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How Time Constraint Affects the Disposition Effect?

Xiaofei Niu and Jianbiao Li*

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Abstract: Time constraint is a central aspect of financial decision making. This paper experimentally examines the effect of time constraint on the disposition effect, which refers to the empirical fact that investors have a higher propensity to sell stocks with capital gains compared to stocks with capital losses. We distinguish time pressure from time constraint by implementing three treatments: no time constraint (NTC), 20 seconds time constraint (20TC), and 10 seconds time constraint (10TC). The experimental results show that time constraint affects the disposition effect at some conditions, i.e. the 10TC treatment, in which subjects perceive more time pressure, significantly reduces the disposition effect; this treatment effect, however, vanishes in 20TC treatment, where feelings of stress do not differ from the NTC treatment. Self-control is one of the psychological mechanisms that explains why time pressure reduces the disposition effect.

Keywords: disposition effect, time pressure, time constraint, self-control

JEL classification: G02, G11

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1. Introduction

Time constraint is common to financial decision making. Investors must decide quickly whether to make orders in financial markets within seconds after new information becomes available (Busse and Green, 2002). Bidders in auctions must submit reservation prices before a deadline and could adjust their valuation in an instant by bidding early to learn about common value components (Roth and Ockenfels, 2002). However, despite the prevalence of time constraint among a variety of financial decision making, there has been surprisingly little work done to understand the role of time constraint for the investor behavior, including the so-called disposition effect.

The disposition effect is a behavioral trading pattern that investors have a propensity to sell winner stocks too early and ride loser stocks too long (Shefrin and Statman, 1985). The existence of the disposition effect has been documented in a variety of economic settings, including stock markets (Odean, 1998), housing markets (Genesove and Mayer, 2001), and experimental markets (Weber and Camerer, 1998). In addition to individual investors, evidence of the disposition effect has also been found among professional investors, such as mutual fund managers (Frazzini, 2006) and futures traders (Locke and Mann, 2005). In fact, the disposition effect is not only widespread, it is also an investment mistake that leads to underperformance (Odean, 1998). Thus, a better understanding of how to debias the disposition effect is important for investor performance.

In this paper, we use an experimental market to test the effect of time constraint on the disposition effect. *Time constraint* exists whenever there is a *deadline*, even if a subject can make trading decisions in less time (Ordonez and Benson, 1997). However, setting a time constraint is not enough to ensure that the subject has time pressure. When the time available for a trading decision is initially unrestricted but is then decreased

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1 Outside of the U.S. stock market, the disposition effect has been observed in other countries, such as China (Feng and Seasholes, 2005), Finland (Grinblatt and Keloharju, 2001) and Israel (Shapira and Venezia, 2001).

2 The word “deadline” originated in the 1860’s to refer to a perimeter around a prison. From the early 1900s, the word has been used to refer to any line that should not be crossed (Henry, 1909). In recent times, however, the word refers more to the time frame given to make decisions.
gradually, this may first lead to increased focusing and mobilization of more resources for making the decision (Svenson and Edland, 1987). If the time available is restricted even further this may lead to feelings of stress. *Time pressure* exists when there is a deadline and the subjects recognize that the available time may be too short to make trading decisions. That is, time pressure indicates that the time constraint induces some feeling of stress and creates a need to cope with the limited time (Svenson and Edland, 1987; Ordonez and Benson, 1997). Therefore, when imposing a deadline, it is possible to have time constraint but no time pressure.³

Concerning the effects of time constraint on decision-making, psychological dual-process theories (Kahneman, 2011), which distinguish between intuitive and reflective styles of decision making, offer a unified framework. Intuitive processes tend to be fast, automatic, and emotional. Reflective processes are slow, controlled, and based on calculative reasoning. A general idea is that reflective processes could be disrupted when decisions are made under time constraint (Porcelli and Delgado, 2009), while intuitive processes are not affected by the availability of time (e.g., manipulations of time constraint). Richards et al. (2018) showed that investors with high reliance on intuitive processes have greater disposition effect, but reliance on reflective processes is not related to the disposition effect. Further, they found that the disposition effect is reduced by an emotion regulation strategy (i.e., reappraisal) that changes a situation’s meaning to alter its emotional impact.⁴ Thus, if the role of reflective processes is gradually reduced as the severity of time constraint increases, the disposition effect would become more pronounced under time pressure.

However, there is also evidence that decisions under time constraint may not be necessarily intuitive. Evans, Dillon and Rand (2015) provided evidence that easy

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³ Most of experimental papers do not distinguish time pressure from time constraint. Some papers study time pressure without changing time constraint levels (e.g., Kocher et al., 2013; Lindner and Rose, 2017; Lohse, Simona and Konrad, 2018); some papers vary the levels of time pressure but do not distinguish it from time constraint (e.g., Nursimulu and Bossaerts, 2014; Karagözoglu and Kocher, 2019). In addition, other papers regard time constraint as an external deadline (e.g., Gneezy, Ernan and Roth, 2003).

⁴ Summers and Duxbury (2012) experimentally demonstrated the effect of experienced regret on the disposition effect. Rau (2015) showed that team investor who reports high levels of regret exhibit more pronounced disposition effects than individuals.
decisions are fast, but not intuition; difficult decisions are slow, but not reflection. Decision conflict, rather than the use of intuition and reflection, drives the decision time (Merkel and Lohse, 2019). In contrast to theoretical prediction of dual-process under time constraint, Lindner and Rose (2017) did not find an increase in the degree of present-bias under time constraint by eliciting time preferences in a laboratory. In addition, they found that subjects are significantly more patient under time constraint.

Therefore, a competing hypothesis is that time constraint may reduce the disposition effect. There are two potential explanations for this competing hypothesis. First, imposing time constraint, irrespective of the severity of time limit, could be perceived as an external deadline (Gneezy, Ernan and Roth, 2003). The external deadline may be perceived by the subjects as a precommitment strategy that helps increase time-consistent decisions and overcome the self-control problem (Ariely and Wertenbroch, 2002). Self-control is one of the psychological mechanisms underlying the disposition effect (Shefrin and Statman, 1985). Exogenously increasing the level of self-control can debias the disposition effect (Li et al., 2018). Second, mild time constraint does not induce feelings of stress, it just increases urgency and acts as the spur subjects need to compete trading decisions (Maule and Hockey, 1993). However, extreme forms of time constraint, such as time pressure, can yield physiological reactions that are typically associated with stress (Buckert, Oechssler and Schwieren, 2017). When time is scarce to make trading decisions, the feelings of stress increase the need to cope with the limited time (Svenson and Edland, 1987). The straightforwardly available strategy is to rely on explicit or focal reference point, which is more salient than the implicit reference (Karagözölü and Kocher, 2019). That is, time pressure may change trading behavior by shifting basis of decision to explicit or focal reference point (Saqib and Chan, 2015). Adapting to the explicit reference point, such as prespecified capital gains and losses limit, leads to more time-consistent

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5 One indication of stress is heart rate. Goulart et al. (2013) investigated the psychophysiological correlates of the disposition effect by measuring the heart rate of 40 subjects while they completed a simulated trading task. They found that subjects with a higher disposition effect are those with relatively lower heart rate, indicating the heart rate is negatively correlated with the disposition effect.
decisions and lower disposition effect (Li et al., 2018)

The two explanations are consistent with the time constraint reducing the disposition effect by increasing the time-consistent decisions. One important difference between the two, though, is whether the reduction of disposition effect depends on time constraint levels. According to the first explanation, time constraint would generally reduce the disposition effect as the external deadline is an effective precommitment device. According to the second explanation, the impact of time constraint on disposition effect may depend on severity of time limit, i.e. disposition effect could only be reduced under the time pressure.

To clarify how time constraint affects the disposition effect, we implement three treatments in our laboratory experiment: no time constraint (NTC), 20 seconds time constraint (20TC), and 10 seconds time constraint (10TC). Our main treatment variable is the time allotted to subjects for reaching a trading decision. Specifically, in the NTC treatment, the trading decisions are made without time limit. In the 20TC treatment, subjects are given 20 s to make trading decisions. In the 10TC treatment, subjects are forced to reach their trading decisions within 10 s. Exogenously varying the time constraint levels allows us to distinguish time pressure from time constraint: the 20TC treatment is a loose deadline and expected to be not very binding, while the 10TC treatment is a tight deadline and designed to induce feelings of time pressure.

