

Hardardottir, Hjördis

**Working Paper**

## Many Balls in the Air Make Time Fly: The Effect of Multitasking on Time Perception and Time Preferences

Working Paper, No. 2019:11

**Provided in Cooperation with:**

Department of Economics, School of Economics and Management, Lund University

*Suggested Citation:* Hardardottir, Hjördis (2019) : Many Balls in the Air Make Time Fly: The Effect of Multitasking on Time Perception and Time Preferences, Working Paper, No. 2019:11, Lund University, School of Economics and Management, Department of Economics, Lund

This Version is available at:

<https://hdl.handle.net/10419/260281>

**Standard-Nutzungsbedingungen:**

Die Dokumente auf EconStor dürfen zu eigenen wissenschaftlichen Zwecken und zum Privatgebrauch gespeichert und kopiert werden.

Sie dürfen die Dokumente nicht für öffentliche oder kommerzielle Zwecke vervielfältigen, öffentlich ausstellen, öffentlich zugänglich machen, vertreiben oder anderweitig nutzen.

Sofern die Verfasser die Dokumente unter Open-Content-Lizenzen (insbesondere CC-Lizenzen) zur Verfügung gestellt haben sollten, gelten abweichend von diesen Nutzungsbedingungen die in der dort genannten Lizenz gewährten Nutzungsrechte.

**Terms of use:**

*Documents in EconStor may be saved and copied for your personal and scholarly purposes.*

*You are not to copy documents for public or commercial purposes, to exhibit the documents publicly, to make them publicly available on the internet, or to distribute or otherwise use the documents in public.*

*If the documents have been made available under an Open Content Licence (especially Creative Commons Licences), you may exercise further usage rights as specified in the indicated licence.*

Working Paper 2019:11

Department of Economics  
School of Economics and Management

# Many Balls in the Air Make Time Fly: The Effect of Multitasking on Time Perception and Time Preferences

Hjördis Hardardottir

August 2019

Revised: September 2019



**LUND**  
UNIVERSITY

# Many balls in the air make time fly: The effect of multitasking on time perception and time preferences\*

Hjördis Hardardottir<sup>†</sup>

## Abstract

In this paper, we study how increasing the cognitive demands of multitasking affects time preferences. The novelty of this paper is that it studies how time perception mediates the effect of multitasking on time preferences. Results from experimental psychology have demonstrated that people tend to experience the passage of time as quicker when they are busy with cognitively-demanding tasks. If time is experienced as passing faster, the future should be experienced as being closer, and patience should increase. However, a standard prediction from behavioral economics is that being cognitively loaded leads to less patient decisions. Our hypothesis is that increases in patience, driven by the speeding up of time, and decreases in patience, driven by decreased cognitive capacity, added together explain the total effect of increasing the cognitive demands of multitasking on time preferences. We also shed light on whether the observed relationship between time preferences and time perception within subjects is mirrored when comparing between subjects.

*Keywords:* Time preferences; Multitasking; Cognitive load;  
Time perception; Foundations of preferences

*JEL Codes:* C91; D91.

---

\*I am grateful for the financial support from Torsten Söderbergs stiftelse, Riksbankens jubileumsfond and Stiftelsen for framjandet av ekonomisk forskning vid Lunds Universitet. I would like to thank Erik Wengström for his invaluable guidance. I would also like to thank Isabelle Brocas, Juan Carillo, Matteo M. Galizzi, Sean Hofland, Helga Fehr-Duda, John Smith and Agnieszka Tymula as well as the participants at the RPW seminar at the University of Zurich, the Arne Ryde CNEE workshop in Lund, the ESA world conference in Berlin and the 13th Nordic conference on behavioral and experimental economics for their useful comments. Finally, I would like to thank the lab-staff at the University of Zurich and the University of Copenhagen for helping setting up this experiment, and special thanks goes to Marco Islam for helping with the experiment in Lund.

<sup>†</sup>Department of Economics, Lund University, P.O. Box 7082, S-220 07 Lund, Sweden. E-mail: hjordis.hardardottir@nek.lu.se.

# 1 Introduction

Economic decisions are not made in a vacuum. They are dependent on the situation of the agent making the decision. An increasingly common view within economics is that circumstances affect decisions not only through altering incentives or beliefs but also by affecting preferences. A number of papers have studied the long-term effects of life events on preferences.<sup>1</sup> However, the circumstances of an agent can also affect preferences in the short term. Tired or alert, stressed or relaxed, frightened or calm—our state determines our preferences. Otherwise, how could we explain the fact that people take more risks when they are sleep-deprived if sleep deprivation does not affect beliefs or incentives?<sup>2</sup> One aspect of a decision-making agent’s environment concerns whether or not the circumstances allow for undivided focus on the decision task. It is becoming increasingly common that people find themselves in situations where they are disturbed by competing tasks demanding their attention. In the digital world of today, people are constantly accessible, which leads to situations such as e-mails arriving at any time. How multitasking (or task-switching)<sup>3</sup> affects our decision-making is a relevant issue in a world in which juggling many tasks has become the norm. In this paper, we use experimental methods to study how increasing the difficulty of competing tasks affects time preferences, holding the frequency of task-switching constant.

In particular, we look at the role of time perception when intertemporal decisions are made while multitasking. Time perception is the subjective experience of the passage of time and has been shown to vary greatly, both between individuals and within individuals, over time and across contexts. To give an example, it is well known that children perceive time differently than adults (Droit-Volet, 2013). Also, most people have had the experience of time “flying by” when they are busy while it sometimes feels as if 5 minutes is an eternity when waiting for the bus. The way we perceive time has been studied within psychology, and experimental results show that time perception is indeed highly context-dependent (see Grondin (2010) for a review of the literature on time perception).

If we assume that we anchor our intertemporal decisions to our own subjective perception of time rather than to clock time, as is generally assumed

---

<sup>1</sup>See e.g. Malmendier & Nagel (2011), Nishiyama (2006) and Callen et al. (2014).

<sup>2</sup>According to Killgore (2015) and Castillo et al. (2017), sleep-deprived individuals are more prone to take risks than individuals that have slept enough.

<sup>3</sup>Hereafter, we will use the term multitasking synonymously with task-switching. However, we will not discuss the effect of simultaneously performing more than one task on decision-making (e.g. driving and talking on the telephone).

in the economics literature, differences in time preferences both between individuals and within individuals across contexts would depend on the subjective perception of time. For example, imagine two individuals, A and B, who, when assessing future payoffs, rely on their own subjective perceptions of time. If individual A overestimates clock time while individual B underestimates clock time (e.g. a week feels like a month for individual A but only feels like a few days for individual B), individual A would discount a future prospect at a given date more than individual B would.

On the other hand, multitasking is cognitively constraining. Being cognitively constrained leads to less patience and more present bias according to a number of theories within behavioral economics. Dual-system- and dual-process theories, as well as multiple-selves theories, all predict that patience decreases when subjects are under cognitive load (Kahneman, 2003; Fudenberg & Levine, 2006).

The goal of this paper is to use experimental methods to understand how multitasking demands affect time preferences. In particular, we want to quantify the role of time perception and the role of decreased cognitive capacity when the cognitive demands of multitasking increase. Using a within-subject design, we study how time preferences, time perception, and cognitive capacity are affected when the cognitive demands of multitasking increase. We then study the relationship between the treatment effect on time preferences and the treatment effect on time perception and cognitive capacity. Our findings confirm that time perception plays an important role when the effect of multitasking demands on time preferences is studied. However, we do not find evidence for the channel of cognitive capacity, despite a zero total treatment effect on time preferences. More generally, the results of the paper illustrate the importance of time perception in explaining the context-dependence of time preferences.

## 2 Theoretical motivation

To study the effect of multitasking on decision-making, either the effect of introducing multitasking or the effect of increasing the cognitive demands of multitasking can be studied, keeping the intensity of task-switching constant. In this paper, we focus on the latter. We keep the frequency of task-switching constant but vary the difficulty of the competing tasks. Hence, our approach is also related to the literature on decision-making under cognitive load where cognitive load is induced by increasing task difficulty.<sup>4</sup>

---

<sup>4</sup>A common task in the experimental literature on cognitive load is a memory task in which subjects are asked to remember a short or long number, depending on the cognitive

Multitasking has been shown to increase response times and decrease performance (Jersild, 1927; Rubinstein et al., 2001; Liefoghe et al., 2008). Furthermore, the cost of multitasking has been shown to depend on the difficulty of the primary and secondary tasks<sup>5</sup>, such that switch costs increase with task difficulty, leading to both longer response times and higher error rates (Jersild, 1927; Rubinstein et al., 2001; Borst et al., 2010).<sup>6</sup> It is natural to assume that switching time increases when difficulty increases, since the mere action of leaving one cognitive process and engaging in another is more demanding if the processes are more complex. However, the observed increase in the error-rate when multitasking demands increase is not as straightforward to explain. One possible explanation is that, assuming people have limited cognitive capacity at any point in time, either the fact that the secondary task is difficult or the fact that the task switching itself is demanding when the secondary task is difficult leads to cognitive depletion that reduces the cognitive capacity available for solving the primary task. This, in turn, leads to poorer performance.

The above reasoning is in line with the literature on cognitive load, which predicts that being under cognitive load results in lower performance and worse decision-making due to the fact that decisions are made with constrained cognitive capacity, as captured by the dual-system theory, dual-process model, and multiple-selves model of decision-making. When making an intertemporal decision, most would agree that choosing a late reward requires more cognitive power than choosing an immediate reward. Hence, patience should decrease when multitasking and/or cognitive load is introduced or increased. Despite this prediction, results from previous experimental studies on the relationship between cognitive constraints and time preferences have been mixed (see Deck & Jahedi (2015) for a survey).

The novelty of this paper is that, in addition to looking at the effect of a decrease in cognitive capacity on time preferences when multitasking demands increase, we take into account changes in time perception due to

---

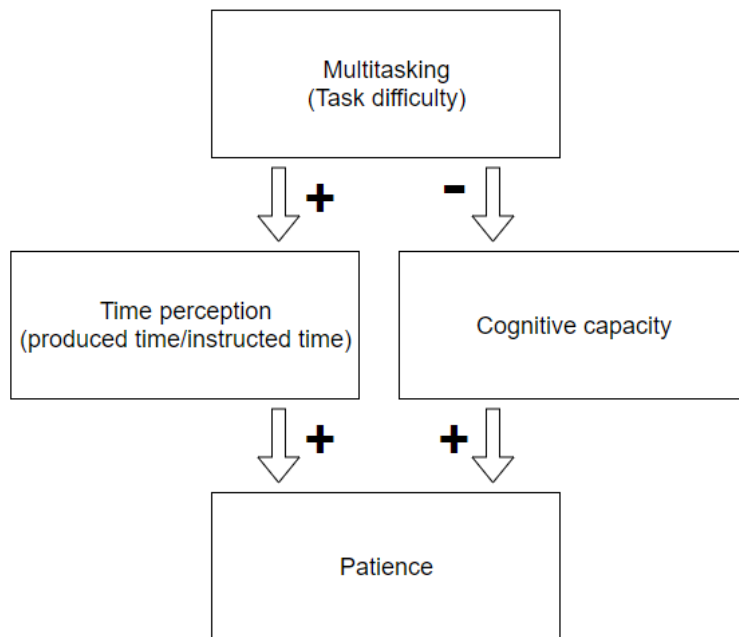
load. Other studies have induced cognitive load by competing tasks that appear from time to time, similar to this study. Cognitive load is then induced by varying the task difficulty.

<sup>5</sup>The primary task is the main task being attended to. The secondary task is the disturbance task.

<sup>6</sup>Here, the similarity and familiarity of the primary and secondary tasks also affect the cost of multitasking. It is harder to switch from a familiar task to an unfamiliar task than vice versa, and it is easier to switch between similar tasks than dissimilar ones. In particular, alternating between similar tasks of varying difficulty has been shown to be more difficult when one switches from the easy task to the difficult task than vice versa. A possible explanation for this is that it is harder to “overwrite” the more intuitive processes used to solve the easy task (Allport et al., 1994; Meuter & Allport, 1999; Monsell et al., 2000; Yeung & Monsell, 2003a,b).

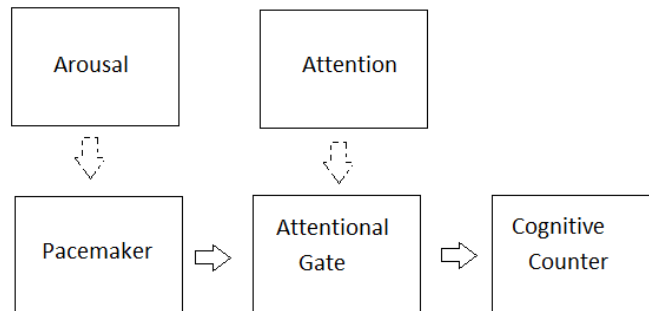
increased multitasking demands. Building on previous results from experimental psychology, our hypothesis is that when multitasking demands increase, the ratio of subjective time to clock time decreases (i.e. the perceived length of a given time interval decreases). Assuming that individuals anchor their intertemporal decisions to their subjective perception of time, a decrease in the ratio of subjective time to clock time leads to more patience over clock time. Since cognitive deficits due to multitasking have been predicted to result in less patience, we anticipated that the two effects shift preferences in opposite directions, possibly canceling each other.

In this study, we aim to separate the effect of increasing multitasking demands on time preferences into these two channels. In order to do this, we estimate the following using a within-subject setup: (i) The effect of increasing multitasking demands on time perception, (ii) the effect of increasing multitasking demands on cognitive capacity, and (iii) the effect of increasing multitasking demands on time preferences. Our hypothesis is that (i) and (ii) are separable and additive, explaining (iii). Figure 1 illustrates the two channels.



**Figure 1:** A flow graph illustrating the effect of multitasking on time preferences.

The attentional-gate model offers a theoretical motivation for our hypothesis that increasing the cognitive demands of multitasking speeds up subjective time. It is a well-known model of time perception within psychology and was presented by Zakay & Block (1997). According to the model, humans have an internal pacemaker that sends pulses to a cognitive counter that perceives time. Between the pacemaker and the cognitive counter is an attentional gate that opens and allows for a flow of pulses from the pacemaker to the cognitive counter when a person attends to time. The more a person attends to time, the more pulses pass through the attentional gate and the longer the perceived length of a given time interval. Being busy with a cognitively-demanding task means that attention must be directed away from the passage of time and to the task, which closes the attentional gate more often than otherwise, causing fewer pulses to pass through the attentional gate to the cognitive counter. The result is a decrease in the ratio of subjective time to clock time, i.e. a given time interval is perceived as shorter due to fewer pulses passing through. Experimental studies have confirmed this (see e.g. Polti et al., 2018). Figure 2 illustrates the main idea with the attentional gate model.



**Figure 2:** A schematic illustration of the attentional-gate model. The flow of the model is illustrated with solid arrows. External factors that affect the model are illustrated with dashed arrows.

In addition, the speed of the pacemaker is determined by arousal. The more aroused a subject is, the faster the pacemaker. Accordingly, a person who is highly aroused and completely focused on the passage of time receives the largest number of pulses to the cognitive counter and hence perceives time as passing very slowly (i.e. a given time interval is experienced as being long). This effect has also been confirmed experimentally, see e.g. Zakay et al. (1983) and Gil et al. (2007).



If time perception is related to time preferences, the most relevant measure of time perception should be the subjective perception of the same future time intervals as the measured time preferences regard (e.g. the perceived length of a time interval that starts today and ends in 6 weeks). However, it is difficult, if not impossible, to measure the subjective perception of future time intervals in a convincing manner.<sup>7</sup> Instead, we measure prospective time perception. Prospective time perception is the perception of an ongoing time interval, which, in our case, is in the range between 7 seconds and 45 seconds. Empirical evidence exists that prospective time perception over such short intervals is related to time preferences. Brocas et al. (2018) found that subjects that have a slower subjective perception of time discount the future to a larger extent than subjects that experience time as passing quicker. Additionally, Park & Capra (2017) discovered that when time perception is manipulated by external tempo, time preferences are also affected, the effect being in the same direction as in Brocas et al. (2018). This suggests that prospective time perception correlates with anticipatory time perception, which in turn affects time preferences over clock time. A more narrative motivation of this is that it is a known human behavior to extrapolate the current state of matters into the future. Projection bias has been shown to shape economic decisions when it comes to tastes and preferences (Loewenstein et al., 2003; Conlin et al., 2007; Busse et al., 2015), why should the perception of time be different?

### 3 Related literature

This paper links to the literature on multitasking and preferences and, more generally, to the literature on cognitive load and preferences. It also relates to the literature on time perception as well as to the small but growing literature linking time perception to time preferences.

Regarding the experimental literature on cognitive load or multitasking and time preferences, experimental studies have shown mixed support for the predictions that subjects should become more impatient, more risk averse, and generally worse decision-makers when cognitively constrained. Hinson et al. (2003) found that subjects became more impatient under cognitive

---

<sup>7</sup>There are studies that have attempted to measure anticipatory time perception using a slider task in which subjects are asked to represent the length of a future time interval with a slide (Zauberman et al., 2009; Bradford et al., 2014). However, the goal of these studies was to relate the logarithmic perception of time to hyperbolic discounting, meaning that the differences in slides within subjects were the unit of measurement. While this might be reasonable, studying individual differences in baseline anticipatory time perception does not make sense due to the lack of a “common unit”.

load, but Franco-Watkins et al. (2006) argued that the results in Hinson et al. (2003) were consistent with increased noise, not increased impatience. The same authors replicated this result in Franco-Watkins et al. (2010). Furthermore, Shiv & Fedorikhin (1999) found that subjects acted more impulsively under cognitive load. In the risk aversion domain, Benjamin et al. (2013) discovered that subjects became more risk averse when cognitively constrained but failed to detect any effect of cognitive load on patience. However, Castillo et al. (2017) found that tired (and hence cognitively constrained) subjects were less risk averse. Lastly, Buser & Peter (2012) looked at cognitive performance when multitasking and found that performance in Sudoku and word-search tasks decreased when subjects were multitasking.

