Unleashing Animal Spirits - Self-Control and Overpricing in Experimental Asset Markets*

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Abstract

One explanation for overpricing on asset markets is a lack of self-control abilities among traders. Self-control is the individual capacity to override or inhibit undesired behavioral tendencies such as impulses, and to refrain from acting on them. We implement the first experiment that is able to address a potential causal relationship between self-control abilities and systematic overpricing on financial markets by introducing an exogenous variation of self-control abilities. Moreover, our experimental treatments seek to detect some of the channels through which individual self-control problems could transmit into irrational exuberance on the aggregate level. We observe a strong and causal effect of self-control abilities on market overpricing. Low self-control traders are associated with significantly larger levels of overpricing, and they earn significantly less on exuberant markets as a consequence of holding assets for too long.

JEL codes: G02, G11, G12, D53, D84

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1 Introduction

> "Even apart from the instability due to speculation, there is the instability due to the characteristic of human nature that a large proportion of our positive activities depend on spontaneous optimism rather than mathematical expectations, whether moral or hedonistic or economic.
> Most, probably, of our decisions (...) can only be taken as the result of animal spirits – a spontaneous urge to action rather than inaction, and not as the outcome of a weighted average of quantitative benefits multiplied by quantitative probabilities."[1]
>
> *John Maynard Keynes*

Examples of traders on financial markets that create extremely high losses when speculating with the money of their companies or customers are abundant. Some of these rogue traders are famous such as Jérôme Kerviel of Société Générale, who lost an estimated €4.9 billion (http://www.nytimes.com/2010/10/06/business/global/06bank.html), or Nicholas "Nick" William Leeson, who caused the collapse of one of the oldest British investment banks as a consequence of speculation. Reading their stories carefully seems to indicate that, at a certain stage, their activities went out of hand; they fell in a kind of fever and could not stop what they were doing even if they knew that it was likely to end in a disaster. In other words, they seem to have completely lost their abilities to exert self-control. Rogue traders are extreme examples. On a more moderate level, loss or impairment of self-control abilities could generally contribute to sub-optimal decision making on financial markets, leading to price exaggerations on the aggregate market level. When Keynes alludes to spontaneous urges as "animal spirits", loss of self-control or its impairment seems to be an important aspect.

This paper is the first to provide causal empirical evidence of the effects of a variation in self-control abilities or willpower on trading behavior. We use a well-understood financial market design in the experimental laboratory (Smith et al., 1988; Kirchler et al., 2012; Noussair and Tucker, 2013; Palan, 2013; Eckel and Füllbrunn, 2015) to investigate whether an exogenous variation in self-control abilities of traders leads to overpricing and irrational exuberance. This experimental asset market is known for its basic tendency to exhibit overpricing; it features a dividend-bearing asset with decreasing fundamental value over ten trading periods in a continuous double-auction market design with open order books. Our main finding is a highly significant increase in the extent of overpricing on markets where trades' self-control abilities have been depleted, using the Stroop task (Stroop, 1935), compared to markets with traders whose self-control abilities have not been

[1] Source: Keynes (1936), p. 136.

depleted, or have been depleted to a lesser degree. Our study design allows us to exclude that this increase is driven by a simple change in risk attitudes or a decrease in cognitive abilities following self-control depletion. When we introduce an asymmetry in self-control abilities on the same market by depleting only half of the traders, we can show that traders low in self-control earn significantly less than their unaffected peers, the larger the absolute extent of overpricing on the market. Most parsimoniously, this finding can be explained by an increased difficulty of low self-control traders to stop speculating and/or to sell their assets at peak prices. Hence, the disposition effect – the suboptimal timing of selling and buying assets (Shefrin and Statman, 1985; Weber and Camerer, 1998) – seems to be related to self-control abilities.

Keynes famously saw "animal spirits" at the root of many (financial) decisions. As often with Keynes, the term was not well-delineated in his work. It could potentially allude to instincts, urges, emotions, or similar concepts. In contrast, self-control abilities and willpower are clearly defined in psychology as the capacities to override or inhibit undesired behavioral tendencies, such as impulses, and to refrain from acting on them (Tangney et al., 2004). Typically, self-control is necessary to guard oneself against undue optimism, actions motivated by emotional responses, and impulsive decisions. Furthermore, self-control is required in order to stick to plans. It is probably important to notice that self-control does not preclude emotional responses; it is just at odds with a reaction that is guided by emotions alone.[2]

But is self-control relevant at all on real-world financial markets? Looking at statements by investment gurus or popular guidebooks on the psychology of investing, the relevance of self-control for investor success on stock-market seems to be obvious. For instance, Warren Buffet emphasizes that "success in investing doesn't correlate with I.Q. once you're above the level of 25. Once you have ordinary intelligence, what you need is the temperament to control the urges that get other people into trouble in investing" (http://www.businessweek.com/1999/99_27/b3636006.htm). In a study by Lo et al. (2005), involving day traders from an online training program, participants regarded attributes related to self-control as the most important determinants of success for traders.[3]

However, much to our surprise, apart from anecdotal and some correlational evidence, there have been no attempts in the economics literature so far to empirically address the effects of self-control abilities on (financial) market behavior. One challenge to overcome is to exogenously vary self-control abilities in order to obtain causal inference. A first step is to use the experimental laboratory and affect *state* self-control levels of traders. Most of the available techniques draw on the concept of self-control depletion or exhaustion. Our experimental identification rests on the assumption

[2] Recent survey papers are provided by Vohs and Baumeister (2011) and de Ridder et al. (2012).

[3] They quote attributes such as persistence, tenacity, perseverance, patience, discipline, planning and controlling emotions, and (lack of) impulsivity as crucial (Lo et al., 2005, table 3).

that self-control is a limited resource and that it is variable over time on the individual level. Evidence for these two characteristics is abundant (Baumeister et al., 1998; Gailliot et al., 2012). The Stroop task is one of the most commonly used tasks in psychology experiments for modulating self-control (Hagger et al., 2010), it is easy to administer, and it allows for additional controls. While validated survey measures for *trait* self-control exist, they can only provide correlational inference. The majority of studies that use both survey measures and behavioral measures conclude that the effects of state self-control interventions can be explained by trait self-control levels. Hence, even if our experiment is confined to the laboratory setting and to a variation of state self-control, it is likely that it extends to real-world situations in which also trait self-control matters. Obviously, controlled evidence from the field is a desirable next step in understanding self-control abilities in investment behavior.

Several implications of our results for real-world investing and trading activities come to mind. Given our findings, investment decisions should not be taken under limited self-control or willpower conditions. For instance, cognitive load, food or sleep deprivation, and self-control effort in unrelated domains have been shown to be correlated with limited self-control abilities. If such conditions are unavoidable, decision aides to sustain self-control such as commitment devices should prove useful to circumvent the potentially negative effects of low self-control trading. As a regulatory measure, cooling-off periods before buying and selling could be helpful in certain environments, but they obviously have detrimental effects in fast-paced markets. In any case, our results suggest that low self-control traders can be exploited by high self-control traders if characteristics are observable.

The remaining paper is organized as follows: Section 2 gives an overview of the literature related to our research question, and in section 3, we explain and motivate our experimental design. Consequently, section 4 presents the results from our main experiment, and section 5 reports on an additional experiment that allows us to understand specific channels through which self-control depletion translates into overpricing and potential disadvantages for traders. Section 6 discusses our findings, and section 7 concludes the paper.

2 Related Literature

Recently, the concepts of self-control and willpower have been addressed in economics both from a theoretical as well as from an empirical angle. In the models at hand, a lack of self-control causes decisions that counteract long-run interests of an individual. Prominent examples are addictive behavior, under-saving and procrastination (Bucciol et al., 2010). Popular ways to model self-control are intra-personal conflicts between multiple selves with diverging interests (Thaler and Shefrin, 1981; Fudenberg and Levine, 2006), models of quasi-hyperbolic discounting, i.e. relative overweighting of present utility (Laibson, 1997), and temptation models a la Gul and Pesendorfer (2001), who model self-control errors as cue-triggered mistakes (see also Benhabib and Bisin (2005); Bernheim and Rangel (2004); Kim (2006)). Furthermore, lack of self-control has been connected to overspending (Heidhues and Koszegi, 2010). In more recent models, willpower has been explicitly modeled as an internal depletable resource (see Ali, 2011; Fudenberg and Levine, 2012; Ozdenoren et al., 2012). The theoretical literature in economics on self-control and its implication for consumer choices has been growing rapidly lately, whereas the empirical literature is much more limited.

In the following overview, we focus on empirical self-control papers in economics that are related to saving and investment decisions. One strand of the literature relies on survey evidence. Ameriks et al. (2003, 2007) consider the connection between wealth accumulation and self-control in a sample of highly educated US households. Ameriks et al. (2003) attribute differences in savings among households to differing "propensities to plan" – i.e. different individual costs of exerting self-control. Ameriks et al. (2007) use the difference between planned behavior and expected behavior in a hypothetical scenario as a measure for self-control problems. They find a positive correlation between better self-control abilities and wealth accumulation, in particular for liquid assets. Gathergood (2012) conduct a similar study in the UK with a representative sample. He reports a positive association of lack of self-control and consumer over-indebtedness. Interestingly, an experimental study by Vohs and Faber (2007) shows, that the availability of self-control resources predicts whether people can resist impulse buying temptations, hinting at a causal relation from the availability of self-control resources on saving and spending behaviors of individuals.

A prominent set of papers uses choices that imply a delay of gratification as a measure for self-control abilities or willpower. Much of the research relates to earlier work by Mischel and co-authors (e.g., Mischel et al. (1989)), who analyze the self-control abilities of young children and their predictive power for later life outcomes, ranging from relationships to drug abuse. While this research shows that self-control abilities are an individual trait that seems to be relatively stable over time, recent research in psychology has provided convincing evidence of temporary exhaustibility of willpower. There is convincing evidence that self-control relies on limited resources and effectively works like a muscle, i.e. the exertion of self-control temporarily uses up energy for other acts that require self-control. It uses cognitive control, affective control, or both (Hagger et al., 2010). Self-control abilities regenerate through rest, can be trained and differ between people (Baumeister et al., 1998; Muraven et al., 1999; Muraven and Baumeister, 2000; Tangney et al., 2004; Muraven, 2010).

Self-control can also be related to dual-systems perspectives of decision making. Those share the general assumption that structurally different systems of information processing underlie the production of impulsive, largely automatic forms of behavior, on the one hand (system 1), and deliberate, largely controlled forms of behavior, on the other hand (system 2). System 2 is effortful and requires self-control resources. Thus, if resources are low, reflective operations may be impaired, leading to a dominance of impulsive reactions that could be in conflict with objective reasoning. From this perspective, reducing self-control abilities can be interpreted as increasing the role of the (impulsive) system 1 in decision making (Hofmann et al., 2009).

The idea of ego-depletion introduced by Baumeister et al. (1998) can be used to analyze the causal effects of reductions in self-control abilities, and it has recently been applied to a small set of topics in economics.[4] Researchers have, so far, mainly focused on the effects of reduced self-control resources on individual preferences such as risk preferences and social preferences, and on tasks in which cognitive biases are often observed. Decision making under risk is most closely related to the present setting. The consequences of self-control variations in risky decision making have been studied empirically with inconclusive results: On the one hand, Bruyneel et al. (2009) find that decision makers with reduced self-control take more risks. On the other hand, Unger and Stahlberg (2011) observe an increase in risk aversion after self-control depletion. Bucciol et al. (2011, 2013) show in field experiments with children and adults that self-control depletion leads to reduced productivity in subsequent tasks. De Haan and Van Veldhuizen (2012) find no effect of a repeated Stroop task on the performance in an array of tasks in which framing effects – such as anchoring effects and the attraction effect – are typically observed. Recently, experiments on social preferences have looked at the effects of self-control variations more closely. Achtziger et al. (2011) report a strong but heterogeneous impact of reduced self-control on offers and accepting behavior in ultimatum games, presumably depending on what an individual's more automatic reactions are. Furtner and Kocher (2013) find that individuals with reduced self-control free-ride more often in social dilemmas. In a similar vein, Achtziger et al. (2015) provide evidence for reduced dictator giving after a reduction in self-control abilities.[5]

Our asset market is based on the seminal paper by Smith et al. (1988), who were the first to observe significant overpricing in an experimental double auction market. Many studies have followed up on these early findings.[6] Some of the studies are more relevant for us because specific concepts studied therein could be correlated with self-control abilities. For instance, subject confusion is one of the factors that may contribute to overpricing, since at least some of the traders on the experimental market may not fully understand the experimental instructions, and average prices are significantly reduced when an asset with decreasing fundamental value – the standard fundamental value process of stocks in Smith et al. (1988) markets – is more intuitively explained to the traders as being the stock from a depletable gold mine (Kirchler et al., 2012). Emotion regulation is also correlated with

[4]For an overview of more self-control reducing tasks for the experimental laboratory see the meta study by Hagger et al. (2010).

