings from the experiment will depend on your decisions. At the end of the experiment you will receive your earnings in cash.

Feel free to use pen, scratch paper, and calculator available on your desk.

Please remain seated and do not communicate with other participants during the experiment.

First Part

The first part of the experiment consists of a trial game, followed by 20 repetitions of the same game. The trial game is played to make you familiar and more confortable with the game. The trial won't be considered for payment.

Each game consists of 11 rounds.

In each game you should try to get as many points as possible as your earnings are proportional to the number of points you get during the experiment.

For each 3,500 points, you get 1 Euro.

At the end of the experiment, one of the 20 games will be randomly chosen by the computer and you will be paid according to your individual score (i.e., the number of points you have accumulated) in this selected game.

Introduction to the game

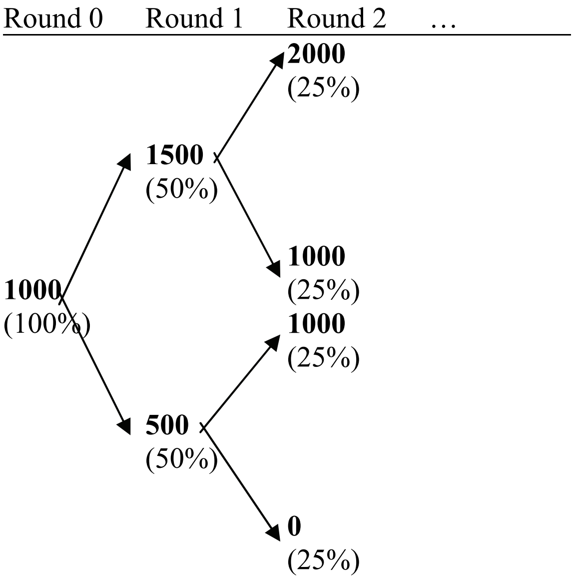
In each game you will start with a score of 1,000 points in Round 0. In the next round (Round 1) and in any subsequent round:

- Your points can either increase by 500 points with a probability of 50 %,
- Or they can decrease by 500 points, also with a probability of 50 %.

For example, from Round 0 to Round 1, in 50 % of the cases your points will increase to 1,500 points (1,000+500), or, in the remaining 50 % of the cases, they will decrease to 500 points (1,000-500).

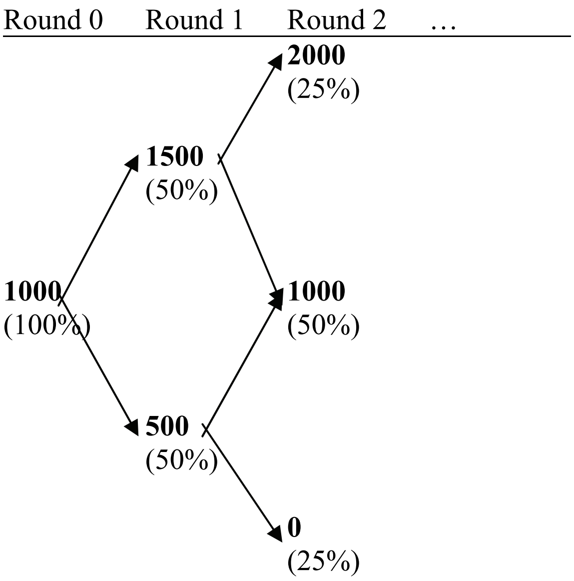
In the diagram, you can see an example for this dynamics for three rounds:

The probability of occurrence of a certain score is written below the respective score in parentheses.



The situation can also be represented in a simpler form. The only difference is that for Round 2, the score of 1,000 appears just once and its probability of occurrence equals the sum of the probabilities that were separately listed in the diagram above.

In the following, we will use this form of representation throughout.



Your screen

You can see the potential developments of your points from round to round on your PC-screen. These developments will be represented in the following form:

Round 0	Round 1	Round 2	Round 3	Round 4	Round 5	Round 6	Round 7	Round 8	Round 9	Round 10
1000	**1500**	**2000**	**2500**	**3000**	**3500**	**4000**	**4500**	**5000**	**5500**	**6000**
100,00%	50,00%	25,00%	12,50%	6,25%	3,13%	1,56%	0,78%	0,39%	0,20%	0,10%
	500	**1000**	**1500**	**2000**	**2500**	**3000**	**3500**	**4000**	**4500**	**5000**
	50,00%	50,00%	37,50%	25,00%	15,63%	9,38%	5,47%	3,13%	1,76%	0,98%
		0	**500**	**1000**	**1500**	**2000**	**2500**	**3000**	**3500**	**4000**
		25,00%	37,50%	37,50%	31,25%	23,44%	16,41%	10,94%	7,03%	4,39%
			-500	**0**	**500**	**1000**	**1500**	**2000**	**2500**	**3000**
			12,50%	25,00%	31,25%	31,25%	27,34%	21,88%	16,41%	11,72%
				-1000	**-500**	**0**	**500**	**1000**	**1500**	**2000**
				6,25%	15,63%	23,44%	27,34%	27,34%	24,61%	20,51%
					-1500	**-1000**	**-500**	**0**	**500**	**1000**
					3,13%	9,38%	16,41%	21,88%	24,61%	24,61%
						-2000	**-1500**	**-1000**	**-500**	**0**
						1,56%	5,47%	10,94%	16,41%	20,51%
							-2500	**-2000**	**-1500**	**-1000**
							0,78%	3,13%	7,03%	11,72%
								-3000	**-2500**	**-2000**
								0,39%	1,76%	4,39%
									-3500	**-3000**
									0,20%	0,98%
										-4000
										0,10%

This table can be interpreted as follows:

In the first round (Round 0) you receive ***1,000*** points (shown in ***italics*** in the diagram). The points you may realize in the next rounds are written in **bold**. The probabilities of occurrence of the scores are listed under the respective score.