The existing literature on time perception under cognitive load has studied the effect of the method used to elicit time perception on the obtained results, analyzed differences in the link to time perception of different types of cognitive load, and compared the effect of cognitive load on prospective time perception to the same effect on retrospective time perception.<sup>8</sup> To summarize the literature, prospective time perception was found to decrease (i.e. the length of a given time interval is experienced as shorter) when under cognitive load (Block et al., 2010; Tse et al., 2004). Interestingly, the opposite held true for retrospective time perception (Zakay & Block, 2004; Macar et al., 1994; Predebon, 1996), which has to do with the fact that while prospective time perception makes use of the working memory and hence competes with the registration of time,<sup>9</sup> retrospective time perception makes use of the memory. A time interval with cognitive load is then seen as longer since more memories were created during the interval compared to an empty time interval in the past. The type of cognitive load also matters. Block et al. (2010) performed a meta-study of the existing studies on the topic and compared how cognitive load induced by response demands, attentional demands, processing difficulty, familiarity, memory demands, and processing changes affects time perception. Their results showed that three out of six methods studied have a significant effect on prospective time perception (attentional demands, processing difficulty, and response demands).

Regarding the branch of the literature that combines time preferences and time perception, the largest focus has been on explaining hyperbolic discounting with a non-linear perception of time. The perception of time, like a range of other perception types, has been shown to be non-linear with respect to clock time. This has been captured in both the Weber-Fechner law, which states a logarithmic relationship between objective stimuli (such

---

<sup>8</sup>Retrospective time perception is the perception of a time interval in the past.

<sup>9</sup>See discussion on the attentional-gate model above.

as time) and the subjective perception of it, as well as in Stevens' power law, which states a power relationship between stimuli and perception (Stevens, 1957). Taking into account this non-linearity when measuring time preferences could explain why time preferences are hyperbolic. Ray & Bossaerts (2011), Wittmann & Paulus (2008), and Takahashi (2005) proposed a theoretical framework in which non-linear time perception is considered when time preferences are formed. Experimental studies focusing on the non-linearity of perceived time relative to clock time and hyperbolic discounting have used a slider-task based measure of anticipatory time perception and related it to time preferences. However, our paper is more related to Brocas et al. (2018) and Park & Capra (2017), as discussed above. In both papers, prospective time perception was related to time preferences, across subjects in the former paper and within subjects using external tempo to manipulate time perception in the latter paper. Although we study the link between time perception and time preferences in a within-subject setup like Park and Capra (2017), the focus of our paper is to examine the effects of increasing the cognitive demands of multitasking on time preferences by analyzing how the total effect is mediated by changes in cognitive capacity and time perception. We will now state the hypotheses of the paper.

## 4 Hypotheses

Based on previous results from experimental psychology and theoretical predictions of the attentional-gate model our first hypothesis is:

**Hypothesis 1:** *The ratio of subjective time over clock time decreases when multitasking demands increase (i.e. a given time interval is perceived as shorter).*

Our second hypothesis connects Hypothesis 1 to time preferences.

**Hypothesis 2:** *Time perception mediates the effect of multitasking demands on time preferences*

We argue that cognitive capacity is limited and hence that cognitive performance deteriorates when subjects are cognitively constrained. Consequently, our third hypothesis is:

**Hypothesis 3:** *Cognitive capacity measured with performance on a cognitive reflection task deteriorates when multitasking demands increase.*

Assuming that the cognitive processes underlying Hypothesis 3 are the same as the cognitive processes leading to a decrease in patience when under cognitive load, our fourth hypothesis links the effect of multitasking demands on cognitive capacity to time preferences.

**Hypothesis 4:** *Cognitive capacity mediates the effect of multitasking demands on time preferences.*

Finally, we combine Hypothesis 2 and Hypothesis 4, assuming that the effects of increasing multitasking demands on time preferences are mediated by time perception and cognitive capacity only.

**Hypothesis 5:** *The effect of an increase in multitasking demands on time preferences is the sum of the effect of an increase in multitasking demands on prospective time perception and the effect of an increase in multitasking demands on cognitive capacity.*

## 5 The Experiment

The experiment was conducted in Lund University, Sweden, in the spring of 2018 and in the Behavioral lab of the University of Copenhagen in the fall of 2018<sup>10</sup>. In total, 151 subjects participated in the multitasking experiment (100 in Lund and 51 in Copenhagen). In the experiment, cognitive capacity, time perception, and time preferences were elicited twice under two different levels of multitasking demands.

The multitasking consisted of answering Stroop tasks (Stroop, 1935) that were either easy or difficult. The tasks popped up with a random delay in between them during the time preference elicitation and the cognitive reflection tasks.<sup>11</sup> In the time perception elicitation, there was no delay between the Stroop tasks, but the place at which the tasks appeared on the screen was random in order to make it harder for the subjects to count time.

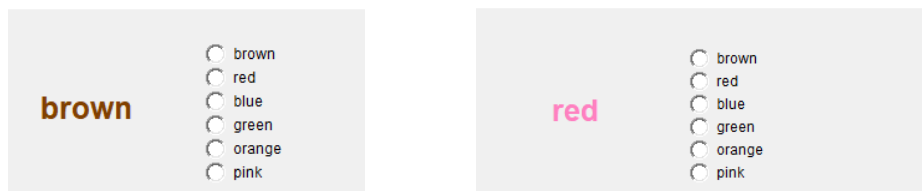
In the Stroop tasks, the subjects saw the name of a color written with colored letters. In the easy condition, the name of the color and the color of the letters were the same, while this was not the case in the difficult condition. The subjects' task was to choose the color of the letters from a list of six colors. It has been well-established that correctly answering a difficult Stroop task requires more cognitive power than correctly answering

---

<sup>10</sup>A pilot was conducted in the behavioral laboratory at the University of Zürich in the spring of 2018.

<sup>11</sup>The Stroop tasks popped up with a Poisson-distributed delay with a mean of 7 (seconds).

an easy Stroop task (Stroop, 1935; MacLeod, 1991). All Stroop tasks in the experiment were incentivized in such a way that answering quickly and correctly maximized the subjects’ earnings.<sup>12</sup> Before each task, the subjects were reminded of this. Figure 3 shows examples of a congruent Stroop task (easy) and a dissimilar Stroop task (difficult).



(a) A congruent Stroop task (easy). (b) A dissimilar Stroop task (difficult).

**Figure 3:** Stroop tasks used to induce multitasking.

The experiment was pre-registered in the AEA RCT registry. We will now describe each of the tasks of the experiment.

## 5.1 Time perception

Prospective time perception was measured using the method of production. Subjects were instructed to press a start button and then, after an interval of 7, 11, 15, 23, 34, or 45 seconds, press a stop button. All subjects produced all six time intervals, during which Stroop tasks were solved. They were incentivized to come as close to the instructed time as they could in their production. Payment depended on the subjects’ ranking amongst the participants in the session in terms of producing the time intervals accurately.

## 5.2 Time preferences

Time preferences were measured using multiple price lists. Each list consisted of 10 choices between an earlier option and a later option. The later option was paid out in one, two, three, six, or nine weeks. In the sessions in Lund, the earlier option was “today”, but in the sessions in Copenhagen, the earlier option was “tomorrow”.<sup>13</sup> In addition, there were alternative multiple price lists with a later payment in one week and a later payment in six weeks in which the upward jump between the 10 choices was smaller than in the

<sup>12</sup>The subjects were paid depending on the share of correct answers and their ranking in the session in terms of the average answering speed to the Stroop tasks.

<sup>13</sup>The reasons for this were a limited subject pool in Lund and constraints on payment methods in Copenhagen.

other lists. The purpose of the alternative multiple price lists was to study the possibility that higher multitasking demands lead to more noise. Considering the structure of multiple price lists, it has been suggested that an increase in noise leads to more earlier choices due to randomness, given that the true shifting point from the earlier payment option to the later payment option is above the middle of the list (Andersson et al., 2016).

We chose not to elicit the curvature of the utility function using double multiple price lists or convex time budgets. Instead, we assumed that the curvature of the utility function is not affected by multitasking demands. Although, theoretically, it might have been optimal to have a full parameter profile, weighing in that the experiment was already mentally demanding, we chose not to estimate the curvature parameter and focused only on the time preference parameters.

In Lund, the “today” payment was (together with other earnings during the experiment, except the show-up fee) paid with SWISH, a mobile payment technology that allows for a direct bank transfer using mobile phones.<sup>14</sup> The subjects received a confirmation that the transaction had gone through directly to their mobile phones. The later payments were transferred to the subjects’ private bank accounts on the given date. In Copenhagen, all payments took place in the lab. After the experiment, the subjects received payment for all parts of the experiment, except for the time preference elicitation part. To receive the randomly-drawn payment for the time preference part, the subjects were instructed to come back to the lab the next day (in the case of an early payment) or on (or after) the indicated date (in the case of a later payment). The different versions of the multiple price lists used in both Lund and Copenhagen are presented in Tables 1 and 2.

### 5.3 Cognitive capacity

We used cognitive reflection questions from Frederick (2005), Toplak et al. (2014), and Thomson & Oppenheimer (2016) to measure cognitive capacity. A total of eight cognitive reflection questions were randomized into the two multitasking conditions (the questions are listed in the Online Appendix). The subjects were incentivized to answer the questions correctly and as quickly as they could. Their payment depended on the number of correctly-answered questions and their average speed in comparison to the other participants when answering the questions.

---

<sup>14</sup>The show-up fee was paid through a bank transfer two weeks after the session in order to counteract incentives to always choose the “today” payment only to avoid multiple payments.

**Table 1:** Weekly discount rates for all multiple price lists (in Swedish kronas). A=payment today. B=later payment in 1, 2, 3, 6 or 9 weeks.

		Version 1, discount rates %							Version 1, alternative, discount rates %				
A	B	1w	2w	3w	6w	9w	A	B	1w	2w	3w	6w	9w
100	90	-10,00	-5,13	-3,45	-1,74	-1,16	100	95	-5,00	-2,53	-1,70	-0,85	-0,57
100	100	0,00	0,00	0,00	0,00	0,00	100	100	0,00	0,00	0,00	0,00	0,00
100	110	10,00	4,88	3,23	1,60	1,06	100	105	5,00	2,47	1,64	0,82	0,54
100	120	20,00	9,54	6,27	3,09	2,05	100	110	10,00	4,88	3,23	1,60	1,06
100	130	30,00	14,02	9,14	4,47	2,96	100	115	15,00	7,24	4,77	2,36	1,57
100	140	40,00	18,32	11,87	5,77	3,81	100	120	20,00	9,54	6,27	3,09	2,05
100	150	50,00	22,47	14,47	6,99	4,61	100	125	25,00	11,80	7,72	3,79	2,51
100	160	60,00	26,49	16,96	8,15	5,36	100	130	30,00	14,02	9,14	4,47	2,96
100	170	70,00	30,38	19,35	9,25	6,07	100	135	35,00	16,19	10,52	5,13	3,39
100	180	80,00	34,16	21,64	10,29	6,75	100	140	40,00	18,32	11,87	5,77	3,81

		Version 2, discount rates %							Version 2, alternative, discount rates %				
A	B	1w	2w	3w	6w	9w	A	B	1w	2w	3w	6w	9w
110	100	-9,09	-4,65	-3,13	-1,58	-1,05	110	105	-4,55	-2,30	-1,54	-0,77	-0,52
110	110	0,00	0,00	0,00	0,00	0,00	110	110	0,00	0,00	0,00	0,00	0,00
110	120	9,09	4,45	2,94	1,46	0,97	110	115	4,55	2,25	1,49	0,74	0,50
110	130	18,18	8,71	5,73	2,82	1,87	110	120	9,09	4,45	2,94	1,46	0,97
110	140	27,27	12,82	8,37	4,10	2,72	110	125	13,64	6,60	4,35	2,15	1,43
110	150	36,36	16,77	10,89	5,31	3,51	110	130	18,18	8,71	5,73	2,82	1,87
110	160	45,45	20,60	13,30	6,44	4,25	110	135	22,73	10,78	7,06	3,47	2,30
110	170	54,55	24,32	15,62	7,52	4,96	110	140	27,27	12,82	8,37	4,10	2,72
110	180	63,64	27,92	17,84	8,55	5,62	110	145	31,82	14,81	9,65	4,71	3,12
110	190	72,73	31,43	19,98	9,54	6,26	110	150	36,36	16,77	10,89	5,31	3,51

**Table 2:** Weekly discount rates for all multiple price lists (in Danish kronas).  
A=payment tomorrow. B=later payment in 1, 2, 3, 6 or 9 weeks.

A	B	Version 1, discount rates %					Version 1, alternative, discount rates %						
		1w	2w	3w	6w	9w	A	B	1w	2w	3w	6w	9w
70	65	-8,33	-4,26	-2,86	-1,44	-0,96	70	67	-5,00	-2,53	-1,70	-0,85	-0,57
70	70	0,00	0,00	0,00	0,00	0,00	70	70	0,00	0,00	0,00	0,00	0,00
70	75	8,33	4,08	2,70	1,34	0,89	70	73	5,00	2,47	1,64	0,82	0,54
70	80	16,67	8,01	5,27	2,60	1,73	70	76	10,00	4,88	3,23	1,60	1,06
70	85	25,00	11,80	7,72	3,79	2,51	70	79	15,00	7,24	4,77	2,36	1,57
70	90	33,33	15,47	10,06	4,91	3,25	70	82	20,00	9,54	6,27	3,09	2,05
70	95	41,67	19,02	12,31	5,98	3,95	70	85	25,00	11,80	7,72	3,79	2,51
70	100	50,00	22,47	14,47	6,99	4,61	70	88	30,00	14,02	9,14	4,47	2,96
70	105	58,33	25,83	16,55	7,96	5,24	70	91	35,00	16,19	10,52	5,13	3,39
70	110	66,67	29,10	18,56	8,89	5,84	70	94	40,00	18,32	11,87	5,77	3,81

A	B	Version 2, discount rates %					Version 2, alternative, discount rates %						
		1w	2w	3w	6w	9w	A	B	1w	2w	3w	6w	9w
80	75	-7,29	-3,71	-2,49	-1,25	-0,84	80	77	-4,38	-2,21	-1,48	-0,74	-0,50
80	80	0,00	0,00	0,00	0,00	0,00	80	80	0,00	0,00	0,00	0,00	0,00
80	85	7,29	3,58	2,37	1,18	0,79	80	83	4,38	2,16	1,44	0,72	0,48
80	90	14,58	7,04	4,64	2,29	1,52	80	86	8,75	4,28	2,84	1,41	0,94
80	95	21,88	10,40	6,82	3,35	2,22	80	89	13,13	6,36	4,20	2,08	1,38
80	100	29,17	13,65	8,91	4,36	2,88	80	92	17,50	8,40	5,52	2,72	1,81
80	105	36,46	16,82	10,92	5,32	3,51	80	95	21,88	10,40	6,82	3,35	2,22
80	110	43,75	19,90	12,86	6,24	4,11	80	98	26,25	12,36	8,08	3,96	2,62
80	115	51,04	22,90	14,74	7,11	4,69	80	101	30,63	14,29	9,31	4,55	3,01
80	120	58,33	25,83	16,55	7,96	5,24	80	104	35,00	16,19	10,52	5,13	3,39

*Notes:* According to the SEK-DKK exchange rate in October 2018 (1 DKK = 1.4 SEK), 70 DKK corresponds to 98 SEK, 80 DKK corresponds to 112 SEK.



## 5.4 Randomization

The order of the tasks was fixed within each session such that the same order was repeated twice, but the order in which a subject performed the easy/difficult multitasking was randomized.<sup>15</sup> For example, in one session, the order of tasks was as follows:

*Time preferences - cognitive reflection tasks - time perception - time preferences - cognitive reflection tasks - time perception.*

Since the order of the tasks was repeated twice, six possible order combinations were possible. The number of subjects that encountered each combination was similar for all six combinations. After the random assignment of the order of the easy/difficult multitasking, a subject might have had the following ordering:

*Time preferences (difficult multitasking) - cognitive capacity (easy multitasking) - time perception (easy multitasking) - time preferences (easy multitasking) - cognitive capacity (difficult multitasking) - time perception (difficult multitasking).*

We will now proceed to presenting the results of the experiment.

## 6 Results

Here, we will present the results of the experiment. First, we will report the estimations of our measures of time perception and time preferences. Then, we will test the five hypotheses of the paper. All regression results will be presented graphically. Complete regression tables corresponding to the figures in this section can be found in the Online Appendix.

### 6.1 Measuring time perception

Human time perception has been shown to be highly nonlinear. Following previous studies that related time perception to time preferences (Park &

---

<sup>15</sup>The reason why the order of the tasks was fixed within the session was to ensure that the data would be balanced with respect to the number of observations with each task first/second/last. Our hypothesis was that there might be a learning effect and/or increasing cognitive fatigue as the experiment proceeded. Hence, we prioritized having the number of observations in which each task was first/second/third balanced over randomizing the order of the tasks.