[5]Martinsson et al. (2014) analyze the relationship between self-control and pro-sociality in an indirect way, but their findings are also in line with the idea that pro-social behavior requires self-control.

[6]Recent surveys can be found in Noussair and Tucker (2013) and Palan (2013).

self-control abilities (Tice and Bratslavsky, 2000), and emotions have been discovered to impact prices on asset markets to a considerable extent. Andrade et al. (2012) find that inducing excitement before trading triggers bubbles in asset markets stronger in magnitude and higher in amplitude compared to other emotions and a neutral condition. In a similar study, Lahav and Meer (2012) find that inducing positive mood leads to higher deviations from fundamental values and thus larger bubbles. The role of emotions in experimental asset markets has also been evaluated using Likert scales (Hargreaves Heap and Zizzo, 2011) and face reading software (Breaban and Noussair, 2013) instead of inducing specific emotions exogenously. Results from these experiments indicate that excitement and a positive emotional state before market opening are correlated with increased prices relative to fundamental values. Moreover, fear at the opening of the market is correlated with lower price levels. There is also some evidence from real-world traders outside the laboratory. For instance, in qualitative interviews with traders from the City of London, Fenton-O'Creevy et al. (2011) found that traders regard emotions induced by previous trades as detrimental for good decision making in future trades. The authors also report marked differences in emotion regulation strategies between inexperienced traders, low-performing experienced traders, and high-performing experienced traders.

However, there is no paper so far that provides causal evidence for the relationship between self-control abilities or willpower and trading behavior on asset markets. Starting in a laboratory environment with full control over decisions seems natural, and it is the path pursued in this paper, but extensions to a field setting that varies self-control abilities naturally seem promising in the future.

3 Experimental Design

Our paper reports on two experiments. The design of Experiment I is described in this section. Experiment II is a natural extension of Experiment I and described in greater detail in section 5. Experiment I consists of four independent parts: (i) instructions and dry runs of the asset market without monetary consequences and without the possibility to build any reputation; (ii) the main treatment variation in self control, the Stroop task (Stroop, 1935) in two versions; (iii) elicitation of risk attitudes and cognitive abilities, both incentivized; and (iv) a fully incentivized asset market featuring a dividend-bearing asset with decreasing fundamental value over ten trading periods in a continuous double-auction market design with open order books.

Our identification of the effects induced by a variation in self-control abilities on market prices relies on the comparison of two versions of the Stroop task. In condition *LOWSELFCONTROL*, all market participants had to perform a variant of the original Stroop task, whereas in condition

Figure 1: Treatment Differences in the Stroop Task

HIGHSELFCONTROL we implement a placebo version of the original Stroop task. This placebo version is much easier to perform than the original Stroop task. Except for this treatment variation in part (ii), the two experimental conditions are identical.

Our variant of the original Stroop task followed a simple protocol: Experimental participants were told that they receive a flat payment of 3 € for solving as many problems as possible correctly within five minutes. A specimen of such a problem is displayed on the left-hand side of Figure 1. The task is to select the color of the font the word in front of a black screen is written in. A selection of six color buttons – always the same and in the same order on the bottom right of the screen – is given, and subjects are instructed to click on the correct one. As soon as they made a selection, the next word-color combination appeared. Consecutive word-color combinations always differed from each other. The difficulty of this task is that the words always describe one of the six colors, and that the incongruence between the color of the word and the word itself causes a cognitive conflict, since reading the word is the dominant cue. Common explanations for the conflict are automaticity of reading the word or relatively faster processing of reading than color perception (MacLeod, 1991). The created conflict has to be resolved, and resolution requires self-control effort. Applying this effort depletes self-control resources and leaves participants with lower levels of willpower and self-control resources after the five minutes.

The Stroop task is one of the most commonly applied methods to deplete self-control resources (Hagger et al., 2010). It can easily be implemented in a computer laboratory, is straightforward to explain, requires only basic literacy skills, and generates additional data on the number of correctly solved problems and the number of mistakes. In our experiment, the difference between *LOWSELFCONTROL* (Stroop task) and *HIGHSELFCONTROL* (placebo task) was the frequency with which a conflicting word-color combination occurred.[7] The instructions for both versions of the task were identical. Actually, all screens in *LOWSELFCONTROL* exhibited such a conflict, while in *HIGHSELFCONTROL* only every 70th screen did. Experimental participants did not receive any information on the occurrence of the conflict. By having an occasional word-color incongruence in *HIGHSELFCONTROL* we were able to ensure that subjects took the task seriously and had to concentrate. If anything, our setup reduces the potential treatment difference (because in *HIGHSELFCONTROL* some self-control depletion might still take place), making the potential result of a significant difference between the two conditions the more difficult to obtain.

We decided to provide participants with a flat payment of 3 € for the Stroop task and the placebo task, respectively, in order to signal that we are interested in their performance. A piece-rate or any other competitive payment scheme is out of question because it would create different wealth levels after the treatment variation that are correlated with the condition. Hence, treatment differences would be confounded potentially with wealth effects. Upon completion of the five minutes, we asked experimental participants about how strenuous they perceived the task on a six-point Likert scale.

Self-control resource depletion can influence emotion regulation, the perception of a strategic situation, the valuation of payoffs and outcomes, and many more relevant variables on the subsequent asset market. In a first attempt, it is impossible and beyond the scope of a single paper to control for all potential transmission mechanisms that a variation in self-control abilities could take on when affecting market price levels. However, we control for two very straightforward ones: cognitive ability and risk attitude.[8] Eliciting control variables has to take place after the self-control variation but before the experimental asset market. In order to avoid that the self-control variation wears off before the asset market interaction starts, it is indispensable that measuring the control variables does not take much time. Otherwise, self-control abilities could regenerate due to rest (Muraven and Baumeister, 2000). Two tasks that fitted this requirement are the Cognitive Reflection Test (CRT) for measuring individual cognitive abilities (Frederick, 2005) and a simple multiple price list lottery design for eliciting individual risk attitudes.

First, our subjects answered the three questions in the standard CRT. It is well-known that CRT responses are correlated with more time-consuming measures of cognitive ability, risk and time preferences (Frederick, 2005), as well as with decisions in a wide array of experimental tasks such as entries in p-beauty-contest games (Brañas-Garza et al., 2012) and performance in heuristics-and-biases tasks (Toplak et al., 2011).[9] Subjects were paid .5 € for every correct answer but did not

[7] The right-hand side of Figure 1 shows an example of congruence between font color and word as used on the placebo task.

[8] For evidence of potential effects of self-control depletion on complex thinking see Schmeichel et al. (2003). As mentioned in the previous section, the evidence on the relationship between self-control abilities and risk attitudes is rather inconclusive.

[9] The CRT is regarded as a measure of cognitive ability and thinking disposition (Toplak et al., 2011). Recently Noussair et al. (2014) found that the CRT is a good predictor of individual trader's profits in asset market experiments.

learn their earnings and the correct answers until the end of the experiment.

Second, we elicited individual certainty equivalents (CE) for a lottery using a multiple price list as a measure for individual risk attitudes. Differences in risk attitudes can be a rational reason for trade (Smith et al., 1988) and might explain initial underpricing of assets on the market, thus sparking off later price increases and overpricing (Porter and Smith, 1995; Miller, 2002). Furthermore, Fellner and Maciejovsky (2007) find that more risk averse individuals display more infrequent trading activities. On a single computer screen, our experimental participants had to choose ten times between a lottery that paid either .20 € or 4.20 € with equal probability and increasing certain amounts of money that were equally spaced between the two outcomes of the lottery. Subjects were allowed to switch only once from the lottery to the certain amount. At the end of the experiment, the computer randomly picked one of the ten decisions of each individual as payoff-relevant and implemented the preferred option, potentially simulating the lottery outcome.

Immediately after the risk elicitation the main part of the experiment, the asset market, opened. Remember that the instructions for trading had been distributed (and read aloud) before the Stroop task or the placebo task. The asset market featured a continuous double auction with open order books following Kirchler et al. (2012), i.e. we use a simplified version of the markets in Smith et al. (1988). Each market consisted of ten traders trading a single dividend-carrying asset over the course of ten periods lasting 120 seconds each.[10] Before the first trading period, half of the subjects in a given market received 1000 points in cash and 60 assets, and the other half received 3000 points in cash and 20 assets as their initial endowment. Assignment to the two initial asset allocations was random.

During each trading period, traders could post bids and asks as well as accept open bids and asks. Inactive orders remained in the books until the beginning of the following period, and partially executed bids and asks continued to be listed with their residual quantities. At the end of every period, the asset paid a dividend of either ten or zero experimental points with equal probability. The dividend was added to each trader's cash holdings. Assets had no remaining value after the last dividend payment, i.e. they displayed a declining (expected) fundamental value. This design feature was explicitly stated and highlighted in the instructions. To make things clear, the instructions provided a detailed table with the sum of remaining expected dividend payments per unit of the asset at any point in time. Assets and cash were carried from period to period. Short selling and borrowing experimental points were not allowed. After every period, the average trading price as well as the realizations of the current and all past dividends were displayed on a separate feedback screen. At the end of the ten periods, experimental points were converted into euros, using an

We will discuss the CRT results and their implications in more detail when we discuss our results in section 6.

[10] Appendix A.5 provides the experimental instructions, including a screen shot and a description of the trading screen.

exchange rate of 500 points = 1 €.

At the end of the experiment, subjects learned about their payoffs from all parts of the experiment. We asked them to fill in a short questionnaire concerning demographics and background data. We also asked participants how tired they felt after the experiment and how strenuous they had perceived the entire experiment on a 6-point Likert scale. Then, all earnings were paid out in private and in cash, and the subjects were dismissed from the laboratory. The experiment was conducted in October 2013. 160 participants took part in ten experimental sessions. Hence, we obtained 16 independent observations, eight for each of our treatment conditions. The experiment was programmed using z-Tree (Fischbacher, 2007), and recruitment was done with the help of ORSEE (Greiner, 2004). Experimental sessions lasted for about 90 minutes, and participants earned 18.18 € on average. We only invited students who had never participated in an asset market experiment before. We also excluded students potentially familiar with the CRT or the Stroop task.[11] Prior to the start of the experiment, subjects received written instructions for all parts of the experiment (see Appendix A.5). These were read aloud to ensure common knowledge. Remaining questions were answered in private.

4 Experimental Results

We organize the results section along the following lines: After some definitions regarding our measures for irrational exuberance and mispricing in 4.1, we start our data analysis by looking at the price development on the aggregate market level (4.2. In 4.3, our analysis zooms into single periods of market activity. XXXXXXXXXXXXXXXX

4.1 Definitions and Measures

In order to quantify the tendency of markets to exhibit irrational exuberance we compare trading prices with the fundamental value of the asset. In the following we adopt the approach of Stöckl et al. (2010) and assess the market price developments using *Relative Absolute Deviation* (RAD) (in 1) and *Relative Deviation* (RD) (in 2) as measures for general mispricing and overshooting, respectively.

$$\text{RAD} = \frac{1}{T} \sum_{t=1}^{T} \frac{|P_t - FV_t|}{|\bar{FV}|} \tag{1}$$

[11]Of our 160 subjects, one suffered from some form of dyschromatopsia, i.e. a color vision impairment. We asked for it in the post-experimental questionnaire in order to make sure that it is not a common phenomenon among our participants.

$$\text{RD} = \frac{1}{T}\sum_{t=1}^{T}\frac{P_t - FV_t}{|\bar{FV}|} \tag{2}$$

where P_t is the volume-adjusted mean price in period t, FV_t is the fundamental value of the asset in period t and $\bar{FV}$ denotes the average fundamental value of the asset.

RAD is constructed as the ratio of the average absolute difference between mean market price and fundamental value relative to the absolute average fundamental value of the asset. RD is the ratio of the average difference between mean market price and fundamental value relative to the absolute average fundamental value. The difference between the two measures is how the difference between mean market price and fundamental value enters the calculation: For RAD the difference enters in absolute terms – thus all deviations from the fundamental value, i.e. in either direction, increase RAD, making RAD a measure of average mispricing. For RD the wedge between market price and fundamental value retains its sign – thus periods with overpricing and underpricing can cancel each other out. Hence, RD provides the dominant direction of mispricing, making it a measure of average overpricing.

For simplicity, we assume risk neutrality for the evaluation of the stochastic fundamental value. Both measures are very straightforward to interpret: A RAD of .1 means that prices are on average 10 % off fundamental value, while a RD of .1 indicates that prices are on average 10 % above fundamental value. Obviously, both measures are independent of the number of periods as well as the actual absolute size of the fundamental value, and they increase in the difference between market prices and fundamental value.