Following the design of Frydman et al. (2014), we create an experimental stock market in which subjects could trade stocks. To examine the time-consistent behavior, we also follow Li et al. (2018) and ask subjects to pre-specify their ideal capital gains and capital losses limit at the beginning of the experiment. The pre-specified capital gains and capital losses limit provide subjects the focal reference point.

Our experimental data show that the time constraint in both 20TC and 10TC treatment increases the frequency of last-moment decisions, indicating the time deadline effect is equally pronounced. However, subjects in 10TC treatment perceive significantly more time pressure than in 20TC treatment. The rate of time-violator is

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6 To determine the time constraint levels for the 10TC and 20TC treatments, a pilot experiment with five subjects is conducted.
13.33% and 0% in 10TC and 20TC treatment, respectively. These results indicate that time pressure in 10TC treatment is manipulated successfully.

Importantly, we find that the 10TC treatment, in which subjects perceive more time pressure, significantly decreases the disposition effect. This treatment effect is robust when we rule out the salient reference point by not letting subject pre-specify ideal capital gains and capital losses limit. However, this treatment effect vanishes in the 20TC treatment, where the feelings of time pressure do not differ from the NTC treatment. Specifically, the reduction of the disposition effect in 10TC treatment is primarily driven by a decrease in the propensity to sell winner stocks (PGR) and an increase in the propensity to sell loser stocks (PLR). Moreover, subjects in 10TC treatment exhibit significantly more time-consistent decisions, indicating they have a better self-control. Further mediation analysis reveals that the indirect effect from 10TC treatment through self-control to disposition effect is −0.039, suggesting self-control is one of the psychological mechanisms that explains why time pressure reduces the disposition effect. However, the 20TC treatment does not affect the disposition effect, PGR and PLR. In addition, the 20TC treatment increases the subjects’ time-consistent decisions, but it does not reach significance level.

Taken together, our result tends to rule out the possibility of general effect of time constraint on disposition effect. Rather, our result favors the second interpretation: the disposition effect is reduced under time pressure (i.e., 10TC treatment), but this treatment effect disappears under mild time constraint (i.e., 20TC treatment) due to not exhibiting enough time-consistent decisions. Therefore, the current results seem to suggest a threshold for the role of time constraint in disposition effect, that triggers certain time-consistent decisions. Only time-consistent decisions that cross such a threshold evokes a change of trading behavior. However, it is noted that other potential psychological mechanisms, such as realization utility and cognitive dissonance, may also mediate the relationship between time pressure and disposition effect.

2. Related Literature
Our paper is related to several literature in behavioral finance, which we discuss here.

First, our study complements a nascent experimental literature that considers under what condition the disposition effect might be attenuated. Frydman and Rangel (2014) conducted a laboratory experiment and found that subjects’ disposition effect could be reduced if information of the stock purchase price is not displayed. Using investor level brokerage data from China and a natural experiment, Frydman and Wang (2019) further demonstrated that the salience of information causally affects disposition effect.\(^7\)

Apart from manipulating salience of information, several papers study how to reduce the disposition effect by adapting the reference point. Birru (2015) showed that the nominal change in stock prices caused by stock splits, coupled with investor inattentiveness to the split, leads to a reduction of the disposition effect. The author argued that this result mainly arises from investor failure to update their reference prices following the nominal change. Frydman, Hartzmark, and Solomon (2018) found that when investors sell a stock and quickly buy a different stock, the mental accounting used to track the sold stock is not closed and would be rolled into the new stock. When a mental account is rolled, the reference point used to assess gains and losses for a newly purchased asset remains linked to the amount paid for the original asset. Rolling a mental accounting alleviates the pain of realizing a loss and thus reduces the disposition effect.

Other papers focus on how to improve investor self-control. Fischbacher, Hoffmann and Schudy (2017) investigated whether using stop-loss/take-gain option of automatic selling devices and pre-specified selling plans with reminders could reduce disposition effect. Their findings showed that automatic selling devices reduce the disposition effect by helping investors realize loser stocks whereas reminders about pre-specified selling plans are not enough to reduce the disposition effect, suggesting the important role of self-control for disposition effect. Using non-invasive brain stimulation to exogenously vary subjects’ levels of self-control, Li et al. (2018) found

\(^7\) Goulart et al. (2015) found that when an investor’s financial performance is to be made public the disposition effect would be significantly increased, resulting from a spike in the realization of gains.
that cathodal stimulation significantly reduces the disposition effect by helping subjects to exhibit more time-consistent decisions.

To the best of our knowledge, we are the first to examine how the time constraint affects disposition effect. Consistent with previous studies, we find that adaption of reference point plays an important role in the disposition effect. Specifically, time pressure may prompt subjects to trade stocks based on salient reference point. In our experiment, the pre-specified capital gains and capital losses limit provide subjects the explicit reference point, resulting in more time-consistent decisions. An increase of self-control reduces the disposition effect. Thus, self-control is one of the psychological mechanisms that explains why time pressure reduces the disposition effect.

Second, our paper is related to the experimental studies on the influence of time constraint on individual risk preferences. In general, time constraint has been investigated by comparing the behavior of subjects with and without a time limit. Some studies have used just one time-constrained condition, others two or three. However, many papers select time constraint levels arbitrarily, with no rationale. This leads to the failure of distinguishing time pressure from time constraint, which may cause contradictory results documented in the extant literature. For example, some studies have found that time pressure increases the reflection effect of prospect theory; that is, time pressure increases risk aversion for gains and risk seeking for losses (Kirchler et al., 2017). Other studies, however, have found that people under time pressure are risk-seeking over gains (Nursimulu and Bossaerts, 2014) and risk-averse over losses (Kocher et al., 2013), implying that time pressure reverses the reflection effect (Saqib and Chan, 2015). These findings may be reconciled by drawing a distinction between time pressure and time constraint.

In this paper, we try to fill this gap by examine how time constraint affects the disposition effect. In doing so, time pressure from 10 seconds deadline is operationalized according to Benson and Beach (1996). We also include one treatment in which subjects are given 20 seconds to make trading decisions. This treatment is not very binding because it is a loose deadline. Ensuring the successful manipulation of
time pressure, we find that time constraint affects the disposition effect at some conditions. The disposition effect is significantly reduced in 10TC treatment, where subjects perceive more time pressure. But when feelings of time pressure do not differ from the NTC treatment (i.e., in 20 TC treatment), the disposition effect is not significantly decreased.

In addition, a standard explanation of the disposition effect is the prospect theory (Kahneman and Tversky, 1979; Shefrin and Statman, 1985; Weber and Camerer, 1998; Odean, 1998), which indicates that investors will hold the stock that has gone down in price as they are risk-seeking over losses and sell the stock that has risen in price as they are risk-averse over gains. If this explanation makes sense in our study, we argue that the time pressure to some extent decreases the influence of the reflection effect as subjects in the 10TC treatment are less prone to the disposition effect.

Third, our paper is also related to the recent studies on decision time (for an overview about decision time, see Spiliopoulos and Ortmann, 2018). The decision time is a useful as a simple, cheap and attractive indicator of the nature of a choice (Rubinstein, 2007). Giglio and Shue (2014), in a corporate finance setting, showed that decision time, which begins when a merger is announced, are negatively correlated with the probability the merger is completed. Konovalov and Krajbich (2017) documented that there is a consistent relationship between decision time and strength of risk, time and social preference, namely that people make slower decisions as they approach indifference; and this relationship can be used to infer preferences even when choice outcomes are uninformative or unavailable. Frydman and Krajbich (2017) found that, in information cascade experiment, decision time contain information that is not contained in choice outcomes alone, and subjects are able to infer others’ private beliefs from decision time without any training. In contrast to the above literature that focuses

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8 Recent studies have found that prospect theory is unable to provide a complete explanation of disposition effect for individual investors (e.g., Kaustia, 2010; Barberis and Xiong; 2009; Lehenkari, 2012; Meng and Weng, 2017).

9 Decision time is also valuable for the identification of individual and strategic decision processes (Kocher and Sutter, 2006; Arad and Rubinstein, 2012), model comparison or selection (Marewski and Melhorn 2011), and the investigation of heuristics that combine speed and performance by exploiting environmental regularities (Rubinstein, 2013).
on effect of endogenous decision time, we examine investor financial decision making under exogenous decision time. We extend the literature by showing that time constraint affects the disposition effect at some conditions, such as time pressure in which subjects perceive feelings of stress.