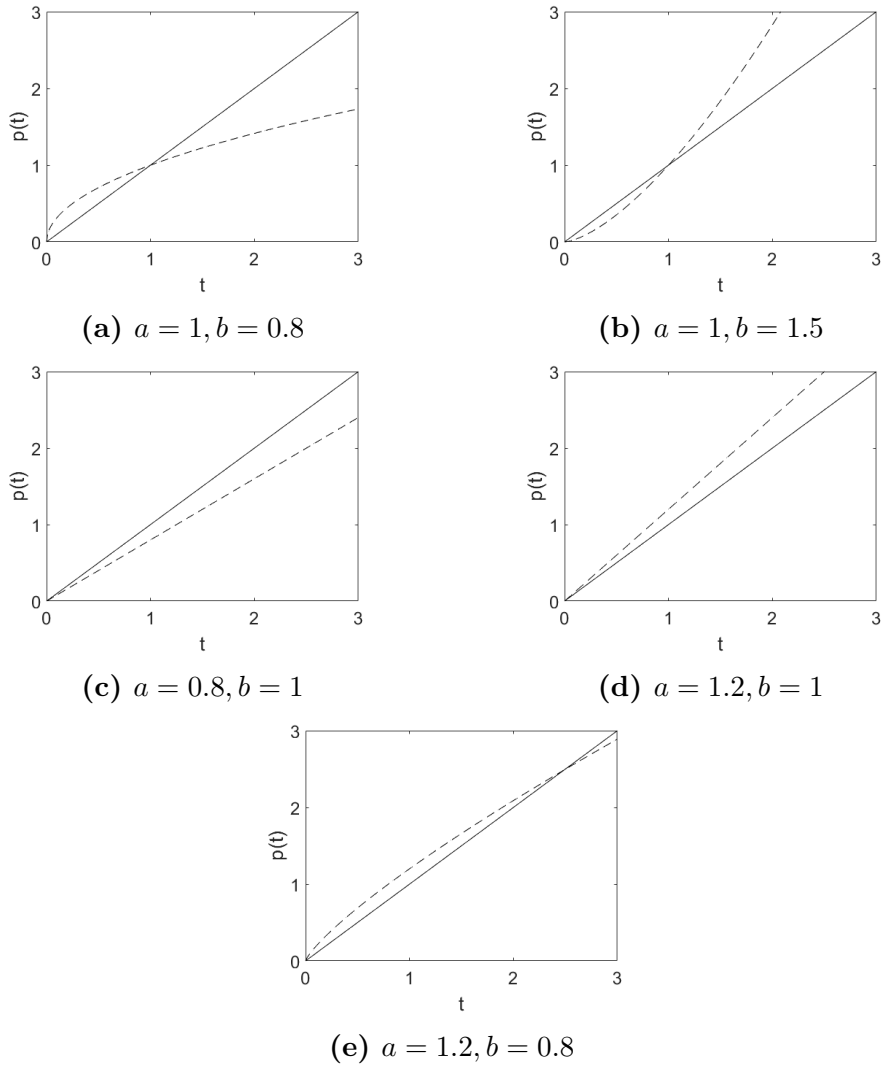
Capra (2017); Brocas et al. (2018)), we fit our results from the time perception elicitation to Stevens’ law of time perception, which states that the time produced in each of the six production tasks in the time perception elicitation part of the experiment is a power function of instructed time:  $p_i(t) = a_i t^{b_i}$ . The parameter  $a$  captures the expansion of produced time relative to instructed time, while the parameter  $b$  captures nonlinearities in the relationship between produced time and instructed time. Accordingly, a subject with  $a = b = 1$  perceives time correctly and has no biases in her produced time. Figure 4 illustrates how produced time depends on  $a$  and  $b$ . The solid lines in Figures (a) to (d) correspond to  $a = b = 1$ , i.e. no biases in time perception, and the dashed lines correspond to produced time, given the parameter values stated under the figure. For example, an individual who perceives time as illustrated in Figure (a) overproduces short time intervals but underproduces long time intervals, indicating that short time intervals are experienced as being shorter than what they are in terms of clock time while long time intervals are experienced as being longer than what they are in terms of clock time.

Fitting the data to Stevens’ law gives us estimates of  $a$  and  $b$ . Two subjects had very high values of  $\hat{a}$  and  $\hat{b}$  ( $\hat{a} = 118.9$  and  $\hat{b} = 4.1$ ) and were removed from the data.<sup>16</sup> In addition, observations from five subjects were removed due to missing data. The remaining pool of subjects used in the following analysis consists of 144 subjects. Figure 5 illustrates the distribution of the parameters for the subjects that remained after elimination of extreme and missing data. Most subjects (165 out of 288 observations) had  $\hat{a} > 1$  and  $\hat{b} < 1$ . This is in line with previous results from the literature that people tend to overproduce time, especially short time intervals (Block & Gruber, 2014). Figure (e) of Figure 4 illustrates an example of a case when  $\hat{a} > 1$  and  $\hat{b} < 1$ .

In addition to the estimated parameters  $\hat{a}$  and  $\hat{b}$ , we use the average of the ratio of produced time to instructed time across all six time intervals (of length 7, 11, 15, 23, 34 and 43 seconds) that the subjects produced as a non-parametric measure of time preferences (TR average). Note that the ratio of produced time to instructed time corresponds to the inverse of the ratio of subjective time to clock time since the time produced is the clock time that corresponds to the experienced (instructed) time. Figure 6 illustrates

---

<sup>16</sup>Given the nature of time measurements, there was considerable variation in our time measuring variables. Therefore, in the Online Appendix, we performed a robustness analysis of our results in which we excluded observations that classified as extreme outliers in terms of the time measuring variables (extreme outliers were defined as observations larger than  $Q3+3IQR$  or smaller than  $Q1-3IQR$ , where  $Q1$  and  $Q3$  are the first and the third quartile, respectively, and the interquartile range,  $IQR=Q3-Q1$ ).

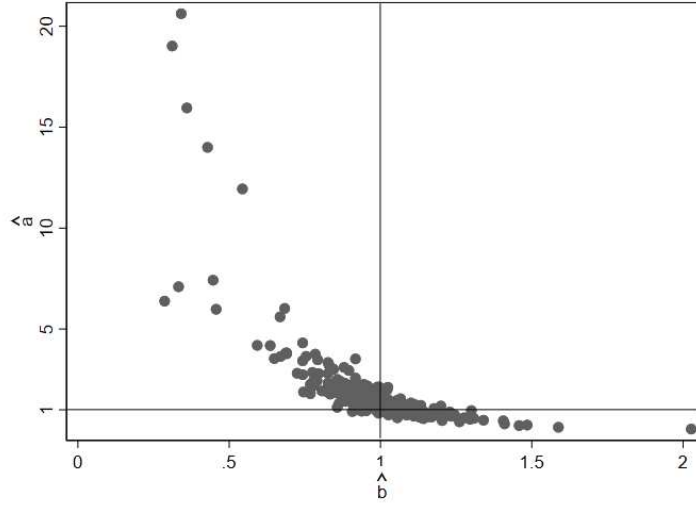


**Figure 4:** Examples of produced time in relation instructed time for different parameters  $a$  and  $b$ .

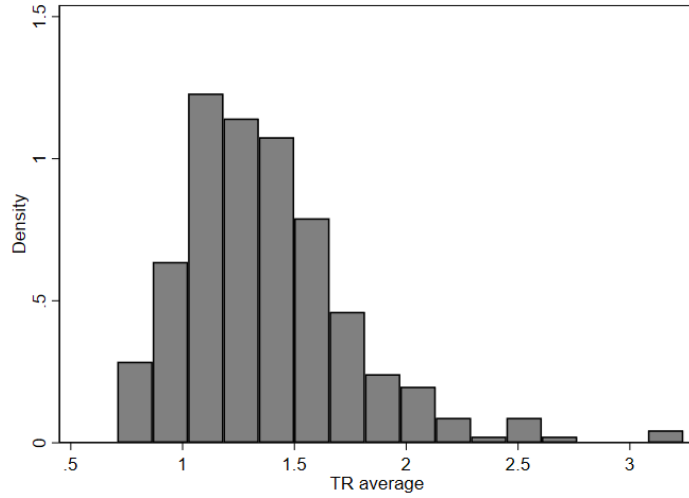
the distribution of the variable TR average. From the figure, we see that in general, TR average is larger than one which means that subjects tend to overproduce time.

## 6.2 Measuring time preferences

We fit our data from the time preferences elicitation tasks to a  $\beta-\delta$  model of time preferences (Laibson, 1997). Hence, we estimate the following equation



**Figure 5:** The distribution of  $\hat{a}$  and  $\hat{b}$  parameters of Stevens' law for time perception.



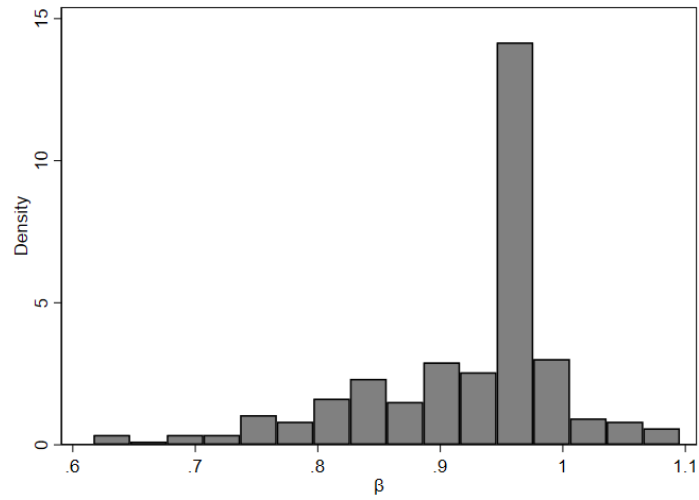
**Figure 6:** The distribution of the average of the ratio of produced time to instructed time across the 6 time intervals produced in the experiment.

using non-linear least squares:

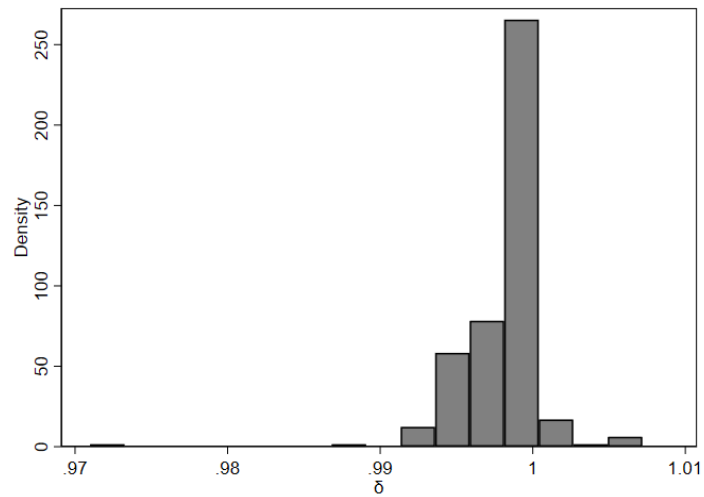
$$D_{i,j} = \beta_i \delta_i^{t_j} \quad (1)$$

where  $D_{i,j}$  is the discount factor of subject  $i$  over time interval  $j$  and  $t_j$  is the length of time interval  $j$ . In addition, we use the principal component

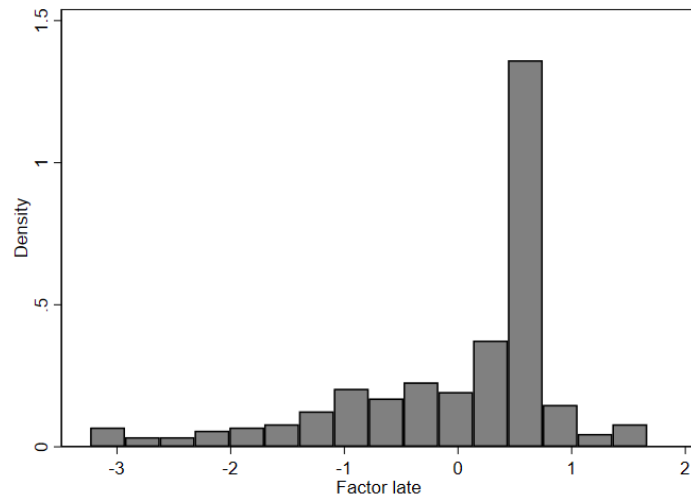
factorization of the number of late answers in all the multiple price lists (Factor late) as a non-parametric measure of time preferences. Figures 7 and 8 illustrate the distribution of the estimated parameters  $\beta$  and  $\delta$ , and Figure 9 illustrates the distribution of Factor late.



**Figure 7:** The distribution of  $\hat{\beta}$



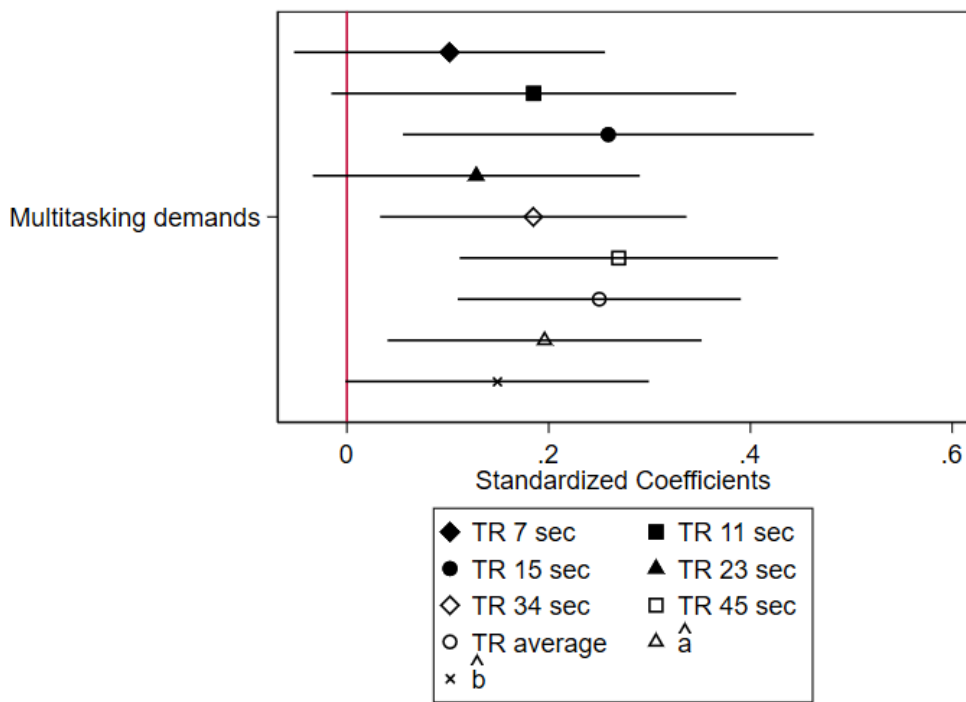
**Figure 8:** The distribution of  $\hat{\delta}$



**Figure 9:** The distribution of Factor late

### 6.3 Hypothesis 1: Time perception when multitasking demands increase

Figure 10 presents coefficient estimates of a regression with our measures of time perception, both parametric (the coefficients  $\hat{a}$  and  $\hat{b}$  of Stevens' power law) and non-parametric (TR average) as dependent variables and a dummy for the difficult multitasking condition as an independent variable. In the regressions with  $\hat{a}$  as the dependent variable we include  $\hat{b}$  as a control variable, and vice versa in the regression with  $\hat{b}$  as the dependent variable. We observe that subjects produce longer time intervals when multitasking demands are higher, hence  $\frac{\text{Subjective time}}{\text{Clock time}}$  decreases and Hypothesis 1 is confirmed.



**Figure 10:** The effect of multitasking demands on time perception.  
*Notes:* Estimated coefficients from OLS regressions, including subject fixed effects with 95% confidence intervals.

## 6.4 Hypothesis 2: Time perception mediates the effect of multitasking on time preferences

We use mediation analysis to explore whether and how time perception mediates the effect of multitasking demands on time preferences. In order to explore the mediation, we study (i) the joint hypothesis that the effect of increased multitasking demands on time perception is zero and that the effect of time perception on time preferences is zero. Hence, we test whether the coefficients  $b_{MD}$  and  $b_{TP}$  of regressions (2) and (3) are zero. Note that  $MD$  stands for multitasking demands.

$$TimePerception = b_0 + b_{MD}MD + SubjectFE + \varepsilon \quad (2)$$

$$TimePreferences = b_0 + b_{TP}TimePerception + SubjectFE + \varepsilon, \quad (3)$$

(ii) The average causal mediation effect, i.e. the difference between the coefficient  $\beta_1$  and the coefficient  $\alpha_1$  in the two following regressions. Again,  $MD$  stands for multitasking demands:

$$TimePreferences = \beta_0 + \beta_1MD + SubjectFE + \varepsilon \quad (4)$$

$$TimePreferences = \alpha_0 + \alpha_1MD + \alpha_2TimePerception + SubjectFE + \varepsilon. \quad (5)$$

If time perception mediates the effect of an increase in multitasking demands on time preferences, the difference  $\beta_1 - \alpha_1$  should be different from zero.

The usual first step in mediation analysis is to investigate the total effect of the treatment variable (multitasking demands, in our case) on the outcome variable (time preferences). However, since we hypothesized that the total effect of increased multitasking demands on time preferences is small due to the counterbalancing effects of time perception and cognitive capacity, we skipped this first step here. Even in the case in which there is a zero total effect of treatment on outcome, mediation analysis makes sense if the mediating variable is believed to have an effect that goes in the opposite direction of the direct effect, possibly resulting in a zero total effect (Shrout & Bolger, 2002).