4.2 Aggregate Price Development

We start our analysis by looking only at aggregate measures on the market level. Figure 2 shows how average market prices in *LOWSELFCONTROL* and *HIGHSELFCONTROL* evolve over time, compared to the fundamental value of the asset. In both conditions, average market prices start out at a similar level, displaying a moderate level of underpricing. However, from the second period onwards, average prices in both conditions exceed the fundamental value. Eventually, average market prices drop sharply, but they do not drop below fundamental value again.

The most conservative comparison between the two treatments are based on market averages over all traders and over all ten periods. These averages are strictly statistically independent. A two-sided Wilcoxon signed-rank test confirms the impression from eyeballing, i.e. that market prices in both conditions are systematically different from the fundamental value (*HIGHSELFCONTROL*: $z = 1.680$, $p = 0.0929$, *LOWSELFCONTROL*: $z = 2.380$, $p = 0.0173$).

Figure 2 suggests more pronounced overpricing in the *LOWSELFCONTROL* condition and a two-

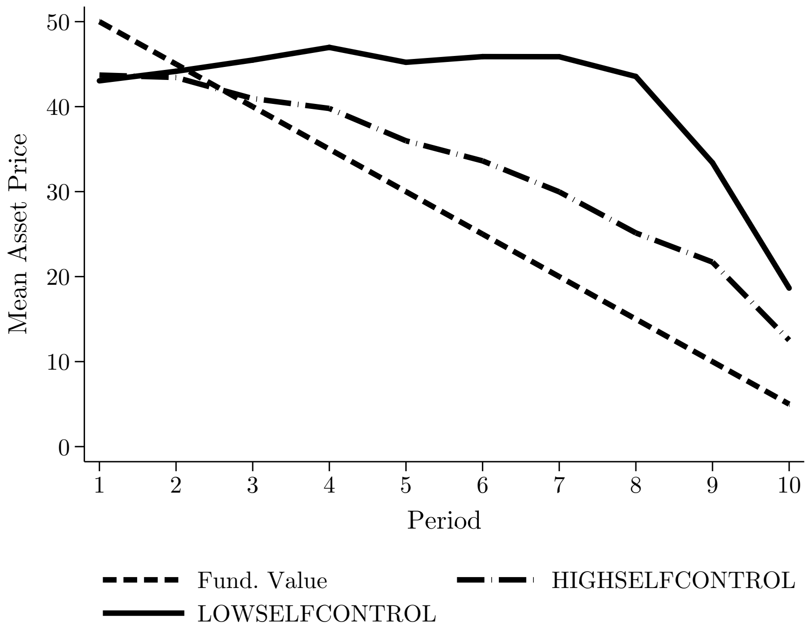


Figure 2: Mean (Volume Adjusted) Trading Prices across Treatments

sided Mann-Whitney test reveals that mean prices are in fact significantly different between the conditions ($z = -1.785$, $p = 0.0742$).

Concerning our mis- and overpricing measures, we find that markets in the *HIGHSELFCONTROL* condition on average exhibit a RAD of 0.3253 and a RD of 0.1885, while in the *LOWSELFCONTROL* condition we observe a RAD of 0.5890 and a RD of 0.4990.[12] Therefore, according to RAD prices in the *HIGHSELFCONTROL* condition deviate by about 33% from fundamental value, whereas they deviate by about 59% from fundamental value in the *LOWSELFCONTROL* condition. The difference between RAD in the two types of markets is significant (Mann-Whitney test, $z = -1.995$, $p = 0.0460$). A comparison of RD tells us that while in *HIGHSELFCONTROL* overpricing is on average 19%, in *LOWSELFCONTROL* prices exceed fundamental value by almost 50%. A Mann-Whitney test suggests that RD is also significantly different between the conditions ($z = -1.785$, $p = 0.0742$).

It is striking that the ratio of overpricing to mispricing of 50 % in *HIGHSELFCONTROL* increases substantially in *LOWSELFCONTROL*, where it climbs to almost 85 %. This suggests that overpricing becomes relatively more pronounced when subjects lack the ability to restrain themselves.

[12] Both measures of mispricing are significantly different from zero for both conditions.

4.3 Period-specific Price Comparisons

Because all markets start out at roughly the same price level and then quickly diverge, it is natural to look at each period separately. By doing so we get a more precise picture, when the price differences between conditions arise. Table 1 reports the per period differences of volume-adjusted mean prices, trade-adjusted mean prices, RAD and RD between *LOWSELFCONTROL* and *HIGHSELFCONTROL*. z-values from Mann-Whitney tests testing the equality of the respective measures between conditions are displayed in parentheses with the respective significance level indicated by stars. While in the first periods we see almost no price differences between the conditions, starting from period five, markets in *LOWSELFCONTROL* exhibit significantly higher mean prices, mispricing and overpricing. Starting in period 5, the gaps in mispricing and overpricing between our conditions become more pronounced at almost the same time, peaking in period 8 and dropping thereafter. There are no significant differences between the conditions in the ultimate period. Thus, there seems to be a more pronounced bubble and burst pattern in *LOWSELFCONTROL* markets, rather than just a uniform level effect from lower self-control.

Period	Δvolume-adjusted mean price	Δtrade-adjusted mean price	ΔRAD	ΔRD
1	-0.67 (0.84)	-0.85 (0.735)	0.0143 (-0.63)	-0.0245 (0.84)
2	0.73 (0.105)	2.87 (-0.21)	-0.0749 (0.21)	0.0266 (0.105)
3	4.53 (-0.84)	3.38 (-0.525)	0.0006 (-0.105)	0.1646 (-0.84)
4	7.18 (-1.47)	7.64 * (-1.89)	0.1720 (-1.26)	0.2612 (-1.47)
5	9.24 * (-1.785)	9.03 * (-1.785)	0.2523 (-1.47)	0.3359 * (-1.785)
6	12.27 ** (-2.205)	12.01 ** (-2.31)	0.4186 ** (-2.205)	0.4461 ** (-2.205)
7	15.90 ** (-2.521)	15.84 ** (-2.415)	0.5703 ** (-2.521)	0.5781 ** (-2.521)
8	18.40 ** (-2.521)	19.00 ** (-2.521)	0.6573 ** (-2.521)	0.6693 ** (-2.521)
9	11.69 ** (-2.1)	11.78 ** (-1.995)	0.4249 ** (-2.1)	0.4249 ** (-2.1)
10	6.13 (-1.26)	6.48 (-1.26)	0.2007 (-1.05)	0.2228 (-1.26)

Differences between *LOWSELFCONTROL* and *HIGHSELFCONTROL* and z-values (in parentheses) for Mann-Whitney tests. Volume-adjusted mean prices denote the average price per asset, while trade-adjusted mean prices denote average price per trade.
* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Table 1: Period-specific Effects

Figure 3 displays the price evolution of each individual market separately for the two conditions.

It is noticeable that there is also a high degree of endogeneity in price evolution and a lot of heterogeneity among markets in the same condition. The left panel represents the markets from the *HIGHSELFCONTROL* condition, while the right panel shows the *LOWSELFCONTROL* markets. It is striking that average prices in *HIGHSELFCONTROL* markets tend to exhibit a downward sloping market price from the very beginning, while in *LOWSELFCONTROL* there are more markets with a hump-shaped price evolution peaking in some intermediate period. The emergence of overpricing can oftentimes be attributed to constant prices despite decreasing fundamental values (Huber and Kirchler, 2012) which fits price paths in *HIGHSELFCONTROL* markets more than in *LOWSELFCONTROL* markets, where in some markets we even observe increasing prices for a few periods.

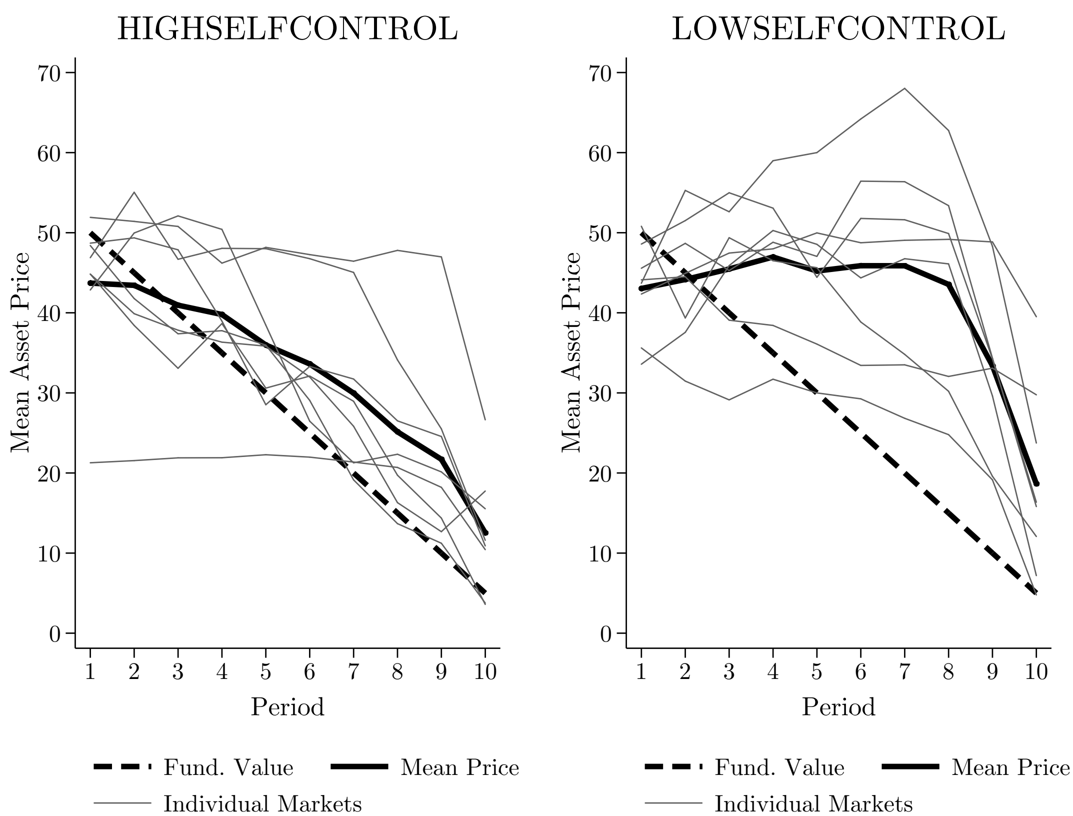


Figure 3: Evolution of Individual Market Prices in *HIGHSELFCONTROL* and *LOWSELFCONTROL*

4.4 Risk Attitudes and Cognitive Abilities

Since the results from the market suggest that there is a strong treatment effect, it seems important to determine the channel via which self-control affects market outcomes. Potentially, reduced self-control could have affected market outcomes via an impact on risk attitudes or cognitive abilities. We now turn to these channels as possible explanations for our results. First of all we look at whether the hard version of the Stroop task had an effect on either measure, then we run regressions, to see whether these measures had a differential impact on market outcomes in *LOWSELFCONTROL* vs. *HIGHSELFCONTROL*.

The average number of correct answers in the CRT was 1.05 in *HIGHSELFCONTROL* and 1.14 in *LOWSELFCONTROL*. The difference in CRT score between the two conditions is not significant according to a Mann-Whitney test ($z = -0.355$, $p = 0.7223$). Furthermore, the certainty equivalent we elicited is on average surprisingly close to the lottery's expected value: 2.2 in *HIGHSELFCONTROL* and 2.145 in *LOWSELFCONTROL*. There is also no significant difference in certainty equivalents between the conditions (Mann-Whitney test, $z = 0.827$, $p = 0.4083$). Thus, there was no impact of reduced self-control on our measure of cognitive abilities and risk attitudes respectively.

In order to detect any influence of our measure of risk attitude and cognitive skills on our market outcomes, we run linear regressions. Since our dataset contains multiple, possibly correlated observations per subject we create a measure for individual overpricing, which we call IndRD. Similar to the measure RD it is defined as the percentage of trading prices exceeding the asset's fundamental value pooled over all periods, but for each subject separately. We use it as the dependent variable in our regressions in table 2 but also provide a more conservative estimate with the traditional RD measure (and hence lower sample size) in the appendix table 4.[13]

In all four models we are interested in the effect of the explanatory variables on IndRD, our measure of individual overpricing. Throughout all specifications, we observe a significant treatment effect: Being in *LOWSELFCONTROL* increases an individual's propensity to trade at excessive prices substantially. Our measure for risk attitude is not significant, but if we also include interactions with our treatment, risk aversion decreases overpricing when self-control capabilities are reduced. Performance on the CRT has no effect. We observe a small gender effect that women tend to increase bubble size, but it is only marginally significant. Hence, introducing measures for risk aversion and cognitive skills and their interactions with our treatment do not decrease the treatment coefficient and it remains highly significant. This leaves us with confidence that neither changes in cognitive skills nor in risk preferences are responsible for our results.