3. Experimental Design

3.1 Basic Design

Our experimental design is based on Frydman et al. (2014). In the experiment, a subject is endowed with 50 Experimental Currency Units (ECU) and three stocks labeled as A, B, and C. The initial price of each stock is 100 ECU. The experiment includes 30 periods. In period 1 to 6, a subject is not given the opportunity to trade any stocks but can observe price updates of the chosen stock. In period 7, a subject can decide to sell a stock for the first time. In the following periods of 8 to 30, the subject may purchase or sell stocks.

From period 7 to 30, every period consists of two parts: a price update and a trading decision, which are shown in two different screens. In the price update part, one of the three stocks is randomly chosen and subjects observe a price change for this stock. In the trading part, the subject is subsequently asked whether he or she wants to trade this stock. No new information is revealed during this part. Each stock receives a price update and could be traded only when it is chosen in a period. The price of the other two unchosen stocks remain unchanged and could not be traded. Period 1 through 6 consist only of a price update screen, and subjects could accumulate price information about the three stocks in the initial set of periods.

We split each period into two screens to temporally separate different types of cognitive operations. At the price update screen, information about the updated price of

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10 In the original experiment design of Frydman et al. (2014), one of the three stocks is also chosen at random in the trading part. Frydman and Rangel (2014) test the cross-stock effects, i.e. if an increase in the price of stock A in the first part impacts purchasing or selling decisions for stocks B or C in the second part of the period. Their results show that that price information for one stock does not affect the subjects’ trading decisions for another one, and no evidence exists for the cross-stock effects.
the stock is processed, and subjects do not have to consider whether to purchase or sell the stock because they are not allowed to make decisions at this part. At the trading screen, subjects need to make decisions about purchasing or selling a stock, but they do not need to process information again since no new information about the updated price is revealed.

The price change of each stock is controlled by a hidden two-state Markov chain that includes a good state and a bad state. The Markov chains of the three stocks are independent of one another. Before period 1, the three stocks are randomly assigned to either a good state or a bad state. States are then updated only after a stock is chosen and receives a price update in the period. Specifically, assume stock $i$ is in a good state in period $t$. If the price update is not about stock $i$ in period $t+1$, the state and price of stock $i$ remain unchanged. Further, if price update is about stock $i$, the state of stock $i$ in period $t+1$ remains good with a probability of 0.8 and switches to bad with a probability of 0.2. In a good state, the price of a stock increases with a probability of 0.7 and decreases with a probability of 0.3. In a bad state, the price of a stock decreases with a probability of 0.7 and increases with a probability of 0.3.

The magnitude of the price change is drawn uniformly from \{5 ECU, 10 ECU, 15 ECU\} and is independent of the direction of the price change. The states of a stock are always hidden to the subject, but the subject can make Bayesian inferences about states from observed price changes. We use the same set of realized prices for all subjects, so that it can reduce error in comparison of trading performance across subjects (Weber and Camerer, 1998; Frydman et al., 2014; Frydman and Rangel, 2014). The realized prices of the three stocks can be seen in Figure 1.

**Figure 1. Realized prices used in the experiment.** The price of each stock is updated 10 times. Stock A is updated five times for price increase and five times for price decrease. The realized price of Stock A is shown in black. Stock B is updated seven times for price increase and three times for price decrease. The realized price of Stock B is shown in red. Stock C is updated three times for price increase and seven times for price decrease. The realized price of Stock C is shown in green.
Following Li et al. (2018), we ask subjects to pre-specify their ideal capital gains and capital losses limit at the beginning of the experiment. Specifically, subjects need to answer two questions: “During the experiment, how much capital gains of a held stock brings to you, you will sell it?” and “During the experiment, how much capital losses of a held stock brings to you, you will sell it?”. Non-binding limits of capital gains and capital losses are possible, and subjects could not adjust limits during the entire experiment.

During the experiment, each subject is only allowed to hold a maximum of one unit of each stock and cannot hold any negative unit where short-selling is not allowed. The trading decision in a period is, therefore, reduced to whether to sell a stock (conditional on holding it) or purchase it (conditional on not holding it). A subject can carry a negative cash balance to allow the purchase of a stock even without enough cash. The amount of negative cash balance is subtracted from the subject’s total payoff at the end of the experiment.

At the end of the experiment, a subject’s holdings of the three stocks are liquidated at the stocks’ current prices and added to cash value. Subjects were given a financial incentive to maximize their final payoffs. Specifically, if the total value of a subject’s cash and stock holdings at the end of experiment is $Y$ in ECU, then his take-home payoff is $Y/20$ Chinese yuan, and we add another 5 Chinese yuan ($0.80) as show-up fee.

3.2 Treatments and Procedures
We vary the time available to the subjects for making a trading decision and implement three between-subject treatments: no time constraint (NTC), 20 seconds time constraint (20TC), and 10 seconds time constraint (10TC). In the NTC treatment, subjects have no time constraint to trade stocks. In the 20TC treatment, the subjects are given 20 seconds to make stock trading decisions, and in the 10TC treatment they are given 10 seconds.

Benson and Beach (1996) argued that most papers select time constraint levels arbitrarily with no rationale, and suggested that researchers should first timed subjects on a pilot and then select as their constraint the execution time that is (about) one standard deviation below the mean. In our pilot experiment with five subjects, the average decision time is 15.25 seconds per decision with a standard deviation of 5.09 seconds. Thus, the time constraint in 10TC treatment is imposed 10 seconds (≈15.25–5.09), which is expected to induce feelings of stress. In 20TC treatment the time constraint is imposed 20 seconds (≈15.25+5.09), this treatment is expected to be not very binding, but it still has a time deadline.

The time constraint is only set in the trading part. In the price update part of each period, subjects have no time constraint to process the information about the updated price of the stock across treatments. To make the treatments fully comparable, a clock at the top of the screen is clearly visible in all treatments. In the NTC treatment, however, it does not play any role in causing the trading part to end.

In the trading part, subjects need to click a button to make their stock trading decision. In the 20TC and 10TC treatment, if a subject fails to make a stock trading decision before time runs out, the computer will randomly make a trading for the subject.

We conducted the experiment at Nankai University throughout 2018 and 2019. The experiment was programmed using z-Tree (Fischbacher, 2007). We had forty-five subjects in each treatment, one hundred and thirty-five subjects (87 female, age ranging from 19 to 28) in total, with nine subjects in each session. There were five sessions for each of the three treatments. A session lasted about 50 to 70 minutes. The average

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11 Several papers have adopted this method to select the time constraint level, such as Huber and Kunz (2007).
earning was 36 Chinese yuan ($6.51). Upon arrival, subjects were seated at visually isolated computer workstations. Instructions were read aloud and subjects also received a copy of the instructions.\textsuperscript{12} Participants were prohibited from talking during the experiment.

3.3 Measurement of Disposition Effect

We follow Odean’s (1998) methodology to measure the magnitude of disposition effect. For each period, a stock is counted as a “Realized Gains” (“Realized Losses”) if it is sold at a price that is higher (lower) than the purchase price, and a “Paper Gains” (“Paper Losses”) if it is not sold at a price that is higher (lower) than the purchase price. The total number of Realized Gains, Realized Losses, Paper Gains and Paper Losses across all periods is tallied, and the proportion of gains realized ($PGR$) and the proportion of losses realized ($PLR$) are computed:

$$PGR = \frac{\# \text{ Realized Gains}}{\# \text{ Realized Gains} + \# \text{ Paper Gains}}$$

$$PLR = \frac{\# \text{ Realized Losses}}{\# \text{ Realized Losses} + \# \text{ Paper Losses}}$$

The individual measure of the disposition effect is the difference between these two ratios, ($PGR–PLR$). The size of the disposition effect increases in $PGR–PLR$.

3.4 Measurement of Self-Control

Most models of self-control share a common structure: an individual wants to make an ideal decision, but he or she is tempted to deviate from this ideal.\textsuperscript{13} The individual’s actual decision is a balance between the two forces. With this spirit Ameriks et al. (2007) introduce a measure of self-control, i.e. the difference between the actual decision and ideal decision. We follow Ameriks et al. (2007) and measure the level of self-control.

\textsuperscript{12} At the end of the instructions phase and prior to the start of the experiment, all subjects had to complete a quiz to ensure that they understood the instructions required for the experiment.\textsuperscript{13} Models that fit this framework include the model of the dual-self model of impulse control in Thaler and Shefrin (1981) or in Fudenberg and Levine (2006), quasi-hyperbolic discounting and time-inconsistent preference in Laibson (1997), the model of temptation and self-control in Gul and Pesendorfer (2001), the model of addiction and cue-triggered mistake in Bernheim and Rangel (2004).
Table 1 shows the time-consistent and time-inconsistent decision in the four decision channels. Gain is the amount of stock current price beyond its purchase price. Loss is the amount of stock current price under its purchase price. Limit is the value of subjects’ prespecified capital gains or losses limit.