Testing (i), we regress time perception on multitasking demands, controlling for subject fixed effects. Then, we regress time preferences on time perception, again controlling for subject fixed effects. We do this for all combinations of our measures of time perception and time preferences. Using a Wald test, we then test the joint hypothesis that the coefficients for multitasking demands in the first regression and for time perception in the latter regression are zero. The results of this exercise are presented in Table 3. As



**Table 3:** A Wald test of the joint null hypotheses that  $b_{MD} = 0$  and  $b_{TP} = 0$  of the regressions  $TimePerception = b_0 + b_{MD}MD + controls$  and  $TimePreferences = b_0 + b_{TP}TimePerception + controls$ .

Measure of time preferences - Measure of time perception (controls)	$b_{MD}$	$b_{TP}$	p-value of joint zero-hypotheses
Factor late - TRaverage	0.1***	0.3**	<0.001
$\hat{\beta}$ - TRaverage ( $\hat{\delta}$ )	0.1***	0.04***	<0.001
$\hat{\delta}$ - TRaverage ( $\hat{\beta}$ )	0.1***	0.0006	<0.001
Factor late - $\hat{a}(\hat{b})$	0.44**	0.04*	<0.001
$\hat{\beta}$ - $\hat{a}(\hat{b}, \hat{\delta})$	0.44**	0.002	0.0162
$\hat{\delta}$ - $\hat{a}(\hat{b}, \hat{\beta})$	0.44**	-0.00003	0.0469
Factor late - $\hat{b}(\hat{a})$	0.03*	0.33	0.0086
$\hat{\beta}$ - $\hat{b}(\hat{a}, \hat{\delta})$	0.03*	-0.005	0.1379
$\hat{\delta}$ - $\hat{b}(\hat{a}, \hat{\beta})$	0.03*	-0.00002	0.1401

\*p<0.1, \*\*p<0.05, \*\*\*p<0.01

Notes: All regressions include subjects fixed effects.

the table shows, for all but two specifications, the joint hypothesis that both  $b_{MD}$  and  $b_{TP}$  are zero is rejected at the 0.05 level.

Testing (ii), we estimate equations (4) and (5) and test whether  $\beta_1 - \alpha_1 = 0$ . While the results in Table 3 suggest that time perception mediates the effect of multitasking demands on time preferences, in (ii), we quantify the mediation effect. In Table 4 we test  $\beta_1 - \alpha_1 = 0$  for all combinations of time preference measures and time perception measures. From the table, it can be seen that the difference between  $\beta_1$  and  $\alpha_1$  is significantly different from zero at the 0.05 level when time preferences are measured with  $\hat{\beta}$  and time perception is measured with TR average. When Factor late is used as a measure of time preferences, time perception mediates multitasking demands for both TR average and  $\hat{a}$  and  $\hat{b}$ , although the mediation effect is only significant at the 0.1 level. We follow the advice of Shrout & Bolger (2002) and use a bootstrapped test to circumvent problems with asymmetric or non-normal data.

To summarize, the results of the mediation analysis suggest that time perception mediates the effect of multitasking demands on time preferences. Hence, Hypothesis 2 is confirmed.

**Table 4:** A test of the hypothesis that  $\beta_1 - \alpha_1 = 0$  using bootstrapped standard errors.

Dependent var. - Independent var. (controls)	$\beta_1 - \alpha_1$	Bootstrapped SE	p-value
Factor late - TRaverage	0.033*	0.018	0.074
$\hat{\beta}$ - TRaverage ( $\hat{\delta}$ )	0.004**	0.002	0.017
$\hat{\delta}$ - TRaverage ( $\hat{\beta}$ )	0.00006	0.00007	0.42
Factor late - $\hat{a} + \hat{b}$	0.017*	0.01	0.092
$\hat{\beta} - \hat{a} + \hat{b}$ ( $\hat{\delta}$ )	0.0006	0.001	0.587
$\hat{\delta} - \hat{a} + \hat{b}$ ( $\hat{\beta}$ )	-0.00001	0.00004	0.791

\*p<0.1, \*\*p<0.05, \*\*\*p<0.01

Notes: All regressions include subjects fixed effects.

## 6.5 Hypothesis 3: Cognitive capacity when multitasking demands increase

We now look at the effect of multitasking demands on cognitive capacity. In Figure 8, estimated coefficients of a regression with cognitive capacity as a dependent variable and a dummy for multitasking demands as an independent variable are presented. Recall that our measure of cognitive capacity is the number of correct answers out of four cognitive reflection tasks in each of the two multitasking conditions.

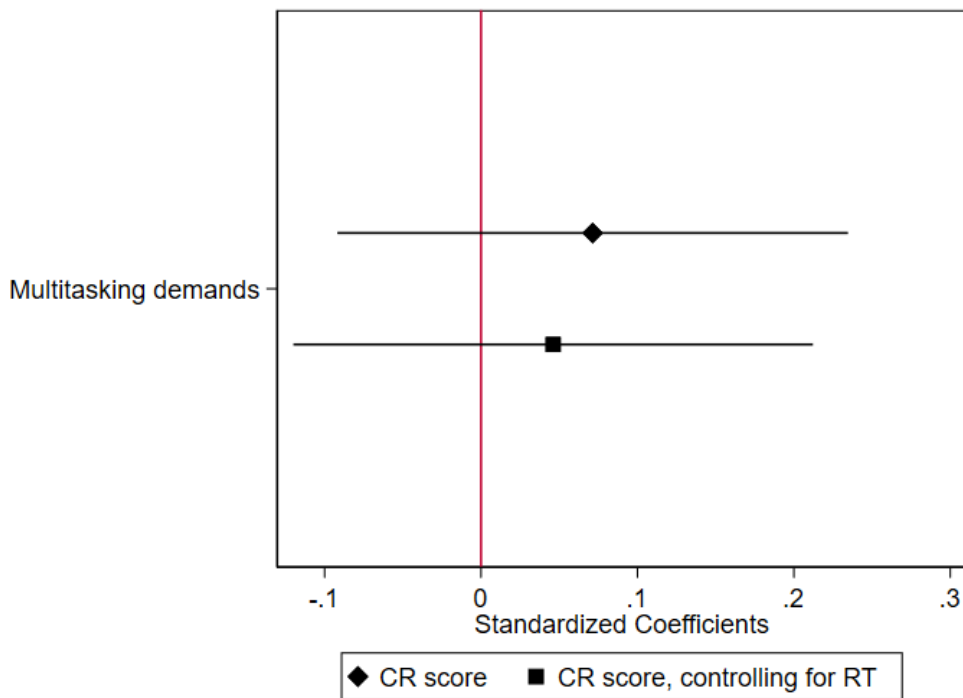
First, we regress performance on the cognitive reflection tasks on a dummy for the difficult multitasking condition without a control for response time<sup>17</sup> (the diamond marker). Then, we redo the same regression with a control for response time and response time squared (the square marker). We find that performance on the cognitive reflection tasks is not affected on average by the increase in multitasking demands, even when controlling for response time.

Despite the stable result that the relationship between multitasking demands and cognitive capacity is not dependent on answering time, it is interesting to study how the response time differs between the two multitasking conditions. This gives us an indication about the mental mechanisms that the subjects used when answering the cognitive reflection questions. In regressions not presented in the paper, we regress answering time on the cognitive reflection tasks on multitasking demands, controlling for subject fixed effect. We find an increase (although not statistically significant) in response time when multitasking demands increased (about 0.15 standard deviation

<sup>17</sup>The response time is the time it takes for a subject to answer the cognitive reflection questions, excluding the time used to answer the pop-up Stroop tasks.

increase in response time when multitasking demand went from easy to difficult (p-value = 0.187)). We also observe that performance on the cognitive reflection tasks is positively related to answering time (one standard deviation increase in answering time comes with a 0.19 standard deviation increase in performance on the cognitive reflection questions (p-value = 0.004)). However, as the results in Figure 11 show, the total effect of multitasking on cognitive capacity does not seem to be driven by this channel.

Taken together, the results suggest that cognitive capacity measured by performance on the cognitive reflection tasks did not, on average, decrease when multitasking demands increased. Hence, Hypothesis 3 is not supported by the data.



**Figure 11:** The effect of multitasking demands on cognitive capacity.  
*Notes:* Estimated coefficients from OLS regressions, including subject fixed effects with 95% confidence intervals.

## 6.6 Hypothesis 4: Cognitive capacity mediates the effect of multitasking demands on time preferences.

We use mediation analysis to explore whether cognitive capacity mediates the effect of multitasking demands on time preferences. First, we look at the joint hypothesis that the effect of increased multitasking demands on cognitive capacity is zero and that the effect of cognitive capacity on time preferences is zero. That is, given the following two regressions,

$$CR_{score} = b_0 + b_{MD}MD + SubjectFE + \varepsilon \quad (6)$$

$$TimePreferences = b_0 + b_{CR_{score}}CR_{score} + SubjectFE + \varepsilon, \quad (7)$$

where  $MD$  stands for multitasking demands, we test  $b_{MD} = 0$  and  $b_{CR_{score}} = 0$  jointly. The coefficient estimates for  $b_{MD}$  and  $b_{CR_{score}}$  and the p-values of a Wald test of the joint hypothesis that  $b_{MD} = 0$  and  $b_{CR_{score}} = 0$  are presented in Table 5.

Then, we estimate the average causal mediation effect by calculating the difference between  $\beta_1$  and  $\alpha_1$  in the two following regressions:

$$TimePreferences = \beta_0 + \beta_1MD + SubjectFE + \varepsilon \quad (8)$$

$$TimePreferences = \alpha_0 + \alpha_1MD + \alpha_2CR_{score} + SubjectFE + \varepsilon, \quad (9)$$

where again, MD stands for multitasking demands. As when Hypothesis 2 was tested, we use bootstrapped test to test whether  $\beta_1 - \alpha_1$  is different from zero. The difference between the estimated coefficient values  $\beta_1$  and  $\alpha_1$  and the p-values of the null hypothesis that  $\beta_1 - \alpha_1 = 0$  are presented in Table 6.

**Table 5:** A Wald test of the joint null hypotheses that  $b_{MD} = 0$  and  $b_{CR_{score}} = 0$  of the regressions  $CR_{score} = b_0 + b_{MD}MD + controls$  and  $TimePreferences = b_0 + b_{TP}CR_{score} + controls$ .

Dependent var. - Independent var. (controls)	$b_{MD}$	$b_{CR_{score}}$	p-value of joint zero-hypotheses
Factor late - CR score (RT, RT <sup>2</sup> )	0.063	-0.0007	0.86
$\hat{\beta}$ - CR score ( $\hat{\delta}$ , RT, RT <sup>2</sup> )	0.063	-0.005	0.39
$\hat{\delta}$ - CR score ( $\hat{\beta}$ , RT, RT <sup>2</sup> )	0.063	-0.0002	0.32

\*p<0.1, \*\*p<0.05, \*\*\*p<0.01

Notes: All regressions include subjects fixed effects.

Taken together, the results presented in Tables 5 and 6 show that cognitive capacity does not mediate the effect of multitasking demands on time preferences. Thus, we cannot confirm Hypothesis 4.

**Table 6:** A test of the hypothesis  $\beta_1 - \alpha_1 = 0$  using bootstrapped standard errors.

Dependent var. - Independent var. (controls)	$\beta_1 - \alpha_1$	Bootstrapped SE	p-value
Factor late - CR score (RT, RT <sup>2</sup> )	0.0064	0.013	0.62
$\hat{\beta}$ - CR score ( $\hat{\delta}$ , RT, RT <sup>2</sup> )	0.00069	0.0017	0.68
$\hat{\delta}$ - CR score ( $\hat{\beta}$ , RT, RT <sup>2</sup> )	0.000068	0.000066	0.28

\*p<0.1, \*\*p<0.05, \*\*\*p<0.01

## 6.7 Hypothesis 5: Time perception and cognitive capacity mediate the total effect of multitasking demands on time preferences

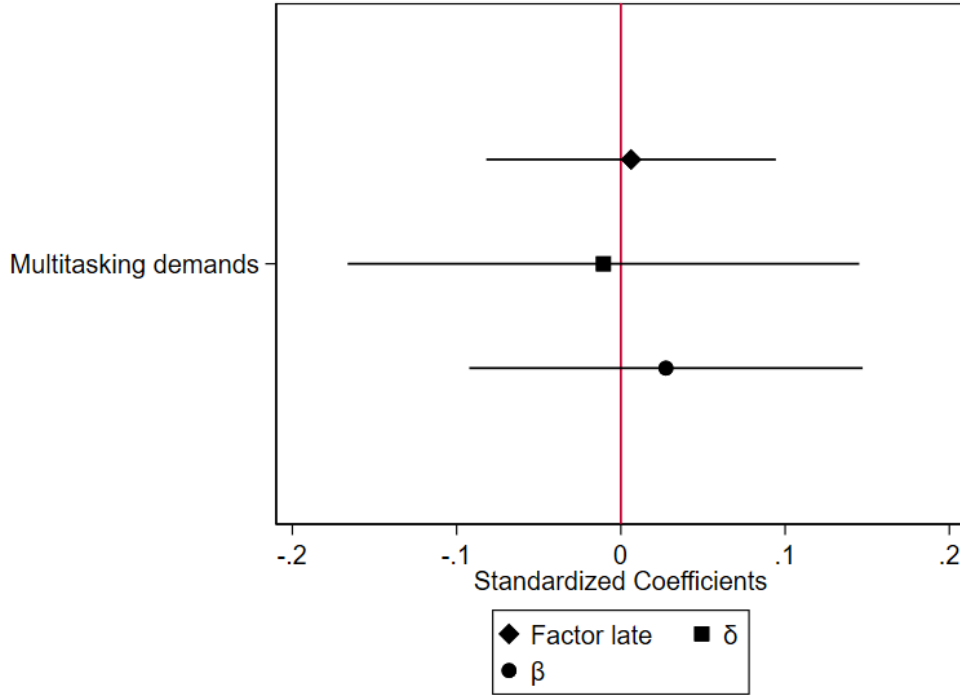
Now, we test whether combining the mediating effects of time perception and cognitive capacity on time preferences can explain the total effect of multitasking demands on time preferences. We begin by studying the total effect of multitasking demands on time preferences. Then, we combine cognitive capacity and time perception by studying the extent to which the estimated treatment effect of increasing multitasking demands for cognitive capacity and time perception, respectively, explains the treatment effect for time preferences.

Figure 12 illustrates how our three measures of time preferences relate to multitasking demands. In the figure, we present coefficient estimates from regressions with the three time preferences measures as dependent variables and a dummy for the difficult multitasking condition as an independent variable. In the regression with  $\hat{\delta}$  as the dependent variable, we include  $\hat{\beta}$  as a control variable, and vice versa for the regression with  $\hat{\beta}$  as the dependent variable. From the figure, it can be seen that we find no relationship between the three measures of time preferences and multitasking demands.

Adding the channel of time perception and the channel of cognitive capacity together in order to explain the total effect of multitasking demands on time preferences, we estimate:

$$\begin{aligned} \Delta TimePref = & \beta_0 + \beta_1 \Delta CR + \beta_2 \Delta TimePerception \\ & + \beta_3 \Delta CR_{RT} + \beta_4 \Delta CR_{RT}^2 + \varepsilon \end{aligned} \quad (10)$$

where  $\Delta$  indicates the difference between the difficult and the easy multitasking conditions,  $CR$  is performance on the cognitive reflection tasks and  $CR_{RT}$  is response time when solving the cognitive reflection tasks (excluding the pop-up Stroop tasks).



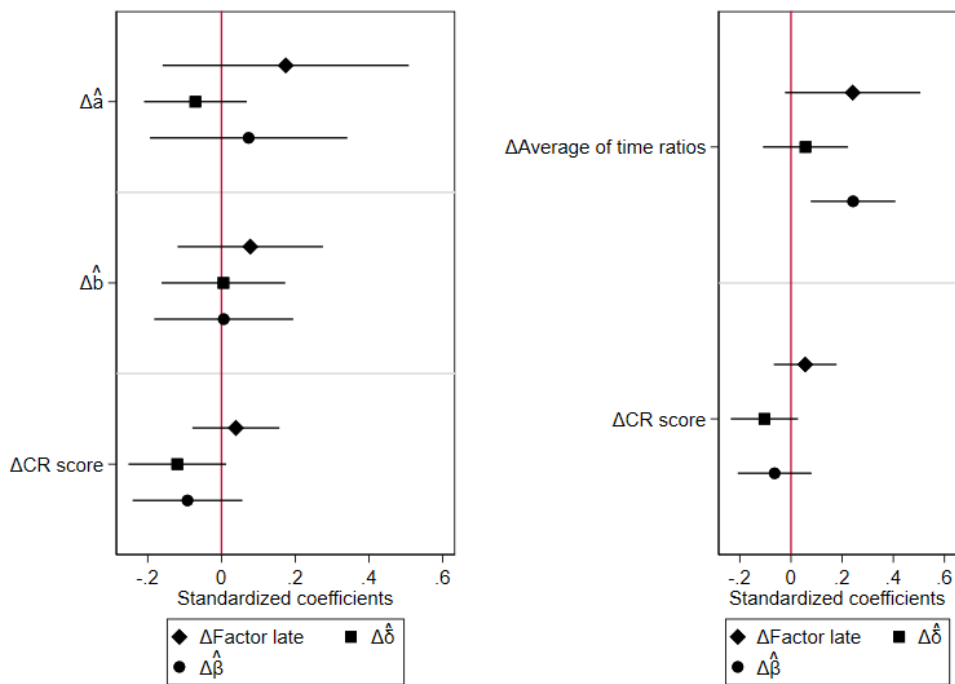
**Figure 12:** The effect of multitasking demands on time preferences.  
*Notes:* Estimated coefficients from OLS regressions including subject fixed effects with 95% confidence intervals.