[13] Additionally, tables 6 and 7 in the appendix show the analysis of IndRD separately for sales and purchases. Both seem to equally contribute to the extent of overpricing, suggesting that depleted subjects use both instruments to engage in trading.

	(1) IndRD	(2) IndRD	(3) IndRD	(4) IndRD
LOWSELFCONTROL	0.357**	0.361**	0.760***	0.771***
	(0.137)	(0.134)	(0.150)	(0.138)
CRT		-0.0448*	-0.0614	-0.0557
		(0.0244)	(0.0361)	(0.0353)
CE		-0.00420	0.0768	0.0796
		(0.0445)	(0.0511)	(0.0510)
CRT × Stroop			0.0361	0.0370
			(0.0465)	(0.0455)
CE × Stroop			-0.202***	-0.207***
			(0.0674)	(0.0646)
Female				0.0665*
				(0.0366)
Constant	0.121	0.177	0.0160	-0.0411
	(0.0879)	(0.109)	(0.0651)	(0.0672)
Observations	160	160	160	160
R^2	0.265	0.282	0.330	0.338

OLS regression, dependent variable is Individual Relative Deviation (IndRD), an individual equivalent to market level Relative Deviation (RD). LOWSELFCONTROL is a dummy where 1 stands for *LOWSELFCONTROL* and 0 for *HIGHSELFCONTROL*. CE is an individual's certainty equivalent. CRT denotes the number of correct answers on the CRT. Heteroskedasticity robust standard errors clustered at market level in parentheses, *** p<0.01, ** p<0.05, * p<0.1

Table 2: Correlates of Individual Miscpricing

4.5 Trading Activity & Survey Responses

A natural extension of the search for a channel for self-control's impact on market outcomes is to look at trading activity, i.e. the number of traded shares per period. Increased passivity and thus a thinner market in *LOWSELFCONTROL*, where few trades could drive overpricing could potentially be responsible for our results, since people low in self-control have been reported to become more passive (Baumeister et al., 1998, Experiment 4). Thus we compare the number of shares traded in each condition. Figure 4 illustrates the evolution of average shares traded per period. Traders in *HIGHSELFCONTROL* traded slightly more overall: while the average trader traded 13.02 shares per period in *HIGHSELFCONTROL*, only 11.39 shares changed hands on average per trader in each period in *LOWSELFCONTROL*. However, according to a Mann-Whitney test, there is no significant difference between amounts traded across conditions ($z = 0.945$, $p = 0.3446$).

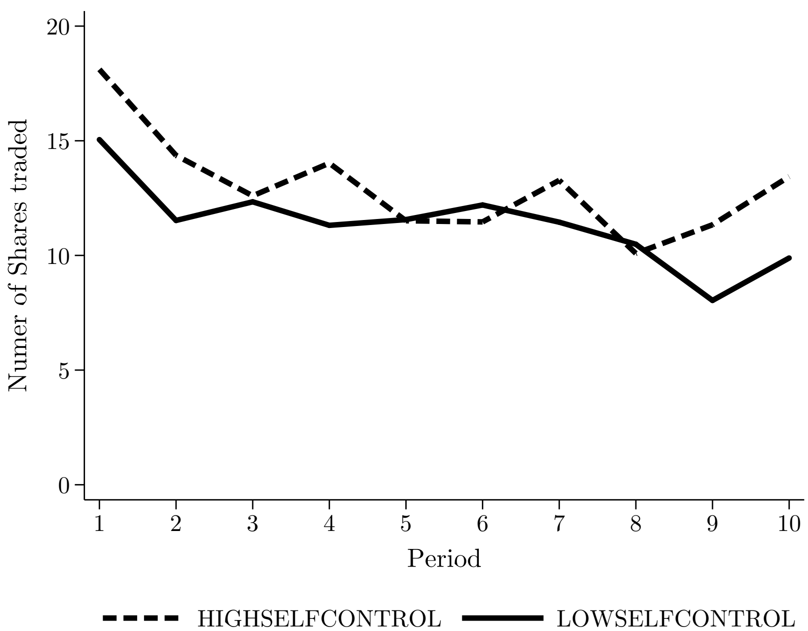


Figure 4: Evolution of Average Shares Traded per Trader by Condition

We shortly want to report results on subjective measures, which we asked for in the questionnaire at the end of the experiment. Additionally to the non-changed market activity, subjects whose self-control had been reduced do not report to be significantly more tired at the end of the experiment (2.8 in *HIGHSELFCONTROL* vs. 2.99 in *LOWSELFCONTROL*, Mann-Whitney test: $z = -0.686$, $p = 0.4926$), making exhaustion an unlikely explanation for our findings. Finally, subjects did not state to be in a significantly worse mood during our experiment.[14]

[14] Valence was 3.7 in *HIGHSELFCONTROL* vs. 3.55 in *LOWSELFCONTROL*, Mann-Whitney test: $z = -1.302$,

5 Experiment II: Asymmetric Markets

5.1 Motivation

The results reported in section 4 referred to markets, in which either all market participants underwent the hard Stroop task or none of them, i.e. either everyone's self-control resources had been reduced or noone's. In this section we report results of markets, in which only half of the participants' self-control was weakened. Each market consisted of 5 participants randomly assigned to the easy Stroop version from our *HIGHSELFCONTROL* and 5 participants randomly assigned to the hard Stroop version from our *LOWSELFCONTROL* condition. We call this new condition *ASYMMETRIC* and for simplicity refer to traders facing the hard version of the Stroop task as *low SC* traders and to those facing the easy version of the Stroop task as *high SC* traders. The motivation for this additional treatment is twofold. Firstly, since in a real world setting it is likely that individuals high and low in self-control interact,[15] we want so see whether the effect of reduced self-control observed in *LOWSELFCONTROL* markets can be replicated with a smaller share of depleted subjects in *ASYMMETRIC* markets. Secondly, since asset markets experiments are zero sum games and behavior is highly endogenous to market prices making it technically impossible for us to analyze differences in behavior resulting from reduced self-control in our pure markets, we wanted a condition, where both *low SC* and *high SC* traders are active at once in order to test for differences in trading behavior and performance. We conducted 4 additional sessions with 8 markets in April 2014. Apart from the assignment to the respective version of the Stroop task, the experimental protocol remained exactly the same.

5.2 Aggregate Price Evolution

Figure 5 shows the evolution of average trading prices in all three treatments. Interestingly, the effect of reduced self-control on mispricing and overpricing does not seem to be reduced if just a part of the trader population is treated. Both *LOWSELFCONTROL* and *ASYMMETRIC* on average display more overpricing than *HIGHSELFCONTROL*. For *ASYMMETRIC* we observe on average a RAD of 0.619 and a RD of 0.573. A Mann-Whitney test confirms that the mispricing measure RAD in *ASYMMETRIC* is significantly different from *HIGHSELFCONTROL* ($z = 2.205$, $p = 0.0274$) but cannot be statistically distinguished from *LOWSELFCONTROL* ($z = 0.210$, $p = 0.8336$). This result also holds for our overpricing measure: RD in *ASYMMETRIC* significantly differs from *HIGHSELFCONTROL* ($z = -2.310$, $p = 0.0209$), but not from *LOWSELFCONTROL*

$p = 0.1930$.

[15] This might be due to dispositional differences in self-control or due to differential previous demands on self-control resources between traders.

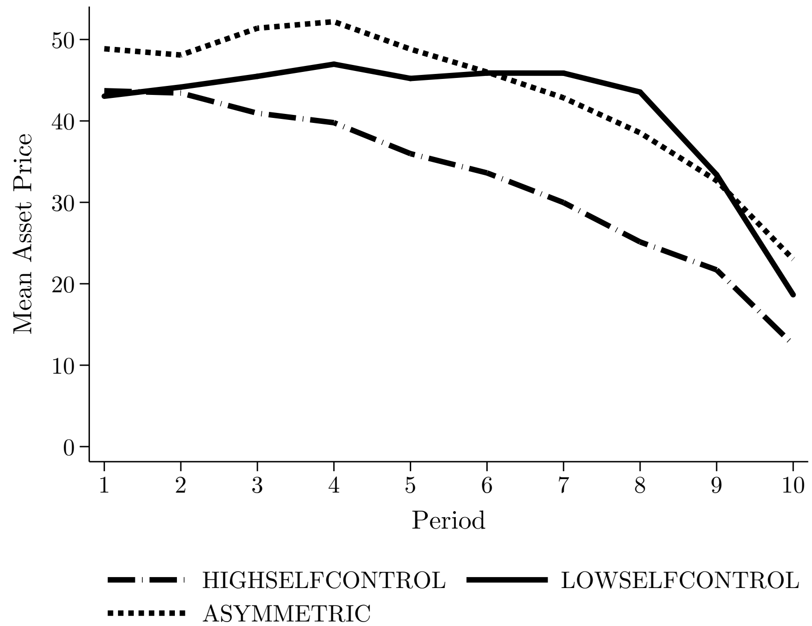


Figure 5: Trading Price Evolution including *ASYMMETRIC*

($z = -0.315$, $p = 0.7527$).[16]

Figure 6 illustrates the evolution of mean trading prices for the 8 individual markets, which were subjected to the *ASYMMETRIC* condition. Qualitatively, we get the same results as in *LOWSELFCONTROL* that in some of these markets prices exhibit a hump-shaped development, increasing initially and peaking in some intermediate period. Thus it seems that already the presence of a moderate share of traders with lower self-control capabilities is sufficient to reproduce the massive overpricing we observed when all traders were depleted.

5.3 Differences in Trading Behavior & Outcomes

In order to investigate individual differences in trading behavior, we both looked at performance as measured by total profits at the end of the asset market and at individuals' pure trading profits, i.e. (hypothetical) trading profits by selling assets for prices above fundamental value and buying assets below fundamental value. On average, *low SC* traders earned 7.92 € and thus slightly less than the 8.08 € earned by *high SC* traders. According to a Mann-Whitney test there is no significant difference between the two groups ($z = 0.327$, $p = 0.7435$). Since *low SC* traders might be differently react differently in more extreme situations, we also looked at RD as a determinant of profits for *low SC* and *high SC* traders respectively. Figure 7 shows average profits of each group

[16]This also holds when looking at quantity- or trade-adjusted mean prices.

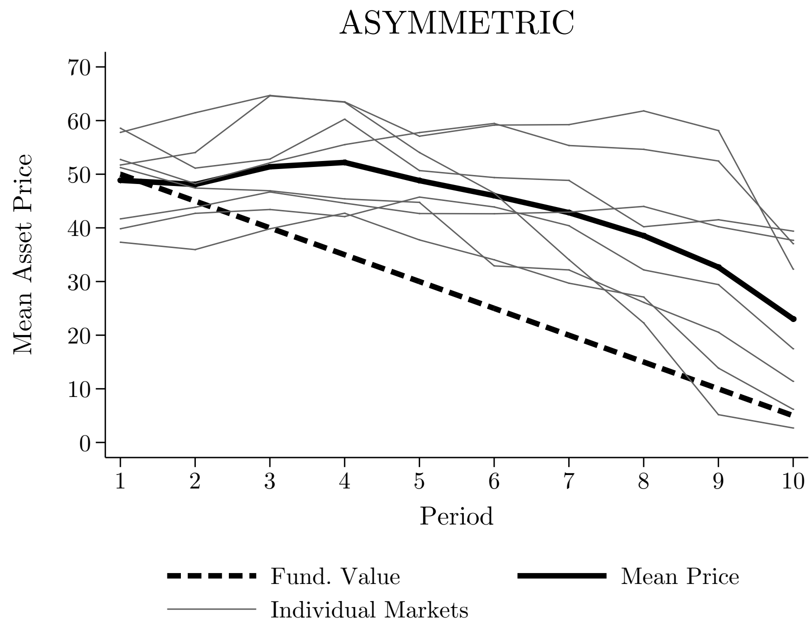


Figure 6: Price Evolution in Individual Markets in *ASYMMETRIC*

of traders for each market plotted against average RD in that market. There seems to be a clear trend that *high SC* traders performed better the larger the overpricing was, while *low SC* traders performed worse with increasing bubble sizes.[17] Spearman's ρ for average final profit per trader group and average RD takes the value of -0.857 and 0.857 (both p=0.0065) for *low SC* and *high SC* traders respectively. This figure therefore suggests a relationship between trading profits and an interaction of *SC* status with the size of overpricing RD. In order to analyze this relationship between profits, bubble sizes and *SC* status taking into account the role of trader's heterogeneity along other dimensions, we performed OLS regressions of profits on various variables, which are displayed in table 3.