Assume that in Round 1, your score increased from 1,000 to 1,500 points. Then the scores that are written in ***italics*** are no longer possible, i.e., their probability of occurrence is 0.

In this case, your PC-screen will look the following way:

Round 0	Round 1	Round 2	Round 3	Round 4	Round 5	Round 6	Round 7	Round 8	Round 9	Round 10
1000	***1500***	**2000**	**2500**	**3000**	**3500**	**4000**	**4500**	**5000**	**5500**	**6000**
0,00%	100,00%	50,00%	25,00%	12,50%	6,25%	3,13%	1,56%	0,78%	0,39%	0,20%
	500	**1000**	**1500**	**2000**	**2500**	**3000**	**3500**	**4000**	**4500**	**5000**
	0,00%	50,00%	50,00%	37,50%	25,00%	15,63%	9,38%	5,47%	3,13%	1,76%
		0	**500**	**1000**	**1500**	**2000**	**2500**	**3000**	**3500**	**4000**
		0,00%	25,00%	37,50%	37,50%	31,25%	23,44%	16,41%	10,94%	7,03%
			-500	**0**	**500**	**1000**	**1500**	**2000**	**2500**	**3000**
			0,00%	12,50%	25,00%	31,25%	31,25%	27,34%	21,88%	16,41%
				-1000	**-500**	**0**	**500**	**1000**	**1500**	**2000**
				0,00%	6,25%	15,63%	23,44%	27,34%	27,34%	24,61%
					-1500	**-1000**	**-500**	**0**	**500**	**1000**
					0,00%	3,13%	9,38%	16,41%	21,88%	24,61%
						-2000	**-1500**	**-1000**	**-500**	**0**
						0,00%	1,56%	5,47%	10,94%	16,41%
							-2500	**-2000**	**-1500**	**-1000**
							0,00%	0,78%	3,13%	7,03%
								-3000	**-2500**	**-2000**
								0,00%	0,39%	1,76%
									-3500	**-3000**
									0,00%	0,20%
										-4000
										0,00%

As you can see, the probabilities of occurrence of the scores have changed. In fact, they change in each round, i.e., they depend on the outcome(s) in the previous round(s).

Your decision and your profit

In each round you may:

- let your point score accumulate as described above (i.e., stay in the game)
- or terminate the game and accept a lump-sum payment of 11,000 points (eleven-thousand) (i.e., leave the game).

The *total* number of points you carry on to each subsequent round increases by **10 %** for each round left in the game (irrespective of whether you play all rounds or not), i.e., your total score will increase by one tenth and is then added to the points you will receive in the subsequent rounds. You can think of this increase as an interest payment.

The interest rate also applies to the lump-sum payment of 11,000 points, after you have left the game. It is added to the points you have collected until you decided to leave the game. Starting from the round in which you decide to terminate the game, this sum increases by 10 % for each of the remaining rounds.

Assume, you decided to terminate the game in Round X and receive 11,000 points.

Then your total score at the end of the game consists of:

- All points you have received before this round, increased by 10 % per round after you received them until round 10
- Plus 11,000 points you get because you have decided to leave the game. The 11,000 points also increase by 10 % for each of the remaining rounds (i.e., from Round X to Round 10).

If you stay in the game until the last round (i.e., play the entire game from Round 0 to Round 10), you automatically get 11,000 points at the end of the game (i.e., in Round 10).

Consider the following example:

Example

Imagine you received the points printed in ***italics***:

Round 0	Round 1	Round 2	Round 3	…
1000	1500	2000	2500	
	500	***1000***	***1500***	
		0	500	
			-500	

In this case your total score is equal to:

- The 1,000 points you received in Round 0 increased by 10 % for each of the remaining 10 rounds of the game, i.e., $\underbrace{1000 \cdot 1.1 \cdot 1.1 \cdot ... \cdot 1.1}_{10 times} = 1000 \cdot 1.1^{10} = 2593.7$
- Plus the 500 points you received in Round 1 increased by 10 % for each of the remaining 9 rounds, i.e., $\underbrace{500 \cdot 1.1 \cdot 1.1 \cdot ... \cdot 1.1}_{9 times} = 500 \cdot 1.1^{9} = 1179$
- Plus the 1000 points of Round 2 increased by 10 % for each of the remaining 8 rounds, i.e., $\underbrace{1000 \cdot 1.1 \cdot 1.1 \cdot ... \cdot 1.1}_{8 times} = 1000 \cdot 1.1^{8} = 2143.6$
- Plus the 1500 points of Round 3 increased by 10 % for each of the remaining 7 rounds, i.e., $\underbrace{1500 \cdot 1.1 \cdot 1.1 \cdot ... \cdot 1.1}_{7 times} = 1500 \cdot 1.1^{7} = 2923.1$
- Plus the 11000 points you received in addition in Round 3 (because you decided to leave the game in this round) also increased by 10 % for each of the remainning 7 rounds, i.e., $\underbrace{11000 \cdot 1.1 \cdot 1.1 \cdot ... \cdot 1.1}_{7 times} = 11000 \cdot 1.1^{7} = 21435.9$

Therefore, your total score in this game equals to:

$2593.7 + 1179 + 2143.6 + 2923.1 + 21435.9 = 30275.3$ points

[…]

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