Table 1. Time-consistent and time-inconsistent decision in the four decision channels. Gain is the amount of stock current price beyond its purchase price. Loss is the amount of stock current price under its purchase price. Limit is the value of subjects’ prespecified capital gains or losses limit.

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<th>Gain (or Loss) ≥ Limit</th>
<th>Gain (or Loss) &lt; Limit</th>
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<td>Realized Gains</td>
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<td>Paper Gains</td>
<td>time-inconsistent</td>
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<tr>
<td>Realized Losses</td>
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<tr>
<td>Paper Losses</td>
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If the Gain is below subjects’ prespecified capital gains limit, Realized Gains is a time-inconsistent decision, and Paper Gains is a time-consistent decision; otherwise Realized Gains is a time-consistent decision, and Paper Gains is a time-inconsistent decision. If the Loss is below subjects’ prespecified capital losses limit, Realized Losses is a time-inconsistent decision and Paper Losses is a time-consistent decision; otherwise Realized Losses is a time-consistent decision and Paper Losses is a time-inconsistent decision.

The individual measure of the self-control is calculated by dividing the sums of time-consistent decisions by the numbers of decisions in the four decision channels. Subjects who have a better self-control would exhibit a higher percentage of time-consistent decisions.

4. Experimental Results

4.1 Time Pressure Manipulations

Figure 2 and 3 shows the distribution of decision time (seconds). Figure 2

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14 The statistical analysis of subjects’ decision time is in seconds because of the time being recorded in seconds by the z-Tree.
depicts the distribution of decision time across treatments. Figure 3 depicts the
distribution of decision time in each treatment.

The median decision time under 10TC treatment is 5 seconds, which is
approximately third of median decision time under NTC treatment (14 seconds). Under
20TC treatment the median decision time is 12 seconds. We test the null hypothesis that
decision times are equal across treatments. Equality of decision times are rejected for
both of treatments (Mann-Whitney test, all ps<0.001), indicating that decision time
becomes shorter with the severity of time constraint.15

**Figure 2. The distribution of decision time (seconds) across treatments.** The boxes
range from the lower quartile to the upper quartile of the distribution. The black band
in the middle of the box represents the median. The whiskers represent the minimum
and the maximum of the distribution.

Importantly, 19.26% of decisions in 20TC are made in the last 10% of the allotted
time (i.e., seconds 19), 19.44% of decisions in 10TC are made in the last 10% of the
allotted time (i.e., seconds 9), whereas 0.09% of decisions in NTC are made in the last
10% of the allotted time (i.e., seconds 29). The percentage of last-moment decisions is
higher in 20TC (or 10TC) treatment than in NTC treatment. Time constraint increases
the frequency of last-moment decisions. In other words, time constraint has the time
deadline effect. However, the 20TC and 10TC treatment do not differ in the percentage

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15 All tests in this paper are two-sided tests except when stated otherwise.
of last-moment decisions, indicating the time deadline effect is equally pronounced in the 20TC and 10TC treatment.

Figure 3. The distribution of decision time (seconds) in the NTC treatment (a), 20TC treatment (b), and NTC treatment (c).
In a post-experimental questionnaire, we collect subjects’ perceived time pressure level of the experiment on a five-point Likert scale. Figure 4 shows the level of perceived time pressure by treatments. During the experiment subjects in the 10TC treatment perceive more time pressure (Mean=3.4, SE=0.166) than subjects in the 20TC treatment (Mean=2.467, SE=0.195) (Mann-Whitney test, z=−3.484, p<0.001), or than subjects in the NTC treatment (Mean=2.089, SE=0.185) (Mann-Whitney test, z=−4.774, p<0.001), indicating time pressure in the 10TC treatment is manipulated successfully. Subjects in the 20TC treatment report higher level of perceived time pressure than subjects in the NTC treatment, but the difference does not reach the significant level (Mann-Whitney test, z=−1.558, p= 0.120), suggesting the 20TC treatment is not very binding.

**Figure 4. The level of perceived time pressure by treatments.** Error bars indicate ±1 SEM.
Moreover, in the 20TC treatment no subjects violate the time constraint. Six subjects (13.33%) in the 10TC treatment violate the time constraint at least once, indicating time pressure have been substantial but not prohibitive. We do not drop these six subjects in subsequent data analysis for two reasons. First, the number of violation decisions is very low, i.e. the number for each subject who do not meet the time constraint are less than four times. Second, dropping the time-constraint violators may lead to selection effects, resulting in a false interpretation of the observed behavior across treatments (Kocher et al., 2019). For example, Tinghög et al. (2013) argue that exclusion of subjects who fail to respond on time in the original studies of Rand et al. (2012) cause a self-selection problem, which may lead to a failure of replicating time constraint effects on cooperation in social dilemmas.

**Result 1** *Time deadline effect is equally pronounced in 20TC and 10TC treatment. NTC treatment does not has the time deadline effect.*

**Result 2** *Time pressure is significantly higher in 10TC treatment than in 20TC treatment or in NTC treatment, whereby the latter two treatments do not differ.*

---

16 The results are robust when we drop the six subjects in the 10TC treatment. In addition, for the 10TC treatment we do not find significant differences in the disposition effect, PGR, or PLR between the subjects who violate the time constraint and other subjects who do not violate the time constraint (Mann-Whitney test, all ps>0.227). There is thus no indication that violators differ from non-violators in their selling behavior.

17 Two subjects violate the time constraint three times, three subjects violate the time constraint two times, and one subject violates the time constraint once.
4.2 Disposition Effect by Treatments

Figure 5 shows the average disposition effect by treatments. The disposition effect in the 10TC treatment is −0.211 (SE=0.047), which is significantly lower than that in the NTC treatment (Mean=0.205, SE=0.063) (Mann-Whitney test, p<0.001, z=5.041) or the 20TC treatment (Mean=0.163, SE=0.062) (Mann-Whitney test, p<0.001, z=−4.342). However, no significant difference in the disposition effect is found between the 20TC and the NTC treatment (Mann-Whitney test, p=0.542, z=0.609). These results indicate that the disposition effect is significantly reduced only in the 10TC treatment.

Figure 5. The disposition effect by treatments. Error bars indicate ±1 SEM.

Figure 6 shows the cumulative distributions for the PGR and PLR by treatments. Figure 6(a) indicates that the cumulative distribution of the PGR in the 10TC treatment significantly differs from the NTC treatment (Kolmogorov-Smirnov test, p<0.001) or the 20TC treatment (Kolmogorov-Smirnov test, p=0.047). That is, the PGR in the 10TC treatment (Mean=0.261, SE=0.027) is significantly lower than that in the NTC treatment (Mean=0.447, SE=0.035) or the 20TC treatment (Mean= 0.433, SE = 0.045). 82.22% of the subjects in the 10TC treatment have a PGR<0.35, whereas only 48.89% of subjects in the NTC treatment and 57.78% of the subjects in the 20TC are in this range. In Figure 6(b), a significant treatment difference in the cumulative distribution
of PLR is also found. The PLR in the 10TC treatment is 0.472 (SE=0.042), which is roughly double of the value in the NTC treatment (Mean=0.241, SE=0.041) (Kolmogorov-Smirnov test, p<0.001) or in the 20TC treatment (Mean=0.270, SE=0.039) (Kolmogorov-Smirnov test, p=0.003). However, the equality of distribution between the 20TC and NTC treatment, irrespective of the PGR or the PLR, cannot be rejected (two-tailed Kolmogorov-Smirnov test, all ps>0.20). Thus, the 10TC treatment reduces the disposition effect due to a lower proportion of gains realized (PGR) as well as a higher proportion of losses realized (PLR).