In specifications (1) and (3) we left out the interaction term of RD$\times$Stroop to show that without this interaction there are no significant differences between profits of *low SC* and *high SC* traders in our markets other than those driven by differences in individual cognitive abilities. However, when we include the interaction term RD$\times$Stroop in specifications (2), (4), and (5), all coefficients on Stroop, RD and RD$\times$Stroop become significant with the sign suggested by figure 7. Thus, the graphical results that *low SC* traders outperform *high SC* traders when bubbles are low and perform worse than *high SC* traders when bubbles are high are confirmed. Now we turn to the results regarding our additional experimental measures. In specification (3) the CRT score is the only significant

[17] Note that due to the asset markets' nature as a zero-sum game, the right panel of figure 7 is just the inverse of the left panel.

	(1) Profit	(2) Profit	(3) Profit	(4) Profit	(5) Profit
Stroop	-0.156	2.347***	-0.200	2.606**	8.388**
	(0.643)	(0.628)	(0.580)	(0.822)	(2.918)
RD	-0.000	2.186***	1.068	3.497**	4.085**
	(-0.000)	(0.490)	(0.872)	(1.244)	(1.363)
RD × Stroop		-4.371***		-4.959***	-5.956**
		(0.981)		(1.377)	(1.781)
CRT			1.512**	1.412**	2.264***
			(0.460)	(0.463)	(0.608)
CE			1.028	1.402	1.946**
			(1.022)	(0.997)	(0.611)
CRT × Stroop					-1.772
					(0.962)
CE × Stroop					-1.565
					(1.601)
Constant	8.078***	6.827***	3.735	1.635	-0.728
	(0.321)	(0.314)	(2.677)	(2.899)	(1.763)
Observations	80	80	80	80	80
R^2	0.000	0.023	0.131	0.157	0.206

OLS regression, dependent variable is final profit from asset market, RD is the average Relative Deviation in a market, RD×Stroop is the interaction of RD and a dummy that equals one, if the subject is assigned to the hard version of the Stroop task. CRT denotes the number of correct answers in the CRT, CE is the individual certainty equivalent, robust standard errors clustered on market level in parentheses, *** p<0.01, ** p<0.05, * p<0.1

Table 3: Determinants of Profits

predictor of trading profits. It remains a significant predictor of profits in specifications (4) and (5). Participants scoring higher on the CRT outperform those scoring lower. The coeffcient on CE is positive throughout all specifications (3) – (5), but only becomes significant in specification (5) where the interaction terms CRT×Stroop and CE×Stroop are included. There is thus weak evidence, that traders with a higher certainty equivalent, i.e. less risk-averse traders, perform better in our *ASYMMETRIC* markets. From specification (5) it seems that the CRT and the certainty equivalent have no significantly different influence on *low SC* traders' profits. However, note that the coefficient on CRT×Stroop is borderline significant with a significance level of $p = 0.108$. Additionally, a post-estimation Wald test whether the coefficients of CRT and CRT×Stroop add up to zero cannot reject the null hypothesis ($\chi^2(1, 7) = 0.37$, $p = 0.56$). Thus, we cannot reject the claim, that the CRT has no predictive value for the profits of *low SC* traders. Similarly, a post-estimation Wald test cannot reject the null hypothesis that the effect for the certainty equivalent is zero for *low SC* traders ($\chi^2(1, 7) = 0.05$, $p = 0.84$). We get qualitatively the same results for pure trading profits which we report in table 5 in the appendix, suggesting that lower profits for traders with low self-control do not stem from a mere preference of holding assets instead of cash, but of their lack of anticipation that trading prices will eventually decrease.

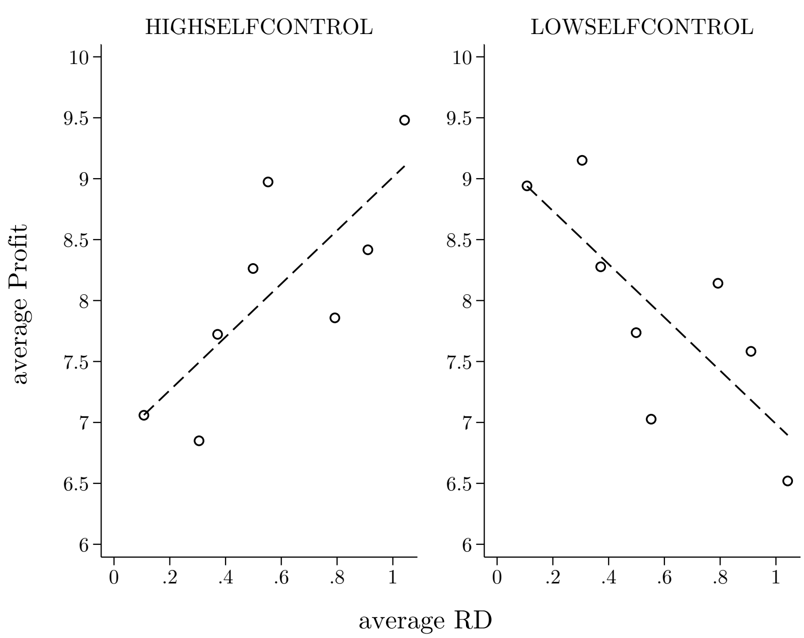


Figure 7: Average Profits in *ASYMMETRIC* Markets by Stroop Version and average Relative Deviation

6 Discussion

In this section we will discuss our results in particular with respect to the channel through which our treatment effect arises. First, we will discuss our findings on risk aversion and the CRT in turn, then we will cover subject confusion, inertia and emotions as possible explanations for our results.
Some authors have speculated about a relationship between risk aversion and overpricing (Porter and Smith, 1995; Miller, 2002). Trader activity has been found to be negatively correlated with risk aversion (Fellner and Maciejovsky, 2007). While the literature exploring the effect of lowered self-control on risk aversion has come to ambiguous results (Bruyneel et al., 2009; Unger and Stahlberg, 2011), we find no significant effect on risk aversion as measured by our certainty equivalent elicitation. Furthermore, in the regression of individual trader profits on risk aversion in table 3, it can be seen that risk attitude plays no different role for traders low in self-control. From these findings we conclude that risk attitudes are an unlikely channel via which the treatment effect in our experiment arises.
Cognitive abilities could have been affected by our treatment and thus have an impact on mispricing. Schmeichel et al. (2003) found that self-control reducing tasks negatively impact information processing such as logic and reasoning, but not previously acquired knowledge. It has previously been shown that both risk aversion and impatience vary systematically with cognitive ability (Dohmen et al., 2010; Benjamin et al., 2006). Our measure for cognitive abilities, the CRT, is correlated with risk and time preferences (Frederick, 2005). It is important here to point out what the CRT measures. Toplak et al. (2011) find that CRT measures are correlated with measures of cognitive ability, thinking disposition – in particular reflectivity – and executive functioning. However, in their sample predictive power of the CRT for rational thought, i.e. performance in heuristics-and-biases tasks, goes beyond the predictive power of measures of cognitive abilities, measures of thinking disposition or measures of executive processing. They conclude that

> "(...) the CRT is a measure of the class of reasoning error that derives from miserly processing."

In our sample, we found no effect of the hard Stroop task on the CRT. This might be because the incentives to do well are relatively high and people can temporarily overcome self-control problems if the motivation is sufficient (Muraven and Slessareva, 2003; Vohs et al., 2012). However, in the regressions in table 3, similar to Noussair et al. (2014), we find that the CRT carries predictive power for traders' profits, but only if they are in complete possession of self-control. It seems that for traders low in self-control the predictive power of the CRT for profits is eliminated. Thus, even though the CRT itself might not be affected by low self-control the cognitive capacities which the CRT measures might be disrupted by our treatment and might effectively become irrelevant in the market.

Subject confusion contributes to the occurence of bubbles in double auction markets of the kind studied in this paper. Both Huber and Kirchler (2012) and Kirchler et al. (2012) find that subjects have problems understanding the non-intuitive decreasing fundamental value process commonly present in double auction markets. Subjects in all our sessions were supplied with a detailed table illustrating the remaining sum of expected dividends for each period. Additionaly, price paths in both the conditions *LOWSELFCONTROL* and *ASYMMETRIC* display a hump shape – i.e. initially increasing prices and a peak in an intermediate period – more often. This is contrasted in our *HIGHSELFCONTROL* markets which more often exhibit relatively constant price paths. Therefore, overpricing in *HIGHSELFCONTROL* seems to be more in line with the explanation of subject confusion, while reduced self-control seems to be distinct and to have an additional impact on overpricing.

Reduced self-control can have an impact on inertia and passivity of people (Baumeister et al., 1998, Experiment 4). Similarly traders in our *LOWSELFCONTROL* and *ASYMMETRIC* conditions could have become more passive and thus might have opened the stage to a few actors, who could have affected price levels easily. However, we did not find any significant differences in market activity between our *LOWSELFCONTROL* and *HIGHSELFCONTROL* markets or between participants subjected to the different versions of the Stroop task in our *ASYMMETRIC* markets. Therefore we are confident to deny that an effect of our treatment on the level of trading activity might have influenced prices in our markets.

Various studies stress the relevance of pre-market emotional state for market outcomes (Hargreaves Heap and Zizzo, 2011; Lahav and Meer, 2012; Andrade et al., 2012; Breaban and Noussair, 2013). Since the task we used for reducing self-control (and in fact also in our control condition) can be considered as relatively demanding and frustrating, before the experiment we considered it more likely that we would induce a negative affective state rather than positivity and excitement as in Lahav and Meer (2012) and Andrade et al. (2012). However, we found no significant differences between our conditions on how participants evaluated their overall emotional state during the experiment. Similarly, studies which included measures of affect as a dependent variable have generally not found effects of self-control depletion on (post depletion) affect (Baumeister et al., 1998; Bruyneel et al., 2006; Hagger et al., 2010).

Apart from the pre-market emotional state, differential emotional reactions during the market could be driving our results. Even though initial differences in mood do not drive our results, it is likely that either differential emotional responses or more reactions towards emotional responses, i.e. more impulsive behavior, occurred in treated participants. Mood regulation has been shown to draw on self-control resources (Baumeister et al., 1998; Hagger et al., 2010). As pointed out in the introduction, regulating affect or emotional responses to price changes requires individuals to control themselves. If the ability for self-control is reduced before the market stage, people might react more emotionally to price changes, e.g. they might get more excited about positive price movements, or act more often on the basis of affect, both of which might increase their reactivity towards price movements (Hargreaves Heap and Zizzo, 2011; Breaban and Noussair, 2013). Bruyneel et al. (2006) have shown that people whose self-control has been reduced rely more on affective and less on cognitive features for product choice. Similarly, it could be the case in our setting that traders with low self-control rely more heavily on the affective feature of the stock, e.g. the thrill from its recent price increase, than on cognitive features, e.g. the knowledge that the fundamental value process of the stock is decreasing.