Figure 13 illustrates the relationship between shifts in time perception and cognitive capacity generated by an increase in multitasking demands and shifts in time preferences generated by an increase in multitasking demands. In all regressions, we control for response time on the cognitive reflection tasks. In addition, we control for  $\Delta\hat{\beta}$  in the regression with  $\Delta\hat{\delta}$  as dependent variable, and vice versa. We see that shifts in time perception correlate with shifts in time preferences, especially for  $\hat{\beta}$  and the non-parametric measure Factor late. Regarding cognitive capacity when multitasking demands increase, we find no evidence that shifts in cognitive capacity due to an increase in multitasking demands relate to corresponding shifts in time preferences, as suggested by the results of the mediation analysis.

It is possible that answering time on the time preferences elicitation matters for our results. For example, it could be the case that answering time increases when the cognitive demands of multitasking increase, compensating for the cognitive constraints multitasking generates. To examine this possibility, in the Online Appendix, we present the same regressions that are

presented here, together with regressions where we control for answering time on the multiple price lists. The results show that controlling for answering time does not alter the results presented in Figures 12 and 13.

Taken together, the results of this section suggest that Hypothesis 5 is partly confirmed. Time perception shifts time preferences such that patience increases when multitasking demands increase. However, we do not observe a relationship between shifts in cognitive capacity and shifts in time preferences.



**Figure 13:** Shifts in time preferences regressed on shifts in time perception and shifts in cognitive capacity when multitasking demands increase. In the figure to the left, coefficient estimates from a regression where time perception is captured with the estimated parameters  $\hat{a}$  and  $\hat{b}$  are presented. In the figure to the right, coefficient estimates from a regression where time perception is captured with TR average are presented.

*Notes:* Estimated coefficients from OLS regressions, including session fixed effects with 95% confidence intervals.

## 7 Discussion

Taken together, the results of this paper show that increasing the cognitive demands of multitasking leads to a faster subjective perception of time (i.e. a given time interval is experienced as shorter) but has no effect on cognitive capacity. Despite the positive effect of shifts in time perception on patience when multitasking demands increase, we do not find any overall effect of increasing the cognitive demands of multitasking on patience.

One potential concern is the large variation in the variables that measure time. In the Online Appendix we exclude extreme outliers<sup>18</sup> in terms of time measures ( $\Delta\hat{a}$ ,  $\Delta\hat{b}$ ,  $\Delta\text{TR}$  average and  $\Delta\text{CR}_{RT}$ ) from the main regressions. This exercise shows that the results of the paper were not affected by this exclusion.

Our experimental setup allows us to use the measures for cognitive capacity, time preferences, and time perception in the easy multitasking condition as an individual measure of cognitive ability, time preferences, and time perception. Therefore, we can compare our results from the within-subjects study to differences between subjects in time perception, cognitive ability, and time preferences. Note that not taking the curvature of the utility function into account in the between-subject setup is problematic, given the established result that utility function curvature has non-negligible effects on measured time preferences (see e.g. Andersen et al., 2008; Andreoni & Sprenger, 2012). However, as a partial remedy, we include a survey-based measure of risk preferences as a control variable in the between-subjects regressions.

In Figure 14 we present results from between-subjects regressions in the easy multitasking condition in which time preferences are regressed on time perception and cognitive ability. Looking at the relationship between time preferences on the one hand and time perception and cognitive ability on the other hand, it can be seen that both time perception and cognitive ability predict time preferences such that a faster subjective time and higher cognitive ability come with more patience. In contrast to the results from the within-subject study, the effect between multitasking demands and cognitive ability is here large and statistically significant.

We also examine whether a survey measure of time preferences is related to our incentivized measures of time preferences. This serves as a validation check for our experimentally-elicited measures of time preferences. In a questionnaire after the experiment, the subjects answered the following question:

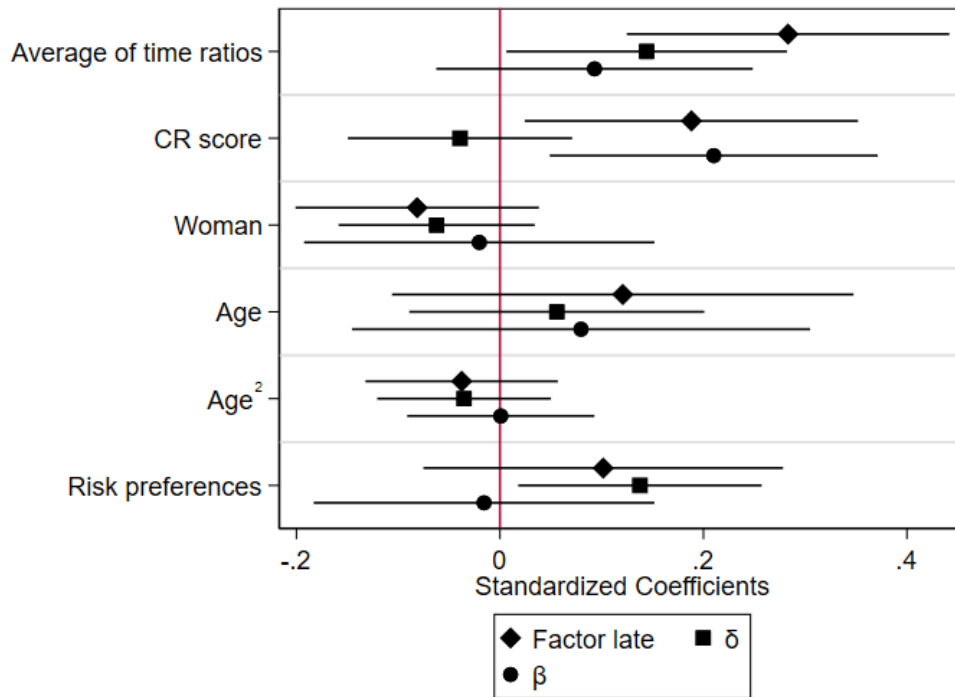
---

<sup>18</sup>Extreme outliers are defined as observations that lie outside the interval  $[\text{Q1}-3\text{IQR}, \text{Q3}+3\text{IQR}]$ , where Q1 and Q3 are the first and third quartiles, respectively, and  $\text{IQR}=\text{Q3}-\text{Q1}$ .



“How willing are you to give up something that is beneficial for you today in order to benefit more from that in the future? Indicate your answer on a scale from 0 to 10 where 0 means that you are ‘completely unwilling to do so’ and 10 means you ‘are very willing to do so’”.<sup>19</sup> This question has been shown to relate to both educational choices and savings around the world (Falk et al., 2018). Table 7 reports the pairwise correlation coefficients between all four time preference measures. We note that both the non-parametric measure and the survey measure of time preferences correlate more with  $\hat{\beta}$  than with  $\hat{\delta}$ .

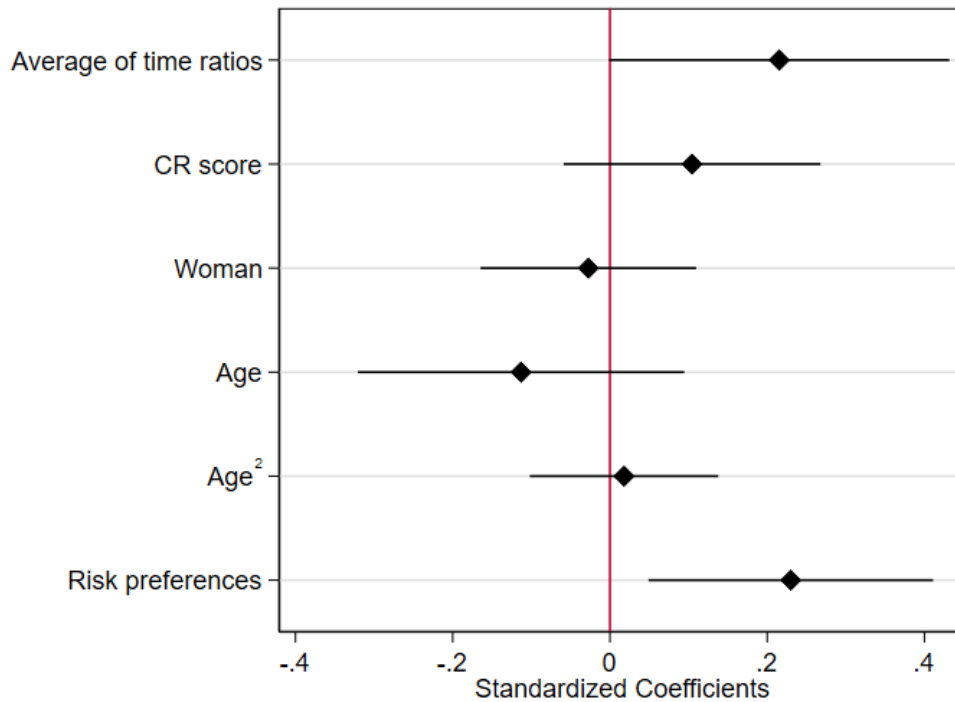
In Figure 15 we present results from the same regressions as presented in Figure 14 but with the survey measure of time preferences as the dependent variable. The results go in the same direction as the results for the experiment-based measures of time preferences.



**Figure 14:** Time preferences, time perception and cognitive ability in a between-subjects setting.

*Notes:* Estimated coefficients from OLS regressions, including session fixed effects with 95% confidence intervals.

<sup>19</sup>The question is borrowed from Falk et al. (2018).



**Figure 15:** Survey based time preferences, time perception and cognitive ability in a between-subjects setting. Dependent variable: Self-reported time preferences.

*Notes:* Estimated coefficients from OLS regressions including session fixed effects with 95% confidence intervals.

Comparing the results from the within-subject study to the results from the between-subjects study, there are two things worth noticing. First, it can be seen that in the within-subject study, the effect of increasing multitasking demands on time preferences is driven by a shift in  $\hat{\beta}$  caused by shifts in time perception. However, in the between-subjects setup, it can be seen that the relationship between time perception and time preferences is driven by  $\hat{\delta}$  to a greater extent than  $\hat{\beta}$ . This suggests that there might be a different mechanism underlying shifts in time preferences due to time perception within individuals but across contexts than when comparing individuals.

Secondly, it can be seen that cognitive ability is strongly correlated to time preferences in the between-subject setup, though uncorrelated to time preferences in the within-subject setup. One potential explanation for this is that differences in cognitive capacity within individuals when multitasking demands increase are fundamentally different from differences in cognitive

**Table 7:** Correlation coefficients of the time preference variables.

	TimePref, survey	$\hat{\delta}$	$\hat{\beta}$	Factor late
TimePref, survey	1.0000			
$\hat{\delta}$	0.2374	1.0000		
$\hat{\beta}$	0.3354	0.0373	1.0000	
Factor late	0.3709	0.3862	0.8152	1.0000

ability between individuals, such that the latter rather than the former relates to time preferences. Another possible explanation is that the measurement of cognitive capacity in the within-subject setting is noisier than in the between-subject setting, possibly due to the importance of response time on the cognitive reflection tasks for performance on the tasks.

Additionally, it is possible that noise is a confounding factor for our results, as noise can be expected to increase when the cognitive demands of multitasking increase. In the Online Appendix, we present results that show a decrease in consistency in the time preference elicitation when multitasking demands increase. We also detect a significant increase in noise in the location of the switching point in the multiple price list when going from the easy multitasking condition to the difficult multitasking condition. Based on the difference between the alternative and the standard multiple price lists, we construct a measure of noise that we added as a control variable to the regressions presented in Figures 12 and 13. Controlling for noise in the regression presented in Figure 12 leads to a significant increase in the coefficients for multitasking demands (in the regression with factor late as dependent variable, the coefficient is now positive and statistically significant) while noise relates negatively to patience. Reassuringly, controlling for noise in the regressions presented in Figure 13 shows that the observed relationship between time perception and time preferences when multitasking demands increase is not driven by noise. Hence, the results suggest that noise is the reason why we observed a zero total effect of increased multitasking demands on time preferences in Figure 12 while, at the same time, we found a strong relationship between time perception and time preferences when multitasking demands increase in Figure 13.

We perform a similar analysis for the between-subjects study in which we investigate whether there is a relationship between noisiness and cognitive ability. We do not find a relationship between inconsistency and cognitive ability, but we do find that consistent subjects with low cognitive ability are more prone to choose the sub-optimal "less later" option in the first line of the multiple price lists. Lastly, we find that noise in the location of the switching point is not correlated with cognitive ability, nor do the results presented in

Figure 14 change when we add our measure of noise and answering time as control variables.

A potential concern with the results is that the channel of time perception and the channel of cognitive capacity, when explaining time preferences under multitasking demands, might be dependent. For example, if there is a causal relationship between time perception and cognitive capacity, the former might drive changes in time preferences while correlation between the latter and time preferences only reflects the causal relationship between time perception and cognitive capacity. In the Online Appendix, we show results from an additional experiment where arousal, induced by external tempo (a metronome) in headphones, was used to manipulate time perception and cognitive capacity. We show that while the effect of arousal on cognitive capacity is similar to the multitasking treatment, the results indicate that time perception is shifted in the opposite direction. This suggests that given a shift in cognitive capacity, depending on the type of treatment, time perception can be shifted either up or down. This demonstrates that the two cannot be linearly dependent and hence strengthens (although not proves) the argument that time perception and cognitive capacity are independent.

A second potential concern is that time perception was measured over very short intervals (seconds), while time preferences were measured over weeks and months. As noted earlier, previous experimental papers on the relationship between time perception and time preferences used similar measures and found a relationship (Brocas et al., 2018; Park & Capra, 2017).<sup>20</sup> Moreover, assuming that time perception is subject to projection bias, it is not surprising that the experience of the current passage of time relates to how people perceive the future. Still, when relating time perception to time preferences, it is the perception of future time intervals that is theoretically most relevant. Since measuring the perception of future time intervals is difficult, we measure future time perspective under both high and low arousal in the Online Appendix and relate shifts in future time perspective to shifts in prospective time perception and time preferences.<sup>21</sup> Our hypothesis is that future time perspective mediates the observed relationship between prospec-

---

<sup>20</sup>In their paper, Brocas et al. (2018) matched time perception to time preferences by ranking subjects on both measures before extrapolating time perception measures upwards in time and time preference measures downwards in time so that they matched. Then, the correlation between measured time perception and time preferences was calculated.

<sup>21</sup>Future time perspective is individuals' perception of their remaining time in life (Carstensen et al., 1999), traditionally measured with a questionnaire. However, Demeyer & De Raedt (2014) validated the use of a scrambled sentence task for the measure of future time perspective, which was the method we used. For more information, see the Online Appendix.

tive time perception and time preferences. Our results go in the expected direction, and we show that future time perspective is related to prospective time perception. However, the relationship between future time perspective and time preferences is weaker, and the estimated mediation effect is not statistically significant. A detailed description of the procedure of the arousal experiment and its results can be found in the Online Appendix.

## 8 Conclusion

In this paper, we examine the effect of multitasking demands on time preferences by studying the role of time perception and cognitive capacity as mediators of the effect. Our results show that measured patience is not affected when multitasking demands increase. However, we observe a relatively strong relationship between shifts in time perception and shifts in time preferences when multitasking demands increase but a zero effect when shifts in cognitive capacity are related to shifts in time preferences. Studying the role of noise in the elicitation of time preference for our results, we find that noise works in the opposite direction to the patience-increasing effect of shifts in time perception. When noise is controlled for, we find a positive relationship between increased multitasking demands and patience, driven by shifts in time perception.

In addition, the experimental setup allows us also to study how cognitive ability and time perception relate to time preferences in a between-subject setup. The results show that in contrast to the within-subject setup, we find a positive relationship between cognitive ability and time preferences as well as a positive relationship between time perception and time preferences.

The results are in line with previous experimental results in Brocas et al. (2018) and Park & Capra (2017) that time perception plays an important role for time preferences, both when it comes to variations in individual preferences across different contexts and when it comes to differences in preferences across individuals.

Our results add to previous research on decision-making under cognitive load or while multitasking and on the link between cognitive ability and decision-making. We observe increases in response time when the cognitive demands of multitasking increase, indicating that people take more time to think in order to compensate for the decrease in cognitive capacity induced by multitasking demands. This suggests that it is not necessarily so that decisions become more intuitive or of lower quality when cognitive load increases. However, in our between-subjects results (where, arguably, response time does not matter as much), we discover a significant relation-

ship between cognitive ability and time preferences indicating more intuitive, impatient choices of subjects with lower cognitive ability.

The results suggest that differences in both time perception and cognitive ability across population groups can explain differences in intertemporal decisions across these groups. For example, age has been shown to relate strongly to both time perception and cognitive ability such that, as we grow older, time is experienced as passing faster and cognitive ability decreases (Murman, 2015). This suggests that while the speeding up of subjective time predicts that patience increases with age, the decline in cognitive ability predicts that patience decreases. Experimental results on time preferences over the lifespan have either found that patience increases uniformly with age (Green et al., 1994; Harrison et al., 2002; Falk et al., 2018) or that there is an inverse u shaped relationship between age and patience (Sozou & Seymour, 2003; Read & Read, 2004; Falk et al., 2018)<sup>22</sup>. The latter type of relationship could be explained by accounting for both a decline in cognitive ability over the lifespan, resulting in less patience, and an increase in the experienced speed of time over the lifespan, resulting in more patience. At a young age, the decline in cognitive ability is slow, and the relationship between age and time preferences is mostly explained by the speeding up of time. For older individuals, the effect of decreasing cognitive ability gradually becomes more important, which leads to a flatter and eventually downward-sloping relationship between age and time preferences.