Figure 6. The cumulative distribution of PGR (a) and PLR (b) by treatments.
Table 2 shows the average number of decisions by treatments and four decision channels (realized gains, paper gains, realized losses, and paper losses). Consistent with the previous results, we find that subjects in 10TC treatment are more likely to hold stocks that have gone up in price and sell stocks that have gone down in price. Compared with NTC (or 20TC) treatment, 10TC treatment has a significantly lower number of decisions in the paper losses channel (NTC=6.6, 10TC=4.467, 20TC=7.311) and a significantly higher number of decisions in the paper gains channel (NTC=3.488, 10TC=5.2, 20TC=3.644) (Mann-Whitney test, all ps<0.01). However, the differences in the number of decisions between the 20TC and the NTC treatment are not significant in the paper gains or paper losses channel. In addition, 10TC (or 20TC) treatment has a significantly lower number of decisions in the realized gains channel (NTC=2.155, 10TC=1.555, 20TC=1.867) and a significantly higher number of decisions in the realized losses channel (NTC=1.222, 10TC=2.555, 20TC=1.733) (Mann-Whitney test, all ps<0.01).

Table 2. The average number of decisions by treatments and decision channels.
Data are shown according to the four decision channels (realized gains, paper gains, realized losses, and paper losses) and whether the decision channel is generated from the no time constraint, 20 seconds time constraint or 10 seconds time constraint treatment. Standard errors of mean are in parentheses. Significance levels: *p < 0.10, **p < 0.05, ***p < 0.01.

<table>
<thead>
<tr>
<th>Decision Channel</th>
<th>Treatment</th>
<th>Mann-Whitney test</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1: NTC</td>
<td>2: 20TC</td>
</tr>
<tr>
<td>Realized Gains</td>
<td>2.155</td>
<td>1.867</td>
</tr>
<tr>
<td></td>
<td>(0.089)</td>
<td>(0.154)</td>
</tr>
<tr>
<td>Paper Gains</td>
<td>3.488</td>
<td>3.644</td>
</tr>
<tr>
<td></td>
<td>(0.311)</td>
<td>(0.412)</td>
</tr>
<tr>
<td>Realized Losses</td>
<td>1.222</td>
<td>1.733</td>
</tr>
<tr>
<td></td>
<td>(0.171)</td>
<td>(0.183)</td>
</tr>
<tr>
<td>Paper Losses</td>
<td>6.6</td>
<td>7.311</td>
</tr>
<tr>
<td></td>
<td>(0.538)</td>
<td>(0.604)</td>
</tr>
</tbody>
</table>

To shed more light on the determinants of selling behavior, we perform Probit regressions of the propensity to sell a stock by a subject using all data. Table 3 reports the estimated values of the regression coefficients. Here, Capital Gain equals one if a subject sells a stock and equals zero if a subject holds it (conditional on the opportunity
to sell). \textit{10TC Treatment} and \textit{20TC Treatment} are treatment dummies. \textit{10TC Treatment × Capital Gain} is the interaction term of the variable \textit{10TC Treatment} and \textit{Capital Gain}. \textit{20TC Treatment × Capital Gain} is the interaction term of the variable \textit{20TC Treatment} and \textit{Capital Gain}. We find that the coefficients for the \textit{Capital Gain} is positive and significant, suggesting subjects have a more propensity to sell a stock that has increased in price. Importantly, the coefficients of \textit{10TC Treatment × Capital Gain} in column (2) and (4) are significantly negative, but the coefficients of \textit{20TC Treatment × Capital Gain} in column (3) and (4) are not significant. 10TC treatment negatively moderates the relationship of capital gains and propensity to sell a stock. That is, the 10TC treatment weakens the positive effect of capital gains on the propensity to sell a stock.

Table 3. Probit regression of subjects’ propensity to sell a stock. Dependent variable is \textit{Propensity to Sell a Stock} that equals one if a subject sells a stock and equals zero if a subject holds it (conditional on the opportunity to sell). \textit{Capital Gain} is calculated by subtracting stock purchase price from stock current price. \textit{10TC Treatment} is a binary variable that equals one if a subject is in the 10 seconds time constraint treatment and zero otherwise. \textit{20TC Treatment} is a binary variable that equals one if a subject is in the 20 seconds time constraint treatment and zero otherwise. Probit regression is with robust standard errors (clustering at the individual level). Robust standard error is displayed in parentheses. Significance levels: *p < 0.10, **p < 0.05, ***p < 0.01.

<table>
<thead>
<tr>
<th>Dependent variable</th>
<th>(1)</th>
<th>(2)</th>
<th>(3)</th>
<th>(4)</th>
</tr>
</thead>
<tbody>
<tr>
<td>\textit{Capital Gain}</td>
<td>0.007*** (0.001)</td>
<td>0.011*** (0.001)</td>
<td>0.006*** (0.001)</td>
<td>0.012*** (0.001)</td>
</tr>
<tr>
<td>\textit{10TC Treatment}</td>
<td>0.142 (0.077)</td>
<td>0.141 (0.087)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>\textit{10TC Treatment × Capital Gain}</td>
<td>\textbf{-0.014*** (0.002)}</td>
<td>\textbf{-0.015*** (0.002)}</td>
<td></td>
<td></td>
</tr>
<tr>
<td>\textit{20TC Treatment}</td>
<td>-0.060 (0.081)</td>
<td>-0.004 (0.094)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>\textit{10TC Treatment × Capital Gain}</td>
<td>0.003 (0.003)</td>
<td>-0.002 (0.003)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>\textit{Constant}</td>
<td>-0.625*** (0.036)</td>
<td>-0.659*** (0.047)</td>
<td>-0.603*** (0.0841)</td>
<td>-0.659*** (0.062)</td>
</tr>
<tr>
<td>\textit{No. of Observations}</td>
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<td>1881</td>
<td>1881</td>
<td>1881</td>
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<tr>
<td>\textit{Clusters}</td>
<td>135</td>
<td>135</td>
<td>135</td>
<td>135</td>
</tr>
<tr>
<td>\textit{Pseudo R}^2</td>
<td>0.021</td>
<td>0.041</td>
<td>0.023</td>
<td>0.041</td>
</tr>
</tbody>
</table>

Table 4 further provides a test on the treatment effect by reporting results from OLS regressions including controls for individual characteristics. Here, the dependent
variable in column (1) and column (2) is the Disposition Effect. The dependent variable in column (3) and column (4) is the proportion of gains realized (PGR). The dependent variable in column (5) and column (6) is the proportion of losses realized (PLR). In addition to the treatment dummies, we also include several demographic variables as additional regressors. The coefficients of the 10TC treatment are significantly negative in columns (1) and (2) (with/without demographic variables) and decrease the share of disposition effect by 41 to 42 percentage points. From column (3) to column (6), we estimate the impact of 10TC treatment on PGR and PLR (with/without demographic variables). The results show that in the 10TC treatment the PGR decreases by 18 percentage points while the PLR increases by 23 percentage points. The coefficients of the 20TC treatment are not significant from column (1) to column (6).

Table 4. Regression analysis of the disposition effect, PGR and PLR. The dependent variable in column (1) and column (2) is the disposition effect. The dependent variable in column (3) and column (4) is the proportion of gains realized (PGR). The dependent variable in column (5) and column (6) is the proportion of losses realized (PLR). Risk Aversion is a subject’s total number of choosing “safe” choices (0 to 10). Loss Aversion is a subject’s value of lambda (0.91 to 5). Trading Experience is a binary variable that equals one if the subject reports that he or she has stock trading experience and zero otherwise. Female is a binary variable that equals one if the subject is woman and zero otherwise. Age is subjects’ year of age (19 to 28). Ordinary least squares (OLS); robust standard errors (clustered at subject individual level) are in parentheses. Significance levels: *p < 0.10, **p < 0.05, ***p < 0.01.