7 Conclusion

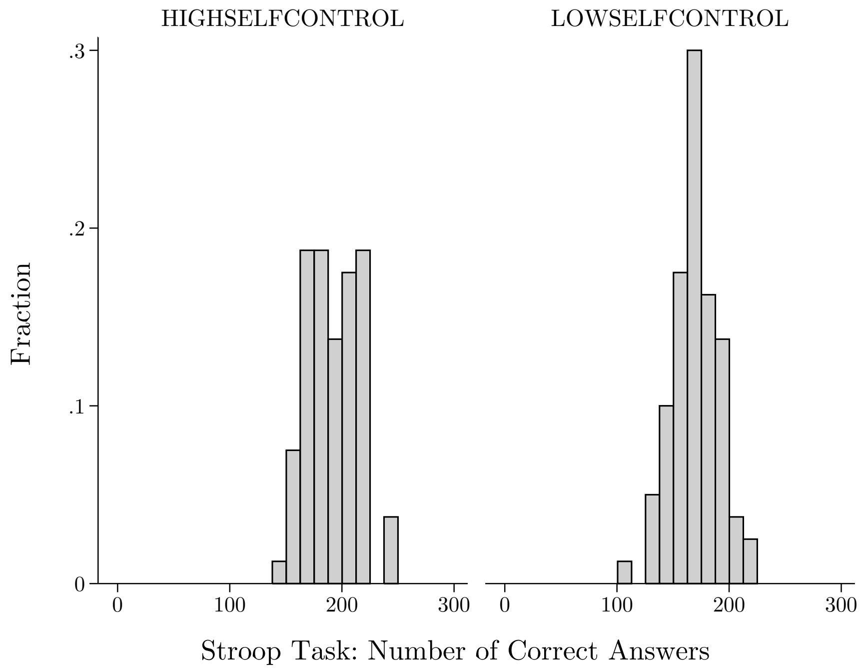
In an experimental asset market setting, we tested the notion that a lack of self-control could fuel overpricing and may have a negative impact on trading behavior. We consider the continouous double auction markets where Smith et al. (1988) first reported a tendency for overpricing and exogenously reduced market paricipants' ability to exert self-control using a hard version of the Stroop task, which has previously been shown to reduce people's ability to exert self-control in subsequent tasks (Baumeister et al., 1998). Comparing two market settings where either everyone's or noone's self-control was reduced, we observe significantly more mispricing and even more overpricing as the result of low self-control capacities. We found no effect of our treatment on a simple measure of risk preferences. Surprisingly, we also found no effect of our treatment on the Cognitive Reflection Test (CRT) Frederick (2005). Additionally neither risk preferences nor the CRT can account for the effect of reduced self-control on overpricing. In order to test the robustness of our results and to determine possible differences in behavior responsible for our findings, we ran additional sessions, where only half the participants' self-control was reduced. The results from these sessions indicate that already a moderate share of participants with lowered self-control capabilities is sufficient to create overpricing of the same magnitude as in markets, where everyone's self-control was reduced. Furthermore, we observe no performance difference between traders with low self-control and with normal self-control on average, but low self-control traders' performance deteriorates with increasing bubble sizes, while "normal" traders earn additional profits. This indicates that traders low in self-control drive bubbles and subsequently lose from them the most. Additionally, we find that the CRT loses its predictive power for profits of low self-control traders. This might indicate that even though the CRT is unaffected, different cognitive processes play a role in traders with low self-control.

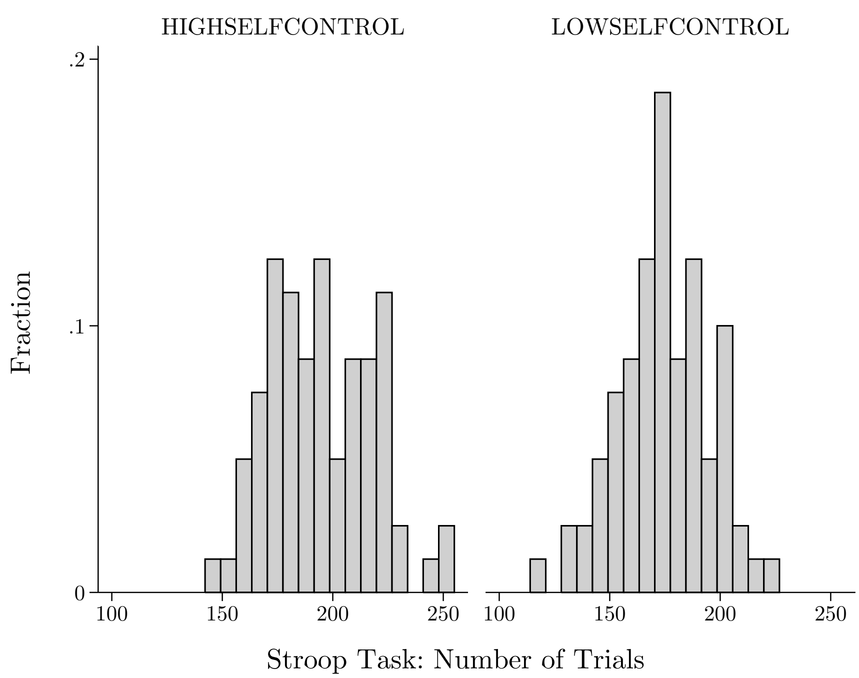
Our findings have some interesting implications: First, our results might contribute to some degree to explain the large heterogeneity in overpricing present in asset market experiments. We have shown that already a moderate number of participants with low self-control are enough to nearly double overpricing. Considering that the stroop task in the first stage of the experiment only lasted five minutes, this is quite a considerable impact. Furthermore, our results can be regarded as indicative of the role of asset markets for traders in real world markets – here both temporary reductions in self-control as well as personality trait self-control might plain an important role. Self-control might also be an important attribute on which individuals self-select into asset markets.

Finally, our experiment opens up further interesting paths for research: First of all, it would be interesting to what extent our results are robust to changes in both market mechanisms, such as a call market, as well as to changes in the fundamental value process, such as to a constant fundamental value process which has been shown to reduce overpricing in Kirchler et al. (2012). It is an interesting alley to further explore via which channel reduced-self control impacts individual decisions. Finally, the role of self-control for professional traders outside the laboratory remains largely unexplored.

A Appendix

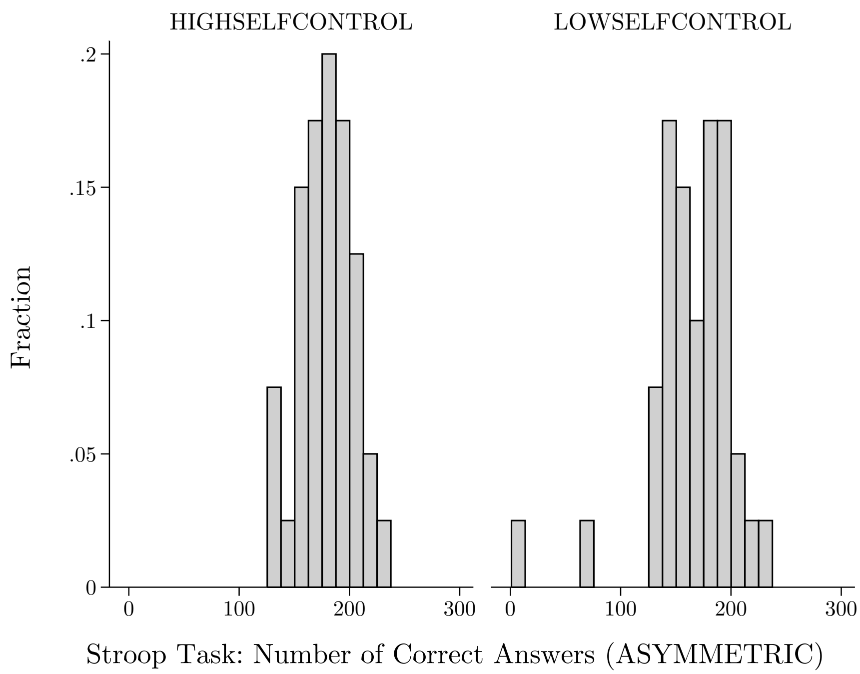
A.1 Distribution of Answers in the Stroop Task

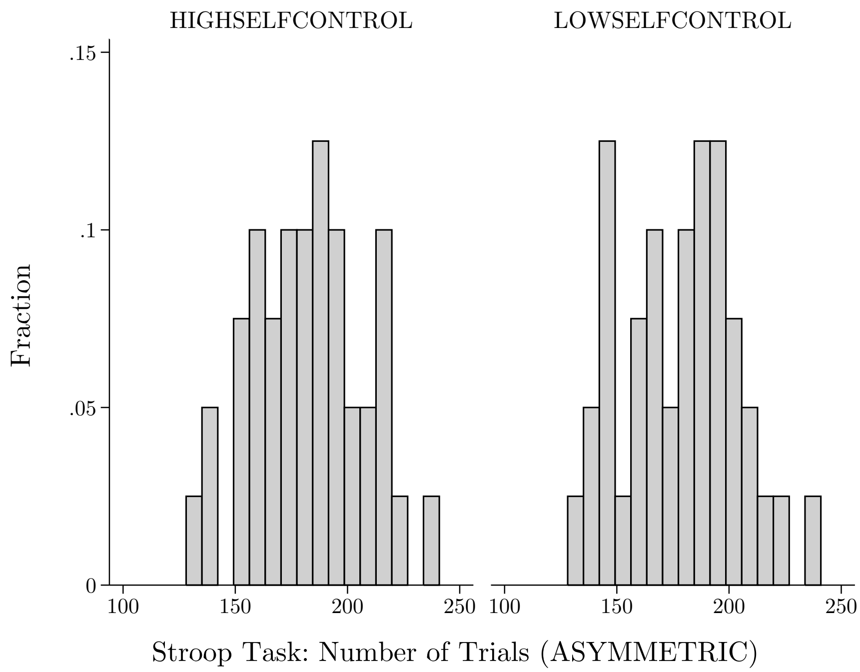




Distribution of Answers in the Stroop Task

HIGHSELFCONTROL	mean	standard deviation
Correct Answers	191.65	22.6146
Trials	194.55	23.55973
LOWSELFCONTROL	**mean**	**standard deviation**
Correct Answers	170.3125	20.68363
Trials	174.45	20.96948

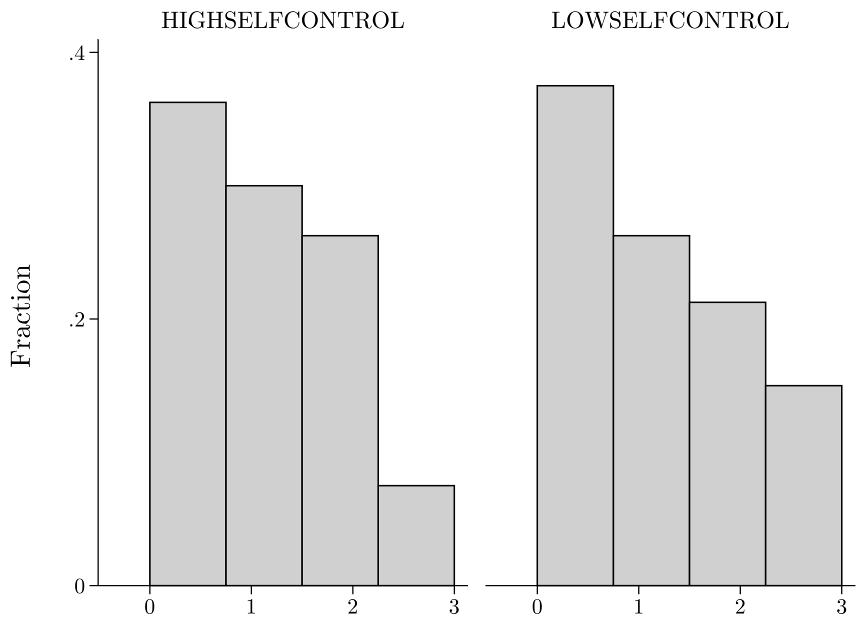




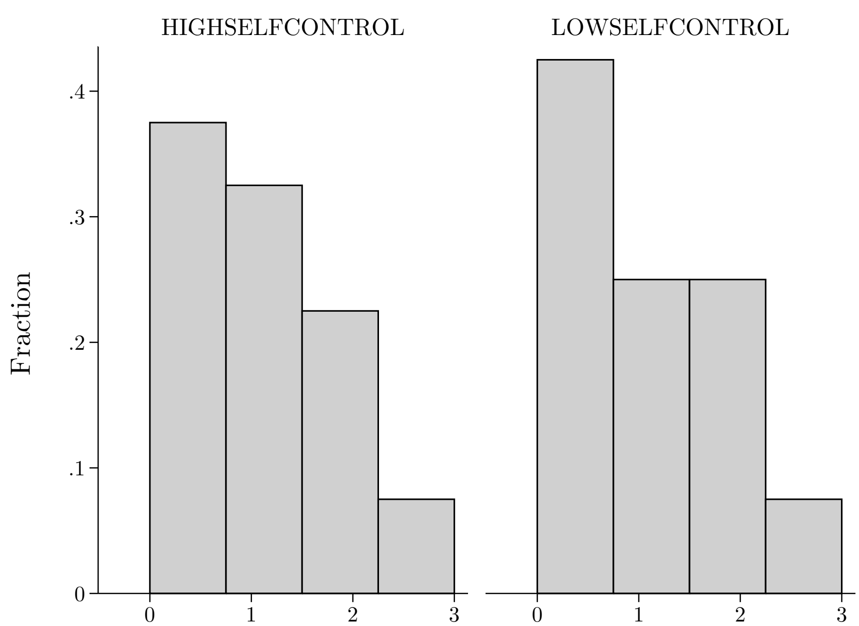
Distribution of Answers in the Stroop Task (ASYMMETRIC)

HIGHSELFCONTROL	mean	standard deviation
Correct Answers	179.225	24.1135
Trials	182.65	24.59784
LOWSELFCONTROL	mean	standard deviation
Correct Answers	164.05	39.93838
Trials	178.3	25.47518