We show that context-dependent shifts in time perception relate to shifts in time preferences. Although we only study the role of multitasking demands in this paper, the context dependence of time perception is a well-established result. Previous results have shown that factors including body temperature, hormones, stress, emotions, and fatigue affect time perception. Our results suggest that the same factors that affect time perception might drive differences in time preferences within individuals and across time and contexts. Thus, taking the context dependence of time perception into account when designing environments where intertemporal decisions are made, can potentially result in better, more patient decision-making.

---

<sup>22</sup>Falk et al. (2018) found a uniform increase in patience over age for non-OECD countries but an inverse U-shaped relationship for OECD countries.

## References

- Allport, D. A., Styles, E. A., & Hsieh, S. (1994). Shifting intentional set: Exploring the dynamic control of tasks. In U. C. & M. M. (Eds.), *Attention and performance series. Attention and performance 15: Conscious and nonconscious information processing* (pp. 421–452). Cambridge, MA, US: The MIT Press.
- Andersen, S., Harrison, G. W., Lau, M. I., & Rutström, E. E. (2008). Eliciting risk and time preferences. *Econometrica*, *76*(3), 583–618.
- Andersson, O., Holm, H. J., Tyran, J.-R., & Wengström, E. (2016). Risk aversion relates to cognitive ability: Preferences or noise? *Journal of the European Economic Association*, *14*(5), 1129–1154.
- Andreoni, J. & Sprenger, C. (2012). Risk preferences are not time preferences. *American Economic Review*, *102*(7), 3357–76.
- Benjamin, D. J., Brown, S. A., & Shapiro, J. M. (2013). Who is ‘behavioral’? Cognitive ability and anomalous preferences. *Journal of the European Economic Association*, *11*(6), 1231–1255.
- Block, R. A. & Gruber, R. P. (2014). Time perception, attention, and memory: A selective review. *Acta Psychologica*, *149*, 129 – 133.
- Block, R. A., Hancock, P. A., & Zakay, D. (2010). How cognitive load affects duration judgments: A meta-analytic review. *Acta Psychologica*, *134*(3), 330–343.
- Borst, J. P., Taatgen, N. A., & Van Rijn, H. (2010). The problem state: A cognitive bottleneck in multitasking. *Journal of Experimental Psychology: Learning, memory, and cognition*, *36*(2), 363.
- Bradford, W. D., Dolan, P., & Galizzi, M. M. (2014). Looking ahead: Subjective time perception and individual discounting. *CEP Discussion Papers*, No. CEPDP1255.
- Brocas, I., Carrillo, J. D., & Tarrasó, J. (2018). How long is a minute? *Games and Economic Behavior*, *111*, 305 – 322.
- Buser, T. & Peter, N. (2012). Multitasking. *Experimental Economics*, *15*(4), 641–655.

- Busse, M. R., Pope, D. G., Pope, J. C., & Silva-Risso, J. (2015). The psychological effect of weather on car purchases. *The Quarterly Journal of Economics*, *130*(1), 371–414.
- Callen, M., Isaqzadeh, M., Long, J. D., & Sprenger, C. (2014). Violence and risk preference: Experimental evidence from Afghanistan. *American Economic Review*, *104*(1), 123–48.
- Carstensen, L. & Lang, F. (2018). The future time perspective scale. retrieved from <https://lifespan.stanford.edu/projects/future-time-perspective-ftp-scale>.
- Carstensen, L. L., Isaacowitz, D. M., & Charles, S. T. (1999). Taking time seriously: A theory of socioemotional selectivity. *American Psychologist*, *54*(3), 165.
- Castillo, M., Dickinson, D. L., & Petrie, R. (2017). Sleepiness, choice consistency, and risk preferences. *Theory and Decision*, *82*(1), 41–73.
- Chie, Q. T. & Karthigeyan, K. K. (2009). The effects of music tempo on memory performance using maintenance rehearsal and imagery. *Sunway Academic Journal*, *6*, 114–132.
- Conlin, M., O'Donoghue, T., & Vogelsang, T. J. (2007). Projection bias in catalog orders. *American Economic Review*, *97*(4), 1217–1249.
- Deck, C. & Jahedi, S. (2015). The effect of cognitive load on economic decision making: A survey and new experiments. *European Economic Review*, *78*, 97 – 119.
- Demeyer, I. & De Raedt, R. (2014). The effect of future time perspective manipulation on affect and attentional bias. *Cognitive Therapy and Research*, *38*(3), 302–312.
- Droit-Volet, S. (2013). Time perception in children: A neurodevelopmental approach. *Neuropsychologia*, *51*(2), 220 – 234.
- Falk, A., Becker, A., Dohmen, T., Enke, B., Huffman, D., & Sunde, U. (2018). Global evidence on economic preferences\*. *The Quarterly Journal of Economics*, *133*(4), 1645–1692.
- Franco-Watkins, A., Pashler, H., & Rickard, T. (2006). Does working memory load lead to greater impulsivity? Commentary on Hinson, Jameson, and Whitney (2003). *Journal of Experimental Psychology: Learning Memory and Cognition*, *32*(2), 443–447.



- Franco-Watkins, A., Rickard, T., & Pashler, H. (2010). Taxing executive processes does not necessarily increase impulsive decision making. *Experimental Psychology*, *57*(3), 193–201.
- Frederick, S. (2005). Cognitive reflection and decision making. *Journal of Economic Perspectives*, *19*(4), 25–42.
- Fudenberg, D. & Levine, D. K. (2006). A dual-self model of impulse control. *American Economic Review*, *96*(5), 1449–1476.
- Gil, S., Niedenthal, P. M., & Droit-Volet, S. (2007). Anger and time perception in children. *Emotion*, *7*(1), 219 – 225.
- Green, L., Fry, A. F., & Myerson, J. (1994). Discounting of delayed rewards: A life-span comparison. *Psychological Science*, *5*(1), 33–36.
- Grondin, S. (2010). Timing and time perception: A review of recent behavioral and neuroscience findings and theoretical directions. *Attention, Perception, & Psychophysics*, *72*(3), 561–582.
- Harrison, G. W., Lau, M. I., & Williams, M. B. (2002). Estimating individual discount rates in denmark: A field experiment. *American Economic Review*, *92*(5), 1606–1617.
- Hinson, J. M., Jameson, T. L., & Whitney, P. (2003). Impulsive decision making and working memory. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *29*(2), 298.
- Jersild, A. T. (1927). Mental set and shift. *Archives of Psychology*.
- Kahneman, D. (2003). Maps of bounded rationality: Psychology for behavioral economics. *The American Economic Review*, *93*(5), 1449–1475.
- Killgore, W. D. (2015). Chapter 30 - Sleep deprivation and behavioral risk-taking. In R. R. Watson (Ed.), *Modulation of Sleep by Obesity, Diabetes, Age, and Diet* (pp. 279 – 287). San Diego: Academic Press.
- Kreutz, G., Ott, U., Teichmann, D., Osawa, P., & Vaitl, D. (2008). Using music to induce emotions: Influences of musical preference and absorption. *Psychology of Music*, *36*(1), 101–126.
- Laibson, D. (1997). Golden eggs and hyperbolic discounting. *The Quarterly Journal of Economics*, *112*(2), 443–478.

- Liefooghe, B., Barrouillet, P., Vandierendonck, A., & Camos, V. (2008). Working memory costs of task switching. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *34*(3), 478.
- Loewenstein, G., O'Donoghue, T., & Rabin, M. (2003). Projection bias in predicting future utility. *The Quarterly Journal of Economics*, *118*(4), 1209–1248.
- Macar, F., Grondin, S., & Casini, L. (1994). Controlled attention sharing influences time estimation. *Memory and Cognition*, *22*(6), 673–686.
- MacLeod, C. M. (1991). Half a century of research on the stroop effect: An integrative review. *Psychological Bulletin*, *109*(2), 163.
- Malmendier, U. & Nagel, S. (2011). Depression babies: Do macroeconomic experiences affect risk taking? *The Quarterly Journal of Economics*, *126*(1), 373–416.
- Meuter, R. F. & Allport, A. (1999). Bilingual language switching in naming: Asymmetrical costs of language selection. *Journal of Memory and Language*, *40*(1), 25–40.
- Monsell, S., Yeung, N., & Azuma, R. (2000). Reconfiguration of task-set: Is it easier to switch to the weaker task? *Psychological Research*, *63*(3-4), 250–264.
- Murman, D. L. (2015). The impact of age on cognition. In *Seminars in hearing*, volume 36, (pp. 111). Thieme Medical Publishers.
- Nishiyama, Y. (2006). The Asian financial crisis and investors' risk aversion. *Asia-Pacific Financial Markets*, *13*(3), 181–205.
- Park, J.-Y. & Capra, C. M. (2017). How did it get so late so soon? The effects of time distortion on discounting.
- Polti, I., Martin, B., & van Wassenhove, V. (2018). The effect of attention and working memory on the estimation of elapsed time. *Scientific Reports*, *8*.
- Predebon, J. (1996). The effects of active and passive processing of interval events on prospective and retrospective time estimates. *Acta Psychologica*, *94*(1), 41–58.

- Ray, D. & Bossaerts, P. (2011). Positive temporal dependence of the biological clock implies hyperbolic discounting. *Frontiers in Neuroscience*, 5, 2.
- Read, D. & Read, N. (2004). Time discounting over the lifespan. *Organizational Behavior and Human Decision Processes*, 94(1), 22 – 32.
- Rubinstein, J. S., Meyer, D. E., & Evans, J. E. (2001). Executive control of cognitive processes in task switching. *Journal of Experimental Psychology: Human Perception and Performance*, 27(4), 763.
- Shiv, B. & Fedorikhin, A. (1999). Heart and mind in conflict: the interplay of affect and cognition in consumer decision making. *Journal of Consumer Research*, 26(3), 278–292.
- Shrout, P. E. & Bolger, N. (2002). Mediation in experimental and nonexperimental studies: new procedures and recommendations. *Psychological Methods*, 7(4), 422.
- Sozou, P. D. & Seymour, R. M. (2003). Augmented discounting: Interaction between ageing and time-preference behaviour. *Proceedings: Biological Sciences*, 270(1519), 1047–1053.
- Stevens, S. S. (1957). On the psychophysical law. *Psychological Review*, 64(3), 153.
- Stroop, J. R. (1935). Studies of interference in serial verbal reactions. *Journal of Experimental Psychology*, 18(6), 643.
- Takahashi, T. (2005). Loss of self-control in intertemporal choice may be attributable to logarithmic time-perception. *Medical Hypotheses*, 65(4), 691–693.
- Teuscher, U. & Mitchell, S. H. (2011). Relation between time perspective and delay discounting: A literature review. *The Psychological Record*, 61(4), 613–632.
- Thomson, K. S. & Oppenheimer, D. M. (2016). Investigating an alternate form of the cognitive reflection test. *Judgment and Decision Making*, 11(1), 99–113.
- Toplak, M. E., West, R. F., & Stanovich, K. E. (2014). Assessing miserly information processing: An expansion of the cognitive reflection test. *Thinking & Reasoning*, 20(2), 147–168.

- Tse, P. U., Intriligator, J., Rivest, J., & Cavanagh, P. (2004). Attention and the subjective expansion of time. *Attention, Perception, & Psychophysics*, *66*(7), 1171–1189.
- Wittmann, M. & Paulus, M. P. (2008). Decision making, impulsivity and time perception. *Trends in Cognitive Sciences*, *12*(1), 7 – 12.
- Yerkes, R. M. & Dodson, J. D. (1908). The relation of strength of stimulus to rapidity of habit-formation. *Journal of Comparative Neurology and Psychology*, *18*(5), 459–482.
- Yeung, N. & Monsell, S. (2003a). The effects of recent practice on task switching. *Journal of Experimental Psychology: Human Perception and Performance*, *29*(5), 919.
- Yeung, N. & Monsell, S. (2003b). Switching between tasks of unequal familiarity: The role of stimulus-attribute and response-set selection. *Journal of Experimental Psychology: Human Perception and Performance*, *29*(2), 455.
- Zakay, D. & Block, R. A. (1997). Temporal cognition. *Current Directions in Psychological Science*, *6*(1), 12–16.
- Zakay, D. & Block, R. A. (2004). Prospective and retrospective duration judgments: an executive-control perspective. *Acta Neurobiologiae Experimentalis*, *64*(3), 319–328.
- Zakay, D., Nitzan, D., & Glicksohn, J. (1983). The influence of task difficulty and external tempo on subjective time estimation. *Perception & Psychophysics*, *34*(5), 451–456.
- Zauberman, G., Kim, B. K., Malkoc, S. A., & Bettman, J. R. (2009). Discounting time and time discounting: Subjective time perception and intertemporal preferences. *Journal of Marketing Research*, *46*(4), 543–556.

## 9 Online Appendix

The Online Appendix is organized as follows. In Section 9.1, we study the possibility that the results of this paper are driven by noise. In Section 9.2, we describe the arousal experiment and report its results. In Section 9.4, we present questions used in the future time perspective part of the arousal experiment as well as the questions used in the cognitive reflection elicitation. In Section 9.5, we present additional regression tables.

### 9.1 Noise

#### Noise in the within-subject study

Noise has been shown to increase when subjects are cognitively constrained (see e.g. Franco-Watkins et al., 2006, 2010) and hence is a potential driver of our results. To exclude the possibility that our results are driven by noise, we quantify the increase in noise as multitasking demands increased by (i) comparing the share of consistent answers in the easy and difficult multitasking conditions, (ii) studying differences in shifting points between the alternative multiple price lists (see description below) and the standard multiple price lists, and (iii) studying the share of sub-optimal answers among the consistent answers.

In Table 8, we present the share of consistent answers in all multiple price lists as well as the share of sub-optimal answers among the consistent answers for both the within-subject and the between-subjects study. For the within-subject study, we compared the two multitasking demands conditions and for the between-subjects study, we compared the answers of subjects with high cognitive ability to the answers of subjects with low cognitive ability, both in the easy multitasking condition.

As can be seen from the table, we find an increase in the share of inconsistent answers when going from low multitasking demands to high multitasking demands. However, those who are consistent in their answers do not increase their share of sub-optimal "less later" answers when multitasking demands increase. Comparing subjects with low cognitive ability with subjects with high cognitive ability, we see that the share of inconsistent answers is about the same in both groups. However, subjects with low cognitive ability submit a larger share of sub-optimal answers than subjects with high cognitive ability. The high number of consistent answers when multitasking demands were low might have been partly due to the fact that participants were told that, usually, subjects shift only once from the early payment option to the late payment option.

Another potential source of noise is the location of the switching point, e.g. due to subjects following the advice to switch only once but choosing the switching point randomly. Two alternative multiple price lists were included to control for this possibility: One with the later payment in one-week time, and the other with the later payment in six-weeks time. The alternative multiple price lists had a lower increment between the choices. Hence, the location of the “true switching point” differed between the two lists such that it was always further down in the alternative version. If there was an increase in noise in the difficult multitasking condition compared to the easy multitasking condition, the difference in discount factors between the standard multiple price list and the alternative version would increase in absolute terms. If the average “true switching point” was above the middle of the list, the difference would become more negative as noise increased, but if the average “true switching point” was below the middle of the list, the difference would become more positive. We observe that the average difference between the alternative and standard multiple price lists is positive in the easy multitasking condition for both the one-week delay and the six-weeks delay versions, confirming that our measure of noise is increasing in noise regarding shifting points in the multiple price lists.

**Table 8:** Consistency.

	<i>Share of inconsistent answers</i>		<i>Share of “less later” answers</i>	
	Easy MT/ CR score $\geq$ 2	Difficult MT/ CR score $<$ 2	Easy MT/ CR score $\geq$ 2	Difficult MT/ CR score $<$ 2
Within	1.7%	9.7%	3.8%	3.4%
Between	1.5%	1.9%	1.7%	6.6%

*Notes:* MT = multitasking. Inconsistent answers are subjects that did not shift once (or not at all) from the early to the late payment option. “Less later” answers are answers in the first line of the multiple price lists where the later option is lower than the earlier option such that the later, lower option is chosen.

Unfortunately, the difference between the alternative and standard versions of the multiple price lists is strongly correlated with the discount factor in the standard list. This is because subjects that report high discount factors in the standard list and answer noisily will, with greater probability, report a smaller discount factor in the alternative list than vice versa. Conversely, subjects who report low discount factors in the standard list and answer noisily will, with a greater probability, report a higher discount factor in the alternative list than vice versa. Additionally, subjects who report

truthfully and have such a low discount factor that it is either not covered by both lists or is only covered by the standard list will be forced to report too high, resulting in the reported discount factor in the standard list being larger than the reported discount factor in the alternative list.

To account for this, we regress the difference between the alternative and standard versions of the multiple price lists on the discount factor from the standard list (also including session fixed effect) and use the residuals from this regression as our measure of noise. We then regress our residuals on a dummy for the difficult multitasking condition to study whether noise increased when going from easy to difficult multitasking. We do this for both the one-week and six-weeks discount factors, and the results are presented in Table 9. From the table, it can be seen that our measure of noise increases when multitasking demands increase for both the one-week delay and the six-weeks delay discount factors.