<table>
<thead>
<tr>
<th>Dependent Variable</th>
<th>Disposition Effect</th>
<th>PGR</th>
<th>PLR</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(1)</td>
<td>(2)</td>
<td>(3)</td>
</tr>
<tr>
<td>10TC Treatment</td>
<td>−0.416***</td>
<td>−0.422***</td>
<td>−0.186***</td>
</tr>
<tr>
<td></td>
<td>(0.079)</td>
<td>(0.077)</td>
<td>(0.077)</td>
</tr>
<tr>
<td>20TC Treatment</td>
<td>−0.042</td>
<td>−0.039</td>
<td>−0.014</td>
</tr>
<tr>
<td></td>
<td>(0.088)</td>
<td>(0.091)</td>
<td>(0.057)</td>
</tr>
<tr>
<td>Risk Aversion</td>
<td>−0.022</td>
<td>−0.014</td>
<td>−0.000</td>
</tr>
<tr>
<td></td>
<td>(0.018)</td>
<td>(0.010)</td>
<td>(0.013)</td>
</tr>
<tr>
<td>Loss Aversion</td>
<td>−0.107*</td>
<td>−0.049</td>
<td>−0.058</td>
</tr>
<tr>
<td></td>
<td>(0.050)</td>
<td>(0.035)</td>
<td>(0.040)</td>
</tr>
<tr>
<td>Trading Experience</td>
<td>0.095</td>
<td>0.022</td>
<td>−0.073</td>
</tr>
</tbody>
</table>

18 These variables are Risk Aversion (measure of how risk-averse a subject is; ranges from 0 to 10 corresponding to the respective subject’s switching point in the elicitation task of Holt and Laury (2002), with larger values indicating higher risk aversion), Loss Aversion (measure of how loss-averse a subject is; ranges from 0.91 to 5 corresponding to the respective subject’s switching point in the elicitation task of Rau (2014), with larger values indicating higher loss aversion), Trading Experience (equals one if the subject had previous experience trading in the stock market and zero otherwise), Female (equals one if the subject is female and zero otherwise), and Age (age of subject in years).
<table>
<thead>
<tr>
<th></th>
<th>(0.093)</th>
<th>(0.055)</th>
<th>(0.060)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Female</td>
<td>0.007</td>
<td>−0.021</td>
<td>−0.028</td>
</tr>
<tr>
<td></td>
<td>(0.071)</td>
<td>(0.047)</td>
<td>(0.051)</td>
</tr>
<tr>
<td>Age</td>
<td>−0.024</td>
<td>−0.012</td>
<td>0.012</td>
</tr>
<tr>
<td></td>
<td>(0.017)</td>
<td>(0.012)</td>
<td>(0.013)</td>
</tr>
<tr>
<td>Constant</td>
<td>0.205***</td>
<td>1.047**</td>
<td>0.447***</td>
</tr>
<tr>
<td></td>
<td>(0.063)</td>
<td>(0.417)</td>
<td>(0.035)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.897***</td>
<td>0.241***</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(0.311)</td>
<td>(0.045)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(0.312)</td>
</tr>
<tr>
<td>No. of subjects</td>
<td>135</td>
<td>135</td>
<td>135</td>
</tr>
<tr>
<td>R²</td>
<td>0.190</td>
<td>0.234</td>
<td>0.108</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.134</td>
<td>0.118</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>0.145</td>
</tr>
</tbody>
</table>

**Result 3** Subjects in 10TC treatment exhibit a significantly lower disposition effect. 20TC treatment does not affect the disposition effect.

**Result 4** 10TC treatment significantly decreases the proportion of gains realized (PGR) and increases the proportion of losses realized (PLR). 20TC treatment does not affect PGR and PLR.

### 4.3 Self-Control by Treatments

The result presented above shows that 10TC treatment significantly reduces the disposition effect, which is driven by a higher PLR and lower PGR. While the 20TC treatment does not have such effect. In the 10TC treatment, subjects perceive significantly more time pressure than in the 20TC treatment. The rate of time-violator in 10TC treatment is 13.33% and 0% in 20TC treatment. To cope with the limited time, subjects in 10TC treatment may rely on straightforwardly available reference point. The pre-specified capital gains and capital losses limit provide subjects the focal reference point, resulting in better self-control. Thus, the self-control may be one of the potential psychological mechanisms that explains why 10TC treatment reduces disposition effect.

Figure 7 provides the distribution of capital gain and capital loss limits. The pre-specified capital loss limits are significantly lower than the capital gain limits (Wilcoxon signed-rank test, $z=6.971$, $p<0.001$). The percentage of capital loss limits that are set below 35 is 84.44%, this percentage for the capital gain limits is only 65.18%. The differences between capital gain and capital loss limits are also significant within each treatment (Wilcoxon signed-rank test, all $p<0.01$). However, the treatment differences in the capital gain limits or in the capital loss limits are not significant (Mann-Whitney test, all $p>0.50$). Subjects are likely to pre-specify higher capital gain.
limit than capital loss limit, but their pre-specified capital gain or capital loss limits do not differ across treatments.

**Figure 7. Distribution of capital gain and capital loss limits.** The distribution of capital gain limits is in the left panel; the distribution of capital loss limits is in the right panel.

Figure 8 depicts the percentage of time-consistent decisions across treatments. Overall, subjects in 10TC treatment exhibit significantly more percentage of time-consistent decisions (Mean=50.46%, SE=2.45%) than that in the NTC treatment (Mean=39.93%, SE=3.47%) (Mann-Whitney test, z=−2.285, p=0.022). The percentage of time-consistent decisions in 20TC treatment is 46.69% (SE=3.02%), which is higher than the NTC treatment and lower than the 10TC treatment, but they do not reach the significant level (Mann-Whitney test, all ps>0.15). 10TC treatment significantly increases the percentage of time-consistent decisions. That is, subjects in 10TC treatment have a better self-control.

**Figure 8. The percentage of time-consistent decisions across treatments.** The percentage of time-consistent decisions is calculated by dividing the sums of time-consistent decisions by the numbers of decisions in the four decision channels. Error bars indicate ±1 SEM.
Specifically, 10TC treatment primarily affects time-consistent decisions through the paper gains and paper losses channels. Table 5 shows the percentage of time-consistent decisions by treatments and decision channels. We find that subjects in 10TC and 20TC treatments have more percentage of time-consistent decisions in paper gains (NTC: 48.41% vs. 20TC: 62.20% vs. 10TC: 54.27%) and paper losses (NTC: 19.53% vs. 20TC: 39.21% vs. 10TC: 49.75%) channels. For the realized gains (NTC: 65.98% vs. 20TC: 40.48% vs. 10TC: 55.71%) and realized losses (NTC: 61.82% vs. 20TC: 47.44% vs. 10TC: 42.61%) channels, however, subjects exhibit less percentage of time-consistent decisions in 10TC and 20TC treatments. Therefore, the self-control is strengthened in 10TC treatment because of an increase in the number of time-consistent decisions through paper gains and paper losses channels.

Table 5. The percentage of time-consistent decisions by treatments and decision channels. Data are shown according to the four decision channels (realized gains, paper gains, realized losses, and paper losses) and whether the decision channel is generated from the no time constraint, 20 seconds time constraint or 10 seconds time constraint treatment. The sums of time-consistent decisions and the numbers of decisions in each decision channel are in parentheses.

<table>
<thead>
<tr>
<th></th>
<th>Treatment</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1: NTC</td>
<td>2: 20TC</td>
<td>3: 10TC</td>
</tr>
<tr>
<td>Realized Gains</td>
<td>65.98% (64/97)</td>
<td>40.48% (34/84)</td>
<td>55.71% (39/70)</td>
</tr>
<tr>
<td>Paper Gains</td>
<td>48.41% (76/157)</td>
<td>62.20% (102/164)</td>
<td>54.27% (127/234)</td>
</tr>
<tr>
<td>Realized Losses</td>
<td>61.82% (34/55)</td>
<td>47.44% (37/78)</td>
<td>42.61% (49/115)</td>
</tr>
<tr>
<td>Paper Losses</td>
<td>19.53%</td>
<td>39.21%</td>
<td>49.75%</td>
</tr>
</tbody>
</table>
Table 6 tests the effect of 10TC treatment on the percentage of time-consistent decisions by reporting results from OLS regressions including controls for individual characteristics. The coefficients of the 10TC treatment in column (1) and column (2) are positive and significant, indicating 10TC treatment increases the percentage of time-consistent decisions by (about) 11 percentage points. The coefficients of the 20TC treatment are also positive, but are not significant.

**Table 6. Regression analysis of the percentage of time-consistent decisions.** The dependent variable is the percentage of time-consistent decisions, which is calculated by dividing the sums of time-consistent decisions by the numbers of decisions in the four decision channels. Ordinary least squares (OLS); robust standard errors (clustered at subject individual level) are in parentheses. Significance levels: *p < 0.10, **p < 0.05, ***p < 0.01.

<table>
<thead>
<tr>
<th>Dependent Variable</th>
<th>Percentage of Time-consistent Decisions</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(1)</td>
</tr>
<tr>
<td></td>
<td>(2)</td>
</tr>
<tr>
<td><strong>10TC Treatment</strong></td>
<td>0.105**</td>
</tr>
<tr>
<td></td>
<td>(0.042)</td>
</tr>
<tr>
<td>20TC Treatment</td>
<td>0.067</td>
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<tr>
<td></td>
<td>(0.046)</td>
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<td>Risk Aversion</td>
<td>−0.001</td>
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<td>(0.008)</td>
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<tr>
<td>Loss Aversion</td>
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<td>(0.041)</td>
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<tr>
<td>Trading Experience</td>
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<td></td>
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</tr>
<tr>
<td>Female</td>
<td>−0.024</td>
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<tr>
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<td>Age</td>
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<td>Constant</td>
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<td><strong>No. of subjects</strong></td>
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</tr>
<tr>
<td><strong>R²</strong></td>
<td>0.045</td>
</tr>
</tbody>
</table>

**Result 5** 10TC treatment significantly increases the percentage of time-consistent decisions, suggesting subjects exhibit a better self-control.