A.2 Distribution of Answers in the Cognitive Reflection Task



CRT: Number of Correct Answers

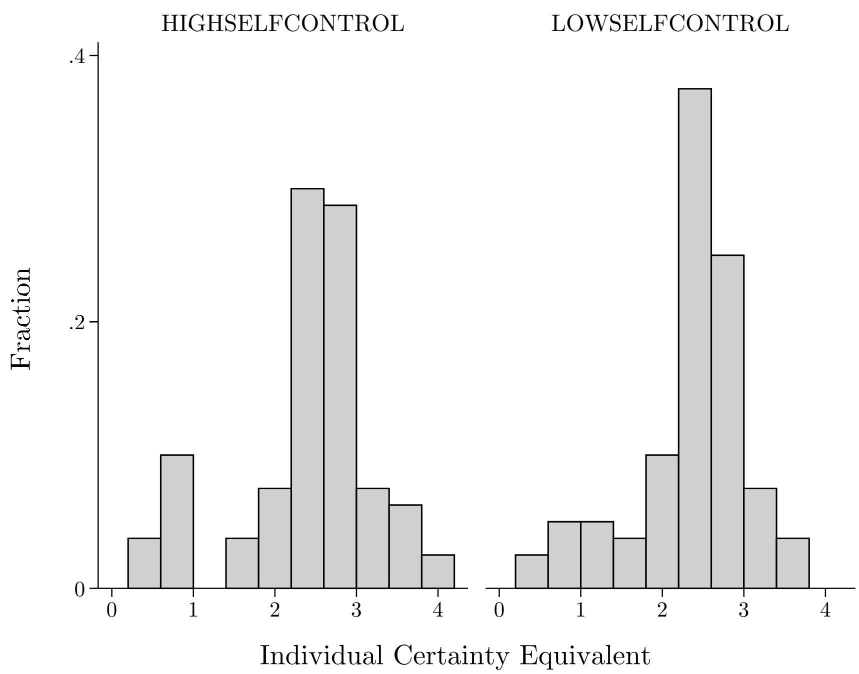


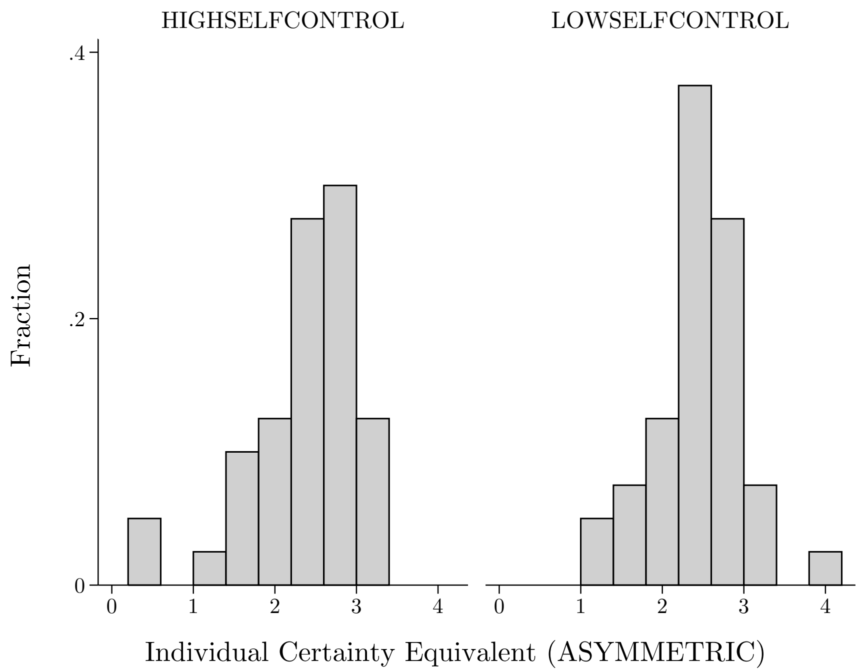
CRT: Number of Correct Answers (ASYMMETRIC)

Distribution of Answers in the Cognitive Reflection Task

	mean	standard deviation
HIGHSELFCONTROL	1.05	.9665284
LOWSELFCONTROL	1.1375	1.087836
ASYMMETRIC	mean	standard deviation
HIGHSELFCONTROL (A)	1	.9607689
LOWSELFCONTROL (A)	.975	.9996794

A.3 Distribution of Certainty Equivalents





Distribution of Individual Certainty Equivalents

	mean	standard deviation
HIGHSELFCONTROL	2.2	.8467361
LOWSELFCONTROL	2.145	.6964467
ASYMMETRIC	mean	standard deviation
HIGHSELFCONTROL (A)	2.16	.6766433
LOWSELFCONTROL (A)	2.24	.5494986

A.4 Additional Regression Results

	(1) RD	(2) RD	(3) RD	(4) RD
Treatment	0.310*	0.334**	3.532***	3.569**
	(0.150)	(0.139)	(1.006)	(1.335)
CRT		-0.335	-0.00199	0.0473
		(0.217)	(0.436)	(0.509)
CE		-0.113	0.799**	0.776
		(0.293)	(0.309)	(0.430)
CRT × Treatment			-0.108	-0.132
			(0.488)	(0.544)
CE × Treatment			-1.424***	-1.421**
			(0.358)	(0.453)
Female				0.590*
				(0.268)
Constant	0.188*	0.789	-1.566	-1.967
	(0.104)	(0.655)	(0.909)	(1.281)
Observations	16	16	16	16
R^2	0.233	0.370	0.579	0.627

OLS regression, dependent variable is Relative Deviation (RD). Treatment is a dummy where 1 stands for *LOWSELFCONTROL* and 0 for *HIGHSELFCONTROL*. CE is an individual's certainty equivalent. CRT denotes the number of correct answers on the CRT. Heteroskedasticity robust standard errors clustered on market level in parentheses, *** p<0.01, ** p<0.05, * p<0.1

Table 4: Correlates of Relative Deviation

	(1)	(2)	(3)	(4)	(5)
			Trading Profits		
Stroop	-0.146	2.113***	-0.192	2.399**	8.386**
	(0.587)	(0.566)	(0.553)	(0.815)	(2.815)
RD		1.973***	0.984	3.226**	3.843**
		(0.486)	(0.820)	(1.133)	(1.222)
RD x Stroop		-3.946***		-4.578**	-5.533**
		(0.972)		(1.358)	(1.627)
CRT			1.388**	1.296**	2.121**
			(0.421)	(0.426)	(0.607)
CE			1.016	1.361	1.957**
			(0.983)	(0.951)	(0.592)
CRT x Stroop					-1.720
					(0.939)
CE x Stroop					-1.692
					(1.581)
Constant	0.0728	-1.057***	-4.073	-6.011*	-8.476***
	(0.294)	(0.283)	(2.545)	(2.723)	(1.517)
Observations	80	80	80	80	80
R^2	0.000	0.022	0.132	0.158	0.215

OLS regression, dependent variable is average trading profit from asset market in € , RD is the average Relative Deviation in a market, RD×Stroop is the interaction of RD and a dummy that equals one, if the subject is assigned to the hard version of the Stroop task. CRT denotes the number of correct answers in the CRT, CE is the individual certainty equivalent, robust standard errors clustered on market level in parentheses, *** $p<0.01$, ** $p<0.05$, * $p<0.1$

Table 5: Determinants of Trading Profits

	(1)	(2)	(3)	(4)
		Individual RD of purchases		
LOWSELFCONTROL	0.369**	0.375**	0.900***	0.911***
	(0.136)	(0.131)	(0.124)	(0.112)
CRT		-0.0725**	-0.0861**	-0.0802**
		(0.0301)	(0.0366)	(0.0347)
CE		-0.00916	0.0943	0.0972
		(0.0516)	(0.0612)	(0.0605)
CRT × Stroop			0.0324	0.0334
			(0.0552)	(0.0537)
CE × Stroop			-0.258***	-0.263***
			(0.0722)	(0.0697)
Female				0.0683
				(0.0529)
Constant	0.0839	0.180	-0.0331	-0.0918
	(0.0822)	(0.111)	(0.0699)	(0.0770)
Observations	160	160	160	160
R^2	0.227	0.265	0.327	0.334

OLS regression, dependent variable is Individual Relative Deviation (IndRD) for purchases, an individual equivalent to market level Relative Deviation (RD) restricted to purchases only. LOWSELFCONTROL is a dummy where 1 stands for *LOWSELFCONTROL* and 0 for *HIGHSELFCONTROL*. CE is an individual's certainty equivalent. CRT denotes the number of correct answers on the CRT. Heteroskedasticity robust standard errors clustered at market level in parentheses, *** p<0.01, ** p<0.05, * p<0.1

Table 6: Determinants of individual RD based on purchases

	(1)	(2)	(3)	(4)
	Individual RD of sales			
LOWSELFCONTROL	0.326**	0.326**	0.596**	0.607**
	(0.147)	(0.147)	(0.230)	(0.218)
CRT		-0.00262	-0.0346	-0.0290
		(0.0289)	(0.0431)	(0.0437)
CE		0.0121	0.0745	0.0773
		(0.0459)	(0.0526)	(0.0535)
CRT × Stroop			0.0620	0.0630
			(0.0557)	(0.0550)
CE × Stroop			-0.156*	-0.160*
			(0.0841)	(0.0810)
Female				0.0655
				(0.0472)
Constant	0.193*	0.169	0.0654	0.00916
	(0.103)	(0.128)	(0.0850)	(0.0939)
Observations	160	160	160	160
R^2	0.188	0.188	0.216	0.222

OLS regression, dependent variable is Individual Relative Deviation (IndRD) for sales, an individual equivalent to market level Relative Deviation (RD) restricted to sales only. LOWSELFCONTROL is a dummy where 1 stands for *LOWSELFCONTROL* and 0 for *HIGHSELFCONTROL*. CE is an individual's certainty equivalent. CRT denotes the number of correct answers on the CRT. Heteroskedasticity robust standard errors clustered at market level in parentheses, *** p<0.01, ** p<0.05, * p<0.1

Table 7: Determinants of individual RD based on sales

A.5 Instructions

Welcome to the experiment and thank you for your participation!

Please do not talk to other participants of the experiment from now on

General information on the procedure

The purpose of this experiment is to investigate economic decision making. You can earn money during the experiment, which will be paid to you individually and in cash after the experiment has ended.

The whole experiment takes about 1.5 hours and consists of 3 parts. At the beginning you will receive detailed instructions for all parts of the experiment. If you have any questions after reading the instructions or at any time during the experiment please raise your hand. One of the experimenters will then come to you and answer your question in private.

During the experiment, you and the other participants will be asked to make decisions. In some parts, you will interact with other participants. Thus both your own decisions and the decisions of other participants can determine your payoffs. Your payoffs are determined according to the rules which are explained in the following. As long as you can make your decisions, a countdown will be displayed in the upper right corner of the screen which is intended to give you an orientation for how much time you should use to make your choices. In most parts you can exceed the time limit if needed; in some parts, however, you can only act within the time limit (You will be informed about this beforehand). Information screens not requiring any decisions will disappear after the time-out.

Payment

In some parts of the experiment we will not refer points instead of Euros. Points will be converted to Euros at the end of the experiment. You will be informed about the exchange rate at the beginning of the respective part.

For your timely arrival you will receive 4 € additionally to the income earned during the experiment.

Anonymity

We evaluate the data from the experiment only in aggregate and never connect personal information to data from the experiment. At the end of the experiment you have to sign a receipt, which we need for our sponsor. The sponsor does not receive any further data from the experiment.

Aid

On your desk you will find a pen. Please leave it on there after the experiment.

Part I

Task

The first part of the experiment consists of a task that will last 5 minutes. You will see a black screen on which words in different colors will appear. Here you can see an example:

You will be asked to click one of the buttons at the bottom of the screen. You will be asked to choose the button corresponding to the color the word is written in (**not** the word itself). In the example you should click on "yellow".

After clicked a button, the screen disappears and **another word in another color** appears. Please try to solve **as many word/color combinations** as possible within 5 minutes.

After 5 minutes the first part ends automatically and the second part begins.

Payment

You receive 3 € for part I.