**Table 9:** The effect of multitasking demands on noise in shifting points in multiple price lists with 1 week delay and 6 weeks delay, respectively.

	Noise 1	Noise 6
MD	0.0142*** (0.005)	0.0093* (0.005)
Constant	-0.0208*** (0.007)	-0.0136* (0.008)
$N$	266	269
$R^2$	0.074	0.029
Subject FE	Yes	Yes

Standard errors in parentheses

\*  $p < 0.1$ , \*\*  $p < 0.05$ , \*\*\*  $p < 0.01$

*Notes:* MD = multitasking demands. Due to missing data points in the alternative discount factors, 19 and 22 observations, respectively are excluded from the analysis. Noise 1 and Noise 6 are the residuals from the regressions  $\text{Diff1} = b_0D1 + b_1D1^2$  and  $\text{Diff6} = b_0D6 + b_1D6^2$ , where D1 and D6 are the measured discount factors from the multiple price list with delay 1 and 6 weeks, respectively and Diff1 and Diff6 are the differences in discount factors between the standard and the alternative multiple price lists with 1 and 6 weeks delay.

The question then arises whether the increase in noise observed in Table 9 was driving our results. In order to analyze this possibility, we redo the regressions presented in Figures 12 and 13 (the two main regressions of the paper that include time preferences) controlling for noise in the location of shifting points. We do this by including a factor variable that summarizes the two noise variables, Noise 1 and Noise 6. Due to missing data in the noise measures, we drop 23 observations from our main sample. In order to compare coefficient estimates with and without the noise controls, we also include the original regressions, now on the reduced sample. The results are

presented in Tables 10 and 11.

From Table 10, it can be seen that the results in Figure 12 in the paper are affected when noise is controlled for. It is clear that the coefficients for multitasking demands in the regressions where noise was controlled for (regressions 1-3) are larger than corresponding estimates in the original regressions (regressions 4-6). Especially in the first regression, we now observe a statistically significant relationship between multitasking demands and factor late. At the same time, we observe a negative correlation between noise and patience, which suggests that noise might be the factor underlying the coexistence of the results that the overall effect of multitasking demands on time preferences was zero in Figure 12, while we found convincing evidence for the channel of time perception in Figure 13. In the absence of noise, the time perception channel should govern the relationship between multitasking demands and time preferences, leading to a positive total effect, while in the presences of noise, the noise will pull in the opposite direction, resulting in a much reduced or zero total effect.

From Table 11, it can be seen that the observed positive relationship between the treatment effect on time perception and the treatment effect on time preferences is more or less insensitive to the inclusion of treatment differences in noise as control variables. This is reassuring since it indicates that the observed relationship between time perception and time preferences when multitasking demands increase is not dependent on noise.

### **Noise in the between-subjects study**

Noise can also be a concern in the between-subjects study presented in the Discussion section of the paper. It might have been the case that subjects with low cognitive ability were noisier in their answers than subjects with high cognitive ability. In order to study the relationship between noise and cognitive ability in the between-subjects setup, we perform the same analysis that we used in the within-subjects case: (i) We compare the share of consistent answers in the multiple price lists for subjects with less than two correct answers on the cognitive reflection questions to the share of consistent answers of subjects with two or more correct answers on the cognitive reflection questions, (ii) we compare the share of sub-optimal “less later” choices among the consistent answers for subjects with high cognitive ability and subjects with low cognitive ability, and (iii) we study noise in shifting points by comparing the standard and alternative versions of the multiple price lists with a one-week delay and a six-weeks delay, respectively, using the same residual measure of noise as in the within-subject case.

(i) and (ii) are presented in Table 8 and discussed above in relation to



**Table 10:** Time preferences when multitasking demands increase, including noise as control variables.

	Factor late	$\hat{\delta}$	$\hat{\beta}$	Factor late	$\hat{\delta}$	$\hat{\beta}$
MD	0.0833** (0.040)	0.0771 (0.047)	0.0609 (0.055)	0.00159 (0.042)	0.0577 (0.044)	0.0226 (0.052)
Noise	-0.193*** (0.033)	-0.0459 (0.039)	-0.0892** (0.045)			
$\hat{\beta}$		-0.266*** (0.076)			-0.252*** (0.075)	
$\hat{\delta}$			-0.357*** (0.101)			-0.346*** (0.103)
Constant	-0.102* (0.060)	-0.0968 (0.072)	-0.0727 (0.084)	0.0170 (0.065)	-0.0686 (0.068)	-0.0169 (0.080)
$N$	264	264	264	264	264	264
$R^2$	0.229	0.109	0.117	0.000	0.099	0.087
Subject FE	Yes	Yes	Yes	Yes	Yes	Yes

Standard errors in parentheses

\*  $p < 0.1$ , \*\*  $p < 0.05$ , \*\*\*  $p < 0.01$

*Notes:* All variables, except MD, are standardized. Factor late = a factorization of the number of late choices in all multiple price lists, MD=multitasking demands, Noise = a factor variable that summarizes the residuals from the regressions  $\text{Diff1} = b_0 + b_1 D1$  and  $\text{Diff6} = b_0 + b_1 D6$ , where D1 and D6 are the measured discount factors from the multiple price list with delay 1 and 6 weeks, respectively and Diff1 and Diff6 are the differences in discount factors between the standard and the alternative multiple price lists with 1 and 6 weeks delay.

**Table 11:** Differences regression including controls for noise in shifting points in the time preference elicitation.

	(1)	(2)	(3)	(4)	(5)	(6)
	$\Delta$ Factor late	$\Delta\hat{\delta}$	$\Delta\hat{\beta}$	$\Delta$ Factor late	$\Delta\hat{\delta}$	$\Delta\hat{\beta}$
$\Delta$ TR average	0.121 (0.077)	0.0376 (0.040)	0.106 (0.079)	0.127 (0.079)	0.0363 (0.041)	0.107 (0.079)
$\Delta$ CR score	0.0420 (0.073)	-0.0262 (0.044)	-0.0264 (0.077)	0.0409 (0.071)	-0.0261 (0.044)	-0.0256 (0.076)
$\Delta$ CR <sub>RT</sub>	0.183* (0.094)	0.0511 (0.053)	0.174** (0.074)	0.0925 (0.098)	0.0295 (0.052)	0.141** (0.071)
$\Delta$ CR <sub>RT</sub> <sup>2</sup>	0.0838*** (0.023)	0.0442*** (0.014)	0.0372 (0.024)	0.0344* (0.020)	0.0343*** (0.012)	0.0180 (0.021)
$\Delta$ Noise	-0.507*** (0.121)	-0.101 (0.072)	-0.180* (0.093)			
$\Delta\hat{\beta}$		-0.221* (0.125)			-0.196 (0.126)	
$\Delta\hat{\delta}$			-0.510* (0.263)			-0.460 (0.283)
Constant	-0.0178 (0.217)	0.168** (0.076)	0.0517 (0.171)	0.0361 (0.132)	0.179*** (0.060)	0.0617 (0.151)
N	121	121	121	121	121	121
R <sup>2</sup>	0.414	0.255	0.258	0.133	0.222	0.211
Session FE	Yes	Yes	Yes	Yes	Yes	Yes

Standard errors in parentheses

\*p<0.1, \*\*p<0.05, \*\*\*p<0.01

Notes: All variables are standardized.  $\Delta$  indicates different in the corresponding variable between the high and low cognitive load conditions. TR average is the average of the ratio of produced time to instructed time across all six time intervals, CR score is performance on the cognitive reflection tasks, CR<sub>RT</sub> is response time on the cognitive reflection questions. Noise = a factor variable that summarizes the residuals from the regressions Diff1 =  $b_0 + b_1 D1$  and Diff6 =  $b_0 + b_1 D6$ , where D1 and D6 are the measured discount factors from the multiple price list with delay 1 and 6 weeks, respectively and Diff1 and Diff6 are the differences in discount factors between the standard and the alternative multiple price lists with 1 and 6 weeks delay.

the same results for the within-subject case. In Table 12, we regress our two measures of noise on cognitive ability, which was measured as the number of correctly answered cognitive reflection questions in the easy multitasking condition. From the table, it can be seen that noisiness in answering the multiple price lists does not seem to be larger for subjects with lower cognitive ability.

**Table 12:** The relationship between cognitive ability and noise in shifting points in multiple price lists with 1 week delay and 6 weeks delay, respectively.

	Noise 1	Noise 6
CR score	0.001 (0.003)	-0.001 (0.003)
Constant	-0.00479 (0.015)	0.001 (0.015)
$N$	143	143
$R^2$	0.021	0.038

Standard errors in parentheses

\*  $p < 0.1$ , \*\*  $p < 0.05$ , \*\*\*  $p < 0.01$

*Notes:* CR score = Number of correctly answered cognitive reflection questions in the easy multitasking condition. Due to missing data points in the alternative discount factors, 1 observation is excluded from the analysis. Noise 1 and Noise 6 are the residuals from the regressions  $\text{Diff1} = b_0D1 + b_1D1^2$  and  $\text{Diff6} = b_0D6 + b_1D6^2$ , where D1 and D6 are the measured discount factors from the multiple price list with delay 1 and 6 weeks, respectively and Diff1 and Diff6 are the differences in discount factors between the standard and the alternative multiple price lists with 1 and 6 weeks delay.

Despite the non-significant results in Table 12, it might have been the case that noise still shifted the results presented in Figure 14 in the paper. In Table 13, we add our measures of noise as a control variable to the regression presented in Figure 14. Due to missing data in the noise variable, we drop two observations from the analysis. In order to study the effect of controlling for noise, we also present the original regressions on the same reduced sample. The results show that controlling for noise does not change the obtained results, suggesting that the results presented in Figure 14 do hold when noise is controlled for.

## 9.2 The arousal experiment

In the arousal experiment, we study the effect of arousal on time perception and cognitive capacity. We also study whether there is a relationship between time perception and future time perspective.

**Table 13:** Between subjects, time preferences regressed on time perception and cognitive ability given low multi-tasking demands. Including controls for noise and answering speed on the time preference elicitation.

	Factor late	$\hat{\delta}$	$\hat{\beta}$	Factor late	$\hat{\delta}$	$\hat{\beta}$
TR average	0.235** (0.101)	0.161** (0.063)	0.0662 (0.105)	0.254** (0.104)	0.174** (0.072)	0.0580 (0.103)
CR score	0.193** (0.083)	-0.0288 (0.052)	0.207** (0.082)	0.189** (0.085)	-0.0471 (0.055)	0.206** (0.082)
CR <sub>RT</sub>	0.168 (0.122)	-0.00968 (0.075)	0.188 (0.127)	0.216* (0.119)	0.0300 (0.076)	0.224* (0.127)
CR <sub>RT</sub> <sup>2</sup>	-0.0386** (0.019)	-0.0164 (0.012)	-0.0205 (0.019)	-0.0529*** (0.018)	-0.0302** (0.012)	-0.0290 (0.019)
Woman	-0.0573 (0.061)	-0.0634 (0.054)	0.0107 (0.088)	-0.0714 (0.063)	-0.0785 (0.055)	0.00843 (0.095)
Age	0.136 (0.116)	0.0810 (0.066)	0.108 (0.117)	0.117 (0.115)	0.0517 (0.073)	0.0807 (0.115)
Age <sup>2</sup>	-0.0485 (0.046)	-0.0339 (0.037)	-0.0179 (0.045)	-0.0422 (0.048)	-0.0252 (0.041)	-0.00809 (0.045)
Risk preferences	0.112 (0.088)	0.137*** (0.050)	0.00288 (0.088)	0.106 (0.089)	0.128** (0.059)	-0.0210 (0.084)
Noise	0.186** (0.079)	0.219*** (0.071)	0.176* (0.090)			
$\hat{\beta}$		0.0893 (0.058)			0.158*** (0.057)	
$\hat{\delta}$			0.246* (0.148)			0.382*** (0.122)
Constant	0.244 (0.199)	0.0893 (0.136)	0.0935 (0.235)	0.263 (0.221)	0.101 (0.168)	0.0943 (0.238)
<i>N</i>	142	142	142	142	142	142
<i>R</i> <sup>2</sup>	0.247	0.371	0.247	0.210	0.259	0.219
Session FE	Yes	Yes	Yes	Yes	Yes	Yes

Standard errors in parentheses

*Notes:* All variables are standardized.  $\Delta$  indicates different in the corresponding variable between the high and low cognitive load conditions. TR average is the average of the ratio of produced time to instructed time across all six time intervals, CR score is performance on the cognitive reflection tasks, CR<sub>RT</sub> is response time on the cognitive reflection questions. Noise = a factorization of the residuals from the regressions Diff1 =  $b_0D1 + b_1D1^2$  and Diff6 =  $b_0D6 + b_1D6^2$ , where D1 and D6 are the measured discount factors from the multiple price list with delay 1 and 6 weeks, respectively and Diff1 and Diff6 are the differences in discount factors between the standard and the alternative multiple price lists with 1 and 6 weeks delay.

### 9.2.1 Addressing the independence of the channel of time perception and the channel of cognitive capacity

The attentional-gate model serves as a theoretical motivation for using arousal to shift time preferences. While cognitive load (or attention) determines whether or not the attentional gate is open, allowing time pulses to pass through, the speed of the pacemaker is determined by arousal. The more aroused a subject is, the faster the pacemaker. Accordingly, a person who is highly aroused and completely focused on the passage of time receives the largest number of pulses to the cognitive counter and hence perceives time as passing very slowly (one minute might seem like an eternity for this person). This effect has also been confirmed experimentally, see e.g. Zakay et al. (1983) and Gil et al. (2007).

The relationship between arousal and cognitive capacity has also received considerable attention within psychology.<sup>23</sup> Yerkes & Dodson (1908) suggested in their seminal paper that the relationship between arousal and cognitive capacity is hump-shaped. At low levels of arousal, cognitive capacity is low; it then increases with arousal until an optimal level is reached. If arousal increases further, cognitive capacity goes down. In later work, Yerkes and Dodson pointed out that the non-linear relationship between arousal and cognitive capacity only holds when the cognitive task is difficult enough. For easy tasks, they suggested a linear and increasing relationship. In the arousal treatment, we aimed to compare medium-level arousal (close to the optimal level in terms of cognitive capacity) with high-level arousal. Given that we succeeded in placing the arousal levels such that the arousal increased from medium to high on the downward slope of the Yerkes-Dodson curve and that the cognitive reflection tasks were not too easy, cognitive capacity should, in theory, go down. Hence, while the effect of arousal on subjective time is the opposite of the effect of multitasking demands on subjective time, the effect of multitasking demands and arousal on cognitive capacity goes in the same direction.

This would strengthen the argument that the two channels of time perception and cognitive capacity in the multitasking experiment are independent and that the results are not driven by, for example, a causal link between time perception and cognitive performance.<sup>24</sup> For instance, if it was the case that increasing multitasking demands had a causal effect on time perception such

---

<sup>23</sup>The term cognitive performance is generally used in this literature. The concept is the same as cognitive capacity.

<sup>24</sup>To be more precise, the arousal treatment allows us to rule out that the two channels are linearly dependent. However, it is still possible that a non-linear relationship exists between them.

that time was perceived as passing quicker, the two channels would simply be two sides of the same coin. Or, the other way around, when subjective time speeds up, the time people have to solve a given problem decreases which should lead them to be more cognitively constrained than otherwise. We cannot exclude this ex-ante.

### 9.2.2 Addressing the time discrepancy between measures of time perception and time preferences

In order to shed light on the issue of time discrepancy between prospective time perception and time preferences, as a part of the arousal treatment, we measured future time perspective using a scrambled sentence task.<sup>25</sup> We then study whether subjects tend to have a greater future time perspective when their subjective time speeds up and, in turn, if those with greater future time perspective are more patient. We also measure the average causal mediation effect of future time perspective on the relationship between time perception and time preferences. Although future time perspective is not a measure of anticipatory time perception (which would be the appropriate measure to use, were it measurable), it measures whether subjects see the future as more expansive or limited. A higher score on the future time perception test would then imply that the future is experienced as closer and that future time intervals are experienced as shorter. The arousal treatment is summarized in Figure 16. We will now summarize the hypotheses of the arousal experiment.

### 9.2.3 Hypotheses

First, as predicted by the attentional-gate model of time perception and previously demonstrated experimentally by Zakay et al. (1983) and Gil et al. (2007), our sixth hypothesis is:

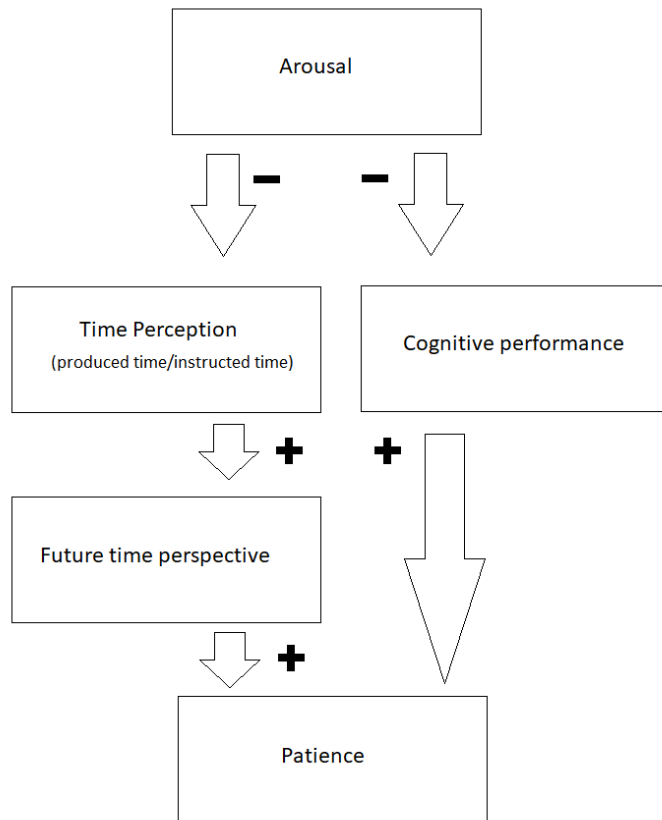
**Hypothesis 6:** *When arousal level increases from medium to high, the ratio of subjective time over clock time increases (i.e. a given time interval is perceived as longer).*

Our seventh hypothesis is an artifact of the Yerkes-Dodson curve. If arousal levels are high enough and the cognitive reflection task is sufficiently hard, performance on the cognitive reflection questions should go down.