Table 4 and Table 6 shows that 10TC treatment negatively affects the disposition effect, but positively affects the percentage of time-consistent decisions. The schematic
diagram of mediation analysis results for the disposition effect are shown in Figure 9. We find that when the percentage of time-consistent decisions is included in the regressions, the coefficients for 10TC treatment become small, but are still significant.

**Figure 9. Schematic diagram of mediation analysis results for the disposition effect.** Reported path values are unstandardized regression coefficients with standard errors in parentheses. Data in grey color represent results when including covariates (Risk Aversion, Loss Aversion, Trading Experience, Female, and Age) in regressions. Significance levels: *p < 0.10, **p < 0.05, ***p < 0.01.

![Diagram](image)

Therefore, a conspicuous finding involves the presence of a significant indirect path from 10TC treatment through the percentage of time-consistent decisions to the disposition effect. To test the indirect effect, we use model 4 of Hayes’ (2013) PROCESS macro. We include 10TC treatment as the independent variable, disposition effect as the dependent variable, and percentage of time-consistent decisions as mediator. The individual characteristics are included as covariates. We use 5,000 iterations to derive a 95% confidence interval for the indirect effect for the mediator. Results reveal that the indirect effect from 10TC treatment through self-control to disposition effect is significant (indirect effect=−0.039, 95% CI: −0.093 to −0.007). The indirect effects are also significant for the PGR (indirect effect=−0.015, 95% CI: −0.045 to −0.001) and PLR (indirect effect=0.025, 95% CI: 0.003 to 0.064).

**Result 6** The self-control mediates the effect of 10TC treatment on disposition effect.
Taken together, we find that the 10TC treatment significantly reduces the disposition effect, and this treatment effect is mediated by the self-control which is measured with percentage of time-consistent decisions. This result reflects two behavioral aspects. First, and most importantly, subjects in 10TC treatment exhibit a lower PGR and a higher PLR. Second, 10TC treatment increases the percentage of time-consistent decisions. However, the 20TC treatment does not affect the disposition effect, and does not significantly influence the percentage of time-consistent decisions. A closer examination of time constraint manipulation indicates that, the time deadline effect is equally pronounced in 20TC and 10TC treatment, but the perceived time pressure is significantly higher in 10TC treatment than 20TC treatment.

5. Robustness Check

We show that time pressure significantly reduces the disposition effect and one of the underlying mechanisms for this treatment effect is exhibiting a better self-control. Here, we first test whether our results are robust when we rule out the salient reference point. Then, we discuss whether our treatment effect is due to the asymmetrically changing difficulty of decision channel by time constraint level.

5.1 Additional Treatment without Salient Reference Point

We propose that time pressure prompt subjects to make trading decisions based on the straightforwardly salient reference point, i.e. the pre-specified capital gains and capital losses limit. In this way, we find that the effect of time pressure on disposition effect is mediated by the time-consistent decisions. However, a potential concern is

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19 We rule out the last-moment decisions to check the robustness. Specifically, in 20TC treatment the decisions made at 19 and 20 seconds are ruled out; in 10TC treatment the decisions made at 9 and 10 seconds are ruled out. The results show that the disposition effect in 10TC treatment is −0.235, which is significantly lower than 0.205 in NTC treatment (Mann-Whitney test, z=4.924, p<0.001). The percentage of time-consistent decisions in 10TC treatment is 0.505, which is significantly higher than 0.399 in NTC treatment (Mann-Whitney test, z=−2.322, p=0.020). However, no significant difference between the 20TC and NTC treatment are found (Mann-Whitney test, all ps>0.15). These analyses indicate that our results are robust.
whether the treatment effect is exclusively driven by the salience of the reference point. In other words, whether time pressure affects the disposition effect in general or at some conditions.

To rule out such a concern, we run an additional treatment without salient reference point. Twenty-eight students (18 female) participate in the no salient reference point (NSRP) treatment. In this treatment, the experiment design and procedure are same with the 10TC treatment, except subjects do not need to pre-specify their ideal capital gains and capital losses limit at the beginning of the experiment.

The average disposition effect in the NSRP treatment is −0.218 (SE=0.068), which is not significantly different from −0.211 in the 10TC treatment (Mann-Whitney test, z=−0.062, p=0.950); but it is significantly lower than 0.205 in the NTC treatment (Mann-Whitney test, z=4.415, p<0.001). For the PGR and PLR, the differences between NSRP and 10TC treatment are also insignificant (PGR: 0.263±0.035 vs. 0.261±0.027; PLR: 0.481±0.056 vs. 0.472±0.042; Mann-Whitney test, all ps>0.50); while significant difference are found between NSRP and NTC treatment (PGR: 0.263±0.035 vs. 0.447±0.035; PLR: 0.481±0.056 vs. 0.241±0.045; Mann-Whitney test, all ps<0.01). These results indicate that the effect of time pressure on disposition effect is robust when we rule out the salient reference point.

In fact, the Figure 9 shows that when the percentage of time-consistent decisions is included in the regression analysis the coefficients for 10TC treatment become small, suggesting self-control is just one of the mediators. Other psychological mechanisms, such as realization utility and cognitive dissonance, may also mediate the relationship between the 10TC treatment and disposition effect.

Previous studies investigating economic decision making under time pressure found that information processing is altered so that less information is searched and integrated (Rieskamp and Hoffrage, 2008; Ibanez, Czermak and Sutter, 2009). Making the stock information (such as purchase price or trading performance) and initial purchase decision less salient significantly decreases the disposition effect (Frydman

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20 Four subjects (14.20%) in this treatment violate the time constraint at least once.
and Rangel, 2014; Goulart et al., 2015; Summers and Duxbury, 2012; Chang, Solomon and Westereld, 2016). Barberis and Xiong (2012) proposed that investors derive utility from realizing capital gains or losses and present a model of “realization utility”. Frydman et al. (2014) provided neural data to test the realization utility model for investors’ behavior. They found strong evidence of investors realize capital gains to experience a positive burst of utility, but do not find a negative burst of realizing capital losses. Apart from the side of biases in realizing capital gains, Chang, Solomon and Westereld (2016) showed that investors avoid realizing capital losses because they dislike admitting that past purchases are mistakes; they demonstrated the role of cognitive dissonance in generating the disposition effect, particularly in the side of realizing capital losses. Thus, time pressure may also reduce the disposition effect by decreasing the perception of realization utility and cognitive dissonance.

5.2 Difficulty of Decision Channel

Another potential concern is that time constraint level may asymmetrically affect change the difficulty of decision channel and the cognition process of behavior, which leads to the different treatment effect.

Zhu et al. (2018) found that, compared with the longer time constraint, imposing the shorter time constraint leads subjects to the inference that a decision is more difficult. Lohse, Simona and Konrad (2018) showed that time constraint impacts the cognition process of deception as the level of awareness of the deception opportunity is significantly decreased under time constraint. The decision time is mainly driven by decision difficulty (Evans, Dillon and Rand, 2015). Thus, time pressure in 10TC treatment may reduce the disposition effect by affecting the difficulty of decision channel or cognition process of realizing capital losses. While 20TC treatment cannot decrease the disposition effect since the decision difficulty could not be weakened.

I show that this is not the case. In all treatments the decision of selling a stock, irrespective of winner stocks or loser stocks, is made in a longer time than the decision of not selling a stock (Wilcoxon signed-rank test, all ps<0.10), and the longest decision time occurs when subjects choose to sell a loser stock whereby holding a winner stock
has the shortest decision time. This result suggests that the time constraint does not change the difficulty of decision channel.

6. Conclusion

Financial decisions often involve serious time constraint. In this paper, we use a laboratory experiment to investigate how time constraint affects the disposition effect, by exogenously imposing a deadline on the stock trading decisions. Specifically, we distinguish time pressure from time constraint by comparing the selling decisions of subjects in the no time constraint (NTC), 20 seconds time constraint (20TC), and 10 seconds time constraint (10TC) treatments.