Part II

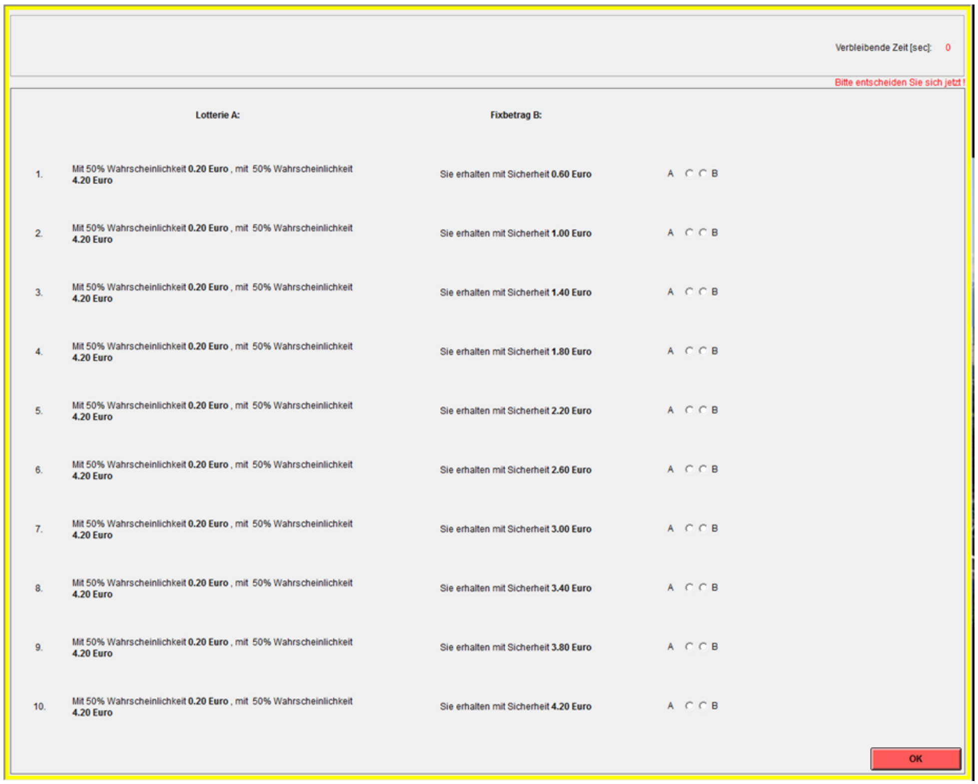
Task

In the second part you first have to answer three questions. For each question answered correctly you receive 0.5 € = 50 Cents.

Afterwards, you will be shown **10 decision problems**. In each of these problems you can choose between **a lottery and a safe amount of money**. The lottery remains unchanged within a period, whereas the safe amount of money increases with every additional decision problem. As the safe amount of money is strictly increasing from row to row, you should stay with the safe amount of money after you have switched to it once.

Your decision is only valid after you have made a choice for each problem and then confirmed it by clicking the OK-button on the bottom right of the screen. Take enough time for your decisions, as your choice – as described in the following – will determine your payoff from this part.

Here you can see what your screen will look like:



Your profit will be determined according to the following rules: First, **the computer chooses randomly and with equal probability one of the ten decision problems for payment**. If you selected the lottery in the relevant problem, the computer will simulate the outcome and you will receive it as payment. If you selected the safe amount in the relevant problem, you will receive it for sure.

For example: Assume the computer randomly chooses the first decision problem and you chose the lottery. Then the computer will simulate the outcomes of this lottery and you either receive 0.2 € (50% probability) or 4.2 € (50% probability).

Payment

The sum of your payoffs from the questions answered correctly at the beginning and your payoff from the decision problem chosen by the computer are your payment for part II of the experiment. Please note: The computer will directly calculate the result. However, you will only learn about this

at the end of the experiments, i.e. how many questions you answered correctly and which decision problem with which outcome the computer selected for you. That information will be presented to you on a separate screen at the end of the experiment.
After the end of part II, part III begins automatically.

Part III

Payment

In the third part of the experiment we refer to points rather than Euros. Points are converted to Euros at the end of the experiment according to the following exchange rate

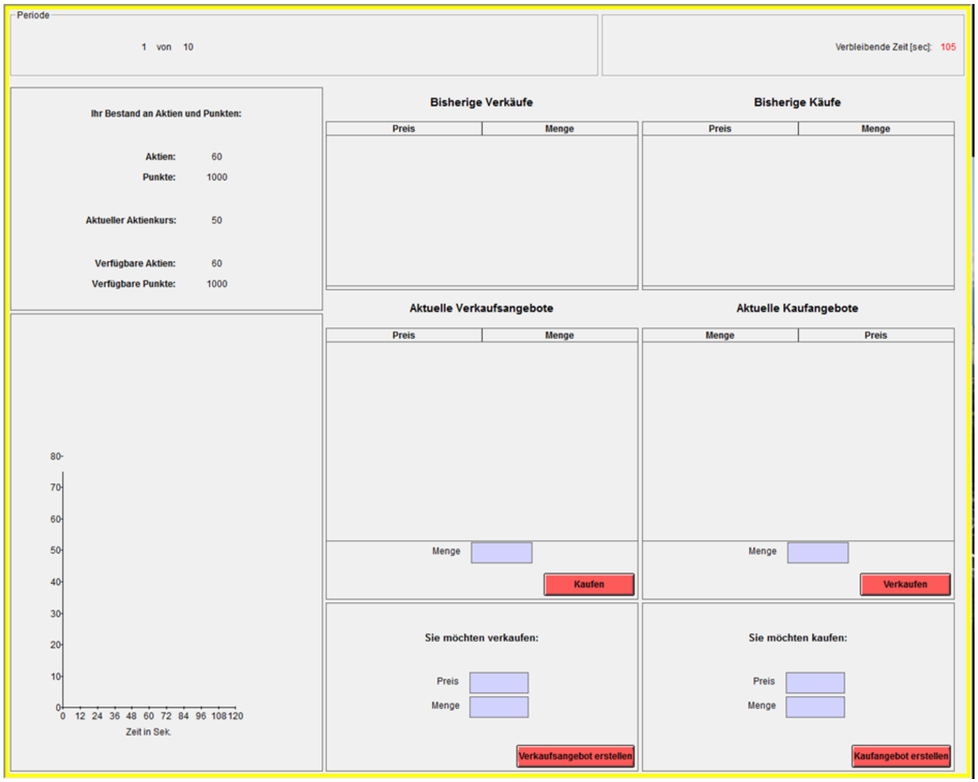
500 points = 1 Euro (1 point = 0.002 Euros = 0.2 Cents)

Short Description

The third part of the experiment consists of a simulated stock market. The stock market lasts for 10 consecutive periods. Within these periods you can buy or sell shares of a single firm.
At the end of each period for every share that you own you receive either a dividend of 10 points (probability 50%) or 0 points (probability 50%).
During the 2 minutes trading period you can either offer to sell or buy shares or accept existing buying or selling offers by other participants.

Detailed description: Trading Period

At the beginning of the first trading period you will receive an endowment of shares and points. Every participant receives either 20 shares and 3000 points or 60 shares and 1000 points. The distribution of endowments is random with a 50% probability of receiving each endowment.
Each period lasts exactly 120 seconds (= 2 minutes) and all screens disappear after the time out. You cannot make any trades or offers until he next trading period starts. During a trading period neither your amount of shares nor your amount of points can fall below zero.
During a trading period your screen will look like the following.
In the upper box you see the current period and how much time you have left in the current period. Below it to the left the box displays how many shares you currently own and how large your current wealth is expressed in points. Additionally the current share price and the amount of available shares and points are displayed.
Available shares are those of your shares that you have not offered for sale yet. If you offer to sell shares, you still own them, but they will be subtracted from your account as soon as someone else accepts your offer. Hence, you can only make sale offers that do not exceed your current amount of available shares.
Available points are those of your points that you have not used for buying offers yet. If you make an offer to buy shares, you still own the points, but they will be subtracted from your account as



soon as someone else accepts your offer. Hence, you can only make buying offers that do not exceed your current amount of available points.

On the bottom left you can see a graph that shows the evolution of share prices in the current period. On the horizontal axis (the x-axis) you can see the time in seconds at which a trade was made. On the vertical axis (the y-axis) you can see the corresponding price.

In the upper part of the screen you see two lists that have the headlines "Previous Sales" and "Previous Purchases". Here, every trade that you made is listed. For each trade where you bought shares, price and quantity will be listed in "Previous Purchases". For each trade where you sold shares, price and quantity will be listed in "Previous Sales".

Below you find two lists with the headlines "Current Selling Offers" and "Current Buying Offers".

Accepting Selling Offers

In the list "Current Selling Offers" you find price and quantity of each offer, in which a participant offers to sell shares. Your own selling offers will also appear in this list. You can accept every offer in this list (except for your own offers) by marking the corresponding entry in the list, entering the quantity you want to buy into the field "quantity", and then confirming by clicking on the button "Buy". If you accept a selling offer, you will receive the number of shares that you have entered from the seller and the seller receives the corresponding price for each share he sold to you.

Please note: You can also buy less than the number of shares stated in the offer. In that case the offer of the seller will remain on display in the list after the trade, but the number of shares on offer will be reduced by your purchase. Example: A seller makes an offer to sell 10 shares at the price of 60 points each. A buyer buys 6 of those shares. Then an offer to buy 4 shares at the price of 60 points each will continue to be available to all other participants.

Please note that the computer automatically marks the best selling offer (i.e. the one with the lowest price) with a blue bar. You can recognize your own offers, as they are not displayed in black but in blue font.

Accepting offers to buy

In the list "Current Buying Offers" you find price and quantity of each offer, in which a participant offers to buy shares. Your own buying offers will also appear in this list. You can accept every offer in this list (except for you own offers) by marking the corresponding entry in the list, entering the quantity you want to sell into the field "quantity", and then confirming by clicking on the button "Sell". If you accept a buying offer, the other participant will receive the number of shares that you entered and you receive the corresponding price for each share you sold.

Please note: You can also sell less than the number of shares the buyer offers to buy. In that case the offer of the buyer will remain on display in the list after the trade, but the number of shares demanded will be reduced by your sale.

Please note that the computer automatically marks the best buying offer (i.e. the one with the highest price) with a blue bar. You can recognize your own offers according to their blue font.

Creating Selling or Buying Offers

In the bottom part of the screen you have the possibility to create your own selling or buying offers. If you want to create an offer to sell, enter the quantity of shares that you want to sell and the price per share which you demand for each unit in the field below "You Want to Sell" . After clicking the button "Create Selling Offer", your selling offer will show up in the list "Current offers to sell". Example: You want to sell 10 shares at a price of 55 points per share. Then you enter 10 into the field "Quantity" and 55 into the field "Price".

If you want to create a buying offer, enter the quantity that you want to buy in the field below "You Want to Buy" and the price per share for which you are willing to buy that quantity. After clicking the button "Make Buying Offer" your offer will show up in the list "Current Buying Offers". Example: You want to buy 20 shares at a price of 45 points per share. Then you enter 20 into the field "amount" and 45 into the field "price".

Please note: An offer to buy or to sell that has been made cannot be cancelled. Only if no one accepts an offer during the course of a trading period, it will not be displayed in the next period of trade.

Dividends

After the end of a trading period the following screen displays a summary of the previous period showing you how many shares and points you own, whether a dividend has been paid and if so, how large your overall dividend payments were.

In each period the dividend per share either amount to 10 points (with a probability of 50%) or to 0 points (with a probability of 50%) and is the same for all shares. After the end of period 10, all shares are worthless. All participants learn the realization of the dividend simultaneously on a separate screen at the end of the corresponding period.

The following table displays the value pattern of a share, i.e. the expected value of the remaining dividends. The first column indicates the current period, in the second column you find the number of remaining dividend payments. The third column shows the average expected dividend per share and period. The last column shows the average of remaining dividends per share in the corresponding period.

Current period	Remaining dividend payments	x	Average dividend value per period (0 or 10 with equal probability)	=	Average remaining dividends per share that you own
1	10		5		50
2	9		5		45
3	8		5		40
4	7		5		35
5	6		5		30
6	5		5		25
7	4		5		20
8	3		5		15
9	2		5		10
10	1		5		5

Assume for example that four trading periods remain. As the dividend per share is either 0 or 10 points with a probability of 50% each, this yields an expected dividend of 5 points per share and period. Assume you only own one single share which you intend to hold until the market closes. Then you can expect a total dividend payment for the four remaining periods of '4 remaining periods' x '5 points' = '20 points'.

Payoff

At the end of part III the shares no remaining value. Only your amount of points will be converted to Euros according to the exchange rate stated above of 1 point = 0.002 Euros = 0.2 Cents.

Afterwards, you will see a screen displaying your payoffs from the second part.

In the following, we will ask you to completely and honestly answer some questions concerning your person. On leaving the laboratory, we will pay you your profit privately and in cash. Please remain seated until we call you up in a random order. Please leave the instructions and the pen at your desk and take your numbered seat card with you.

Practice Period

Before you start today's experiment with part I, you will first play a practice period of part III to become familiar with the stock market. The payoff from this practice period will not influence your final payoff. Please note that the realization of the dividend and your endowment are not necessarily identical to the first period of part III as the realization is random and endowments will be randomly assigned.

After completion of the practicing period part I of the experiment begins.

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