Our data show that the difference in frequency of last-moment decisions between the 20TC and 10TC treatment is not significant. However, significantly more time pressure is perceived by subjects in 10TC treatment than in 20TC treatment. 13.33% subjects violate the time limit in 10TC treatment, while the rate of time-violator is 0% in 20TC treatment. These results indicate that the 20TC treatment is a loose deadline and is not very binding, while the 10TC treatment is a tight deadline and induce feelings of time pressure.

Ensuring the successful manipulation of time pressure, we find that the 10TC treatment, in which subjects perceive more time pressure, significantly reduces the disposition effect. This treatment effect is robust when we rule out the salient reference point, by not letting subjects pre-specify their ideal capital gains and capital losses limit. Specifically, subjects in 10TC treatment exhibit a lower PGR and a higher PLR. Moreover, 10TC treatment significantly increases the time-consistent decisions. Further mediation analysis reveals that the self-control one of the psychological mechanisms that explains why time pressure reduces the disposition effect. However, the 20TC treatment, where the feelings of time pressure do not differ from the NTC treatment, does not affect the disposition effect, PGR and PLR. 20TC treatment increases the subjects’ time-consistent decisions, but it does not reach significance level. Therefore, it seems to be a threshold for the effect of time constraint on disposition effect, that
triggers certain time-consistent decisions.

To the best of our knowledge, we are the first to examine how time constraint affects the disposition effect. We find that the disposition effect is reduced under time pressure, but this effect disappears under mild time constraint. Therefore, the effect of time constraint on the disposition effect may depend on some conditions, such as time pressure in which subjects perceive feelings of stress. In addition, an open question is whether the severity of the time pressure affects the magnitude of disposition effect. However, Karagözoglu and Kocher (2019) found that bargaining behavior under high time pressure is very similar to that under the severely high time pressure. Future study can test the effect of severity of the time pressure on financial decision making.

At last, our results contradict the general idea that the deliberate process would be disrupted by time pressure (Porcelli and Delgado, 2009), which would lead to an increase of the disposition effect under time pressure. However, we find the opposite: subjects exhibit a significantly lower disposition effect under time pressure, indicating the time pressure is not necessarily disrupting the deliberate process (Evans, Dillon and Rand, 2015; Lindner and Rose, 2017).

References


Spiliopoulos, L., & Ortmann, A. (2018). The BCD of response time analysis in


Experiment Instructions for the 10TC treatment

Dear Participant, welcome to our experiment. Please pay attention to the information provided here and make your decisions carefully. If at any time you have questions, please raise your hand and we will attend to you in private.

Please note that unauthorized communication is prohibited. You have the right to withdraw from the study at any point in time, and if you decide to do so your payments earned will be forfeited.

In this experiment you will be given one unit of stock A, one unit of stock B, one unit of stock C, and 50 experimental currencies. The initial price of each stock is 100 experimental currencies per unit.

There are 30 periods in the experiment. Each period one of the three stocks will be chosen randomly and updated its price by the computer. Period 1 to 6, you will only see the information of stock price updating and cannot trade any stock. Since period 7, you have opportunity to buy or sell the stock that is chosen and updated its price.

During the experiment, you will see two types of screens, a price update screen and an action screen. In the price update screen, one stock will be randomly selected and you will be told if the selected stock price has gone up or down, and by how much. Note that you will only see an update for one stock at a time. You will not be asked to do anything during this screen: you will simply see information about the change if price.

Following the price update screen, in the action screen you will be asked whether to take an action. If you currently hold a unit of the stock, you will be asked if you would like to sell the stock at the current price. If you do not currently own a unit of the stock, you will be asked if you would like to buy a unit at the current price.

The experiment will start out with six consecutive price update screens from period 1 to period 6; you will then could buy or sell after each subsequent price update screen from period 7.

Each stock changes price according to the exact same rule. Each stock is either in a good state or in a bad state. In the good state, the stock goes up with 70% chance, and it goes down with 30% chance. In the bad state, the stock goes up with 30% chance, and it goes down with 70% chance. Once it is determined whether the price will go up or down, the size of the change is always random, will either be 5, 10, or 15 experimental currencies. The stock will all randomly start in either the good state or bad state, and after each price update, there is a 20% chance the stock witches state.

For example, if this period stock A is good state, its price will go up with 70% chance, and the amount it goes up by is 5, 10, or 15 with equal chance. At the same time
its price will go down with 30% chance, and the amount it goes down by is 5, 10, or 15 with equal chance. In the next period, if stock A is chosen, it is still good state with 80% chance, and it switches to bad state with 20% chance.

**Stock price changes**

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<thead>
<tr>
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<th>Good state</th>
<th>Bad state</th>
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<td>+</td>
<td>70%</td>
<td>30%</td>
</tr>
<tr>
<td>−</td>
<td>30%</td>
<td>70%</td>
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</table>

**State changes**

<table>
<thead>
<tr>
<th></th>
<th>Good state next period</th>
<th>Bad state next period</th>
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</thead>
<tbody>
<tr>
<td>Good state this period</td>
<td>80%</td>
<td>20%</td>
</tr>
<tr>
<td>Bad state this period</td>
<td>20%</td>
<td>80%</td>
</tr>
</tbody>
</table>

Each period only one of the three stocks will be randomly chosen and updated its price, the price of the other two stocks in this period does not change. You can see the chosen stock, its current price, amount of price change, and your available cash; while the state of the stock is not displayed.

**Please note:**

1. **At the beginning of the entire experiment, you first need to answer two questions:** “How much capital gains of a held stock brings to you, you will sell it” and “How much capital losses of a held stock brings to you, you will sell it”. Nonbinding limits of capital gains and capital losses are possible and you could not adjust limits during the entire experiment.

2. Each period you have no time constraint in the price update screen, but in the action screen you have 10 seconds to make a response by pressing the BUY (SELL) or NOT BUY (NOT SELL) button, otherwise the computer will randomly select a response for you.

3. **You are only allowed to hold a maximum one unit of each stock, and you cannot hold negative units (no short selling). However, you can carry a negative cash balance by buying a stock for more money than you have, but any negative cash balances will be deducted from your final earnings.**

   Your earnings at the end of the experiment will be equal to the amount of cash you accrued over the all periods from buying and selling stocks, plus the current price of any stocks that you own. **Earnings=cash + price A*(hold A) + price B*(hold B) + price C*(hold C).**

   Finally, your earnings will be converted using an exchange of 20:1. That means
we divide your earnings by 20, and pay you this amount plus the 5 yuan show up fee.

**Computer Screens and Examples**

At the beginning of the experiment, you need to answer the questions: “During the experiment, how much capital gains of a held stock brings to you, you will sell it” and “During the experiment, how much capital losses of a held stock brings to you, you will sell it”, see Figure (a). Nonbinding limits of capital gains and capital losses are possible and you could not adjust limits during the entire experiment.

![Figure (a)](image)

Then, for period 1 to 6 you observe a price update screen like Figure (b) in which a stock price is updated and are not allowed to trade the stock; he or she can observe the label of chosen stock (stock A, or stock B, or stock C), the updated price and purchase price of the stock, and their available cash. The price update screen has no time constraint.

For example, if stock C is chosen in period 1, see Figure (b). Stock C has increased 15 experimental currencies; its current price is 115 experimental currencies; your purchase price is 100 experimental currencies; your available cash is experimental currencies 50. From period 1 to 6, you will only see a price update screen.
Figure (b) Price update screen without time constraint

From period 7 to 30, after the price update screen similar with Figure (b), you can observe a screen like Figure (c) or (d) in which you need to make a trading decision. If you hold the chosen stock in a period, a screen like Figure (c) is displayed; you decide whether to sell it. If you do not hold the chosen stock, a screen like Figure (d) is displayed; you decide whether to buy it. Each period in the action screen you have 10 seconds to make a response by pressing the BUY (SELL) or NOT BUY (NOT SELL) button, otherwise the computer will randomly select a response for a subject.

For example, Figure (c) shows the action screen when you hold the updated stock (stock A) in period 8. You need to decide whether to sell the stock through entering the button of “SELL” or “NOT SELL” in 10 seconds.
Figure (c) Action screen with time constraint

For example, Figure (d) shows the action screen when you do not hold the updated stock (stock A) in period 13. You need to decide whether to buy the stock through entering the button of “BUY” or “NOT BUY” in 10 seconds.

Figure (d) Action screen with time constraint