**Hypothesis 7:** *When arousal level increases from medium to high, cognitive capacity deteriorates.*

---

<sup>25</sup>Future time perspective is individuals' perception of their remaining time in life (Carstensen et al., 1999).



**Figure 16:** A flow graph illustrating the arousal experiment

Finally, Hypothesis 8 and 9 regard future time perspective:

**Hypothesis 8:** *Future time perspective is correlated with prospective time perception and time preferences such that as the ratio of subjective time over clock time decreases, future time perspective increases. Further, an increase in future time perspective correlates with increased patience.*

**Hypothesis 9:** *Future time perspective mediates the eventual relationship between prospective time perception and time preferences.*

#### 9.2.4 The experiment

The experiment was conducted in the Behavioral lab of the University of Copenhagen in the fall of 2018. In total, 143 subjects participated in the experiment. In the experiment, performance on a cognitive reflection task,

time perception, time preferences, and future time perspective were elicited twice, each under two different arousal levels.

Arousal was induced with an external tempo in headphones. We followed the results in Chie & Karthigeyan (2009) in which the same piece of music was played at 60 bpm, 120 bpm, and 165 bpm. Cognitive performance was low at 60 bpm, high at 120 bpm, and low again at 165 bpm, suggesting that the maximum point of the Yerkes-Dodson curve lies around 120 bpm. Hence, our medium arousal condition was induced by a metronome playing 120 bpm continuously, and our high arousal condition was induced by a metronome playing 165 bpm continuously.<sup>26</sup>

The order of the tasks was fixed within each session such that the same order was repeated twice, but the order in which a subject performed the high/low arousal version was randomized. For example, in one session, the order of tasks was as follows:

*Time preferences - cognitive reflection questions - time perception - future time perspective - time preferences - cognitive reflection questions - time perception - future time perspective.*

Hence, a subject might have had the following ordering:

*Time preferences (165 bpm) - cognitive reflection questions (120 bpm) - time perception (120 bpm) - future time perspective (165 bpm) - time preferences (120 bpm) - cognitive reflection questions (165 bpm) - time perception (165 bpm) - future time perspective (120 bpm).*

The time preferences elicitation and the cognitive reflection questions were identical to the multitasking experiment, except for the difference in manipulation. In the time perception tasks, in addition to the metronome, the subjects had to solve table tasks during the time intervals.<sup>27</sup> The purpose of the table tasks was to make it harder for the subjects to count time. In the task, the subjects had a period of unknown length to answer each task. The length of the period was between 17 and 22 seconds, and the subjects were assured that the time they had was long enough for them to answer the task in a stress-less yet effective way. Figure 17 illustrates the content of the

---

<sup>26</sup>We chose not to use music but, rather, a neutral tempo from a metronome. This is due to the fact that music is expected to induce emotional responses that are heterogeneous across subjects, which might have affected the results of the experiment (see e.g. Kreutz et al., 2008).

<sup>27</sup>The table task was borrowed from Brocas et al. (2018)



table task. When a subject answered the task or the answering time ended without an answer, a new task appeared on the screen. The subjects had to answer at least 80% of the tasks correctly in order to receive their earnings for the time perception task.

	Handball	Swimming	Gymnastics	Skiing	Ping pong
Red	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>
Green	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>
Blue	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>
Yellow	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>
Purple	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>

**Figure 17:** An example of the table task. The instructions are: “Please type “x” in the box where the column to the left of Gymnastics intersects the row below Green”

Finally, we measured future time perspective. Future time perspective is individuals’ perception of their remaining time in life (Carstensen et al., 1999). It has been shown to relate to behavior in the health domain, risky behavior and school performance, and time preferences (Teuscher & Mitchell, 2011). Future time perspective is traditionally elicited with a questionnaire, such as the future time perspective scale (FTPS) developed by Carstensen & Lang (2018). Demeyer & De Raedt (2014) validated the use of a scrambled sentence task for the measure of future time perspective with the FTPS. Moreover, the authors found that the measured future time perspective can be manipulated with primings that are either future-oriented or present-oriented. In the arousal treatment, we used a scrambled sentence task, similar to the one in Demeyer & De Raedt (2014), to measure future time perspective

under different levels of arousal.

In the task, subjects were presented with a list of words and told to form a sentence from the words. It was possible to form both a future-oriented sentence and a present-oriented sentence from each word list. For example, from the words “far-away, future, close, the, is”, one could form “the future is far-away” or “the future is close”. Both sentences are grammatically correct, but while the former is present-oriented, the latter is future-oriented. The subjects were incentivized to answer the tasks as quickly as they could. Their payment depended on their rank in answering time as well as on the number of correct sentences. The time pressure during the task was important to ensure that the subjects wrote down the sentence that first came to their mind to avoid eventual self-corrections due to aspects such as social norms. The sentences used in the future time perspective task are listed in Section 9.4.1 below.

### 9.2.5 Results

The noise in the time perception elicitation part of the arousal treatment was considerably higher than in the corresponding part of the multitasking experiment. This might have been due to the somewhat demanding nature of the distracting table task that the subjects had to solve during the time perception tasks. In order to deal with the high standard deviations, we exclude observations that are outliers in the time perception elicitation.<sup>28</sup> Out of the 143 subjects participating in the tempo treatment, 38 did not fulfill this condition and were excluded from the analysis.

#### *Separating the two channels: The effect of arousal on time perception and cognitive performance*

In Table 14, we present results from regressions in which the effect of arousal on time perception is studied. Although we only observe a statistically significant effect of tempo on our non-parametric measure of time perception in the case of TR 15s, for  $\hat{a}$  of Steven’s law for time perception, we observe that when the tempo increased from 120 bpm to 165 bpm,  $\hat{a}$  decreased, indicating that  $\frac{\text{Subjective time}}{\text{Clock time}}$  increased. Hence, Hypothesis 6 is confirmed for the parametric measures of time perception but not generally for the non-parametric measures, although all but one coefficient go in the expected direction.

Table 15 reports results from regressions that study the effect of tempo

---

<sup>28</sup>While extreme outliers were defined as observations above  $Q3 + 3 \text{ IQR}$  or below  $Q1 - 3 \text{ IQR}$ , outliers were defined as observations above  $Q3 + \text{IQR}$  or below  $Q1 - \text{IQR}$ , where  $Q1$  and  $Q3$  are the first and the third quartile, respectively, and  $\text{IQR}$  is the interquartile range, i.e.  $Q3 - Q1$ .

on cognitive capacity. From the regression results, it can be seen that there is no effect on cognitive capacity when response time is not taken into account nor when controlling for response time. Hence, Hypothesis 5 is refuted. Reassuringly, the coefficient estimates go in the same direction and are of a similar magnitude

**Table 14:** Time perception, tempo treatment

	TR 7	TR 11	TR 15	TR 23	TR 34	TR 45	TR average
Tempo	-0.0274 (0.121)	-0.182 (0.127)	-0.182* (0.103)	-0.0369 (0.103)	-0.0608 (0.126)	0.0265 (0.033)	-0.118 (0.094)
Constant	0.0411 (0.191)	0.273 (0.201)	0.273* (0.162)	0.0554 (0.163)	0.0912 (0.200)	1.032*** (0.053)	0.177 (0.148)
$N$	210	210	210	210	210	210	210
$R^2$	0.000	0.019	0.029	0.001	0.002	0.006	0.015

	$\hat{a}$	$\hat{b}$
Tempo	-0.137** (0.068)	-0.0482 (0.070)
$\hat{b}$	-0.803*** (0.056)	
$\hat{a}$		-0.828*** (0.058)
Constant	0.205*** (0.107)	0.072*** (0.111)
$N$	210	210
$R^2$	0.685	0.674

Standard errors in parentheses

\*  $p < 0.1$ , \*\*  $p < 0.05$ , \*\*\*  $p < 0.01$

*Notes:* All variables except the dummy for tempo are standardized before the regression in order to make the results comparable to the results in the paper. TRX = the ratio of produced time to instructed time for time interval  $X \in \{7, 11, 15, 23, 34, 45\}$ . TR average is the average of TR7-TR45. Tempo = a dummy variable that takes the value 1 if tempo is 165 bpm. and the value 0 if tempo is 120 bpm.

Taken together, the results in Tables 14 and 15 suggest that while the effect of increased arousal/multitasking demands on cognitive capacity is similar in the arousal and multitasking experiments, the effect of arousal on time perception goes in the opposite direction of the effect of multitasking demands on time perception.

### ***Future time perspective***

In Table 16, we present regressions in which (i) future time perspective is regressed on time perception, (ii) time preferences are regressed on time per-

**Table 15:** Cognitive reflection tasks with tempo treatment

	(1)	(2)
	CR score	CR score
Tempo	0.0270 (0.098)	0.0583 (0.099)
$CR_{RT}$		-0.219* (0.113)
$CR_{RT}^2$		0.0513 (0.036)
Constant	-0.0405 (0.155)	-0.138 (0.161)
$N$	210	210
$R^2$	0.001	0.037
Subject FE	Yes	Yes

Standard errors in parentheses

\*  $p < 0.1$ , \*\*  $p < 0.05$ , \*\*\*  $p < 0.01$

*Notes:* All variables except the dummy for tempo are standardized before the regression in order to make the results comparable to the results in the paper. CR score is performance on the cognitive reflection questions.  $CR_{RT}$  is response time on the cognitive reflection questions. Tempo is a dummy variable that takes the value 1 if tempo is 165 bpm and the value 0 if tempo is 120 bpm.

ception, and (iii) time preferences are regressed on time perception and future time perspective. In regressions (1) to (3), the whole sample is included in the analysis. In regressions (4) to (6), we exclude subjects with differences in answering time on the future time perspective task that exceeded 100 seconds. Focusing only on subjects with small differences in answering speed allows us to eliminate concerns that more time used to answer the scrambled sentence task leads to “self-correction”, i.e. complying to norms that one should think about the future. From the table, it can be seen that, looking at the whole sample, there is little evidence for a link between time perception and future time perspective and future time perspective and time preferences. When subjects with small differences in answering time on the scrambled sentence task are studied, a relatively strong relationship between time perception and future time perspective emerges (about 0.3 standard deviations). We also note that the coefficient on future time perspective is positive as expected but small and statistically insignificant. Lastly, we study whether future time perspective mediates the relationship between time perception and time preferences. The average causal mediation effect is the difference between the coefficients for TR average in regressions 2/3 and 4/5. The difference goes in the predicted direction: adding future time perspective lowers the coefficient on TR average. In order to study whether the difference is statistically significant, we perform a Wald test with bootstrapped standard errors. The p-value of the test is 0.44 for the reduced sample and 0.83 for

the whole sample, indicating that we cannot reject the null hypothesis of no difference between the two coefficients.

To summarize, we find that future time perspective correlates with time perception when response time on the scrambled sentence task is taken into account. Regarding a relationship between future time perspective and time preferences, our results go in the hypothesized direction, but the obtained coefficients are small and not statistically significant. Hence, we find some evidence, although not conclusive, that support Hypothesis 8. After testing for a causal mediation effect of future time perspective in the relationship between time perception and time preferences, we cannot reject the null hypothesis of no mediation. Hence, Hypothesis 9 is refuted.

**Table 16:** Future time perspective and time perception / Future time perspective and time preferences

	(1)	(2)	(3)	(4)	(5)	(6)
	FTP	Factor late	Factor late	FTP	Factor late	Factor late
TR average	0.0380 (0.145)	-0.0381 (0.067)	-0.0403 (0.067)	0.301* (0.180)	0.0283 (0.095)	0.00807 (0.097)
FTP correct	0.350*** (0.111)	-0.0515 (0.051)	-0.0720 (0.054)	0.280** (0.139)	-0.0472 (0.073)	-0.0661 (0.075)
FTP <sub>RT</sub>	0.0319 (0.134)	0.0444 (0.062)	0.0426 (0.062)	0.0796 (0.179)	-0.00880 (0.094)	-0.0142 (0.094)
FTP <sub>RT</sub> <sup>2</sup>	0.0117 (0.069)	0.0110 (0.032)	0.0103 (0.032)	-0.671 (0.557)	0.533* (0.293)	0.578* (0.296)
FTP			0.0585 (0.046)			0.0672 (0.063)
Constant	-0.0117 (0.098)	-0.0109 (0.045)	-0.0103 (0.045)	0.296 (0.273)	-0.205 (0.144)	-0.225 (0.145)
<i>N</i>	210	210	210	148	148	148
<i>R</i> <sup>2</sup>	0.091	0.043	0.059	0.115	0.068	0.083
Subject FE	Yes	Yes	Yes	Yes	Yes	Yes
Constraint	-	-	-	Yes*	Yes*	Yes*

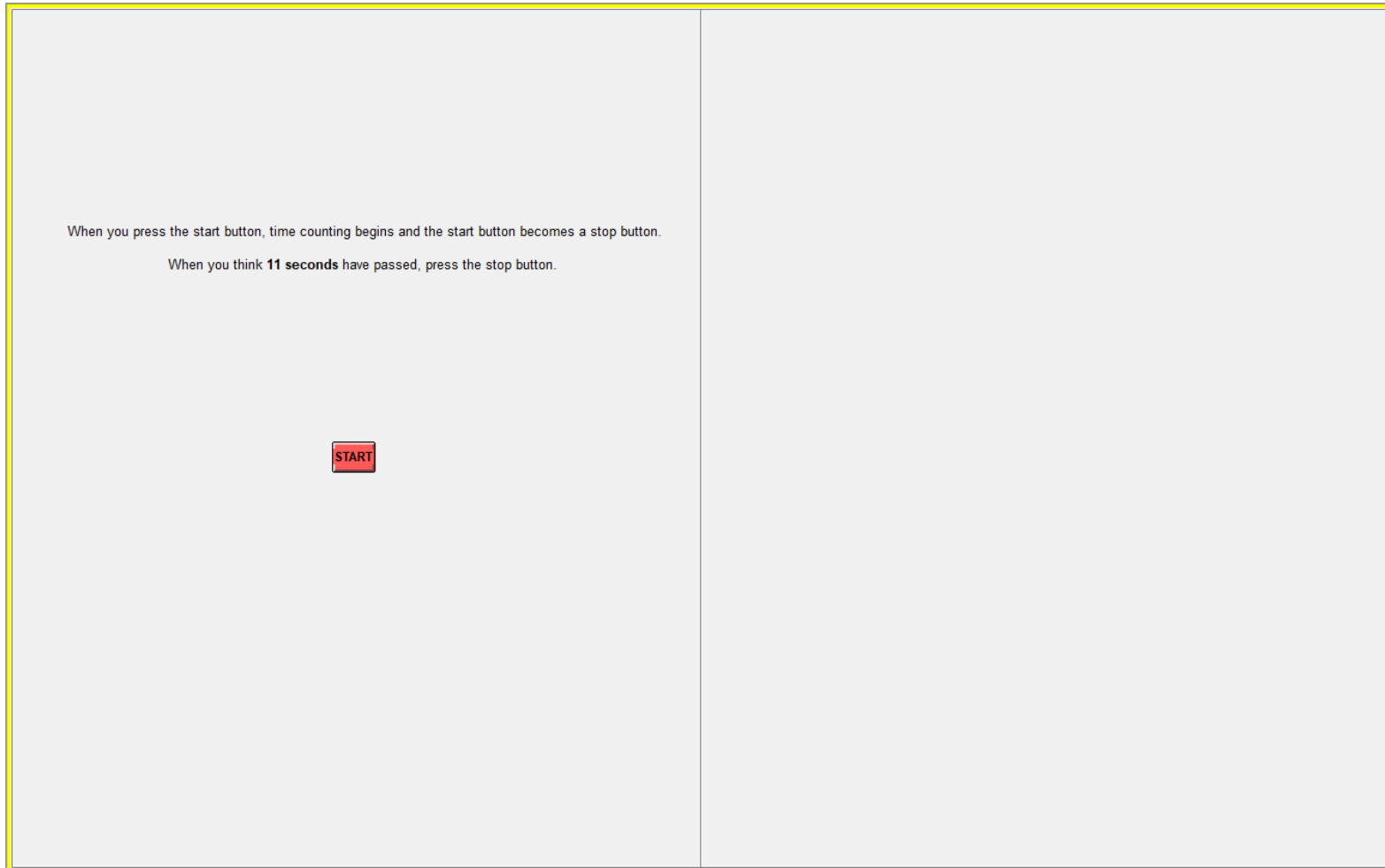
Standard errors in parentheses

\*  $p < 0.1$ , \*\*  $p < 0.05$ , \*\*\*  $p < 0.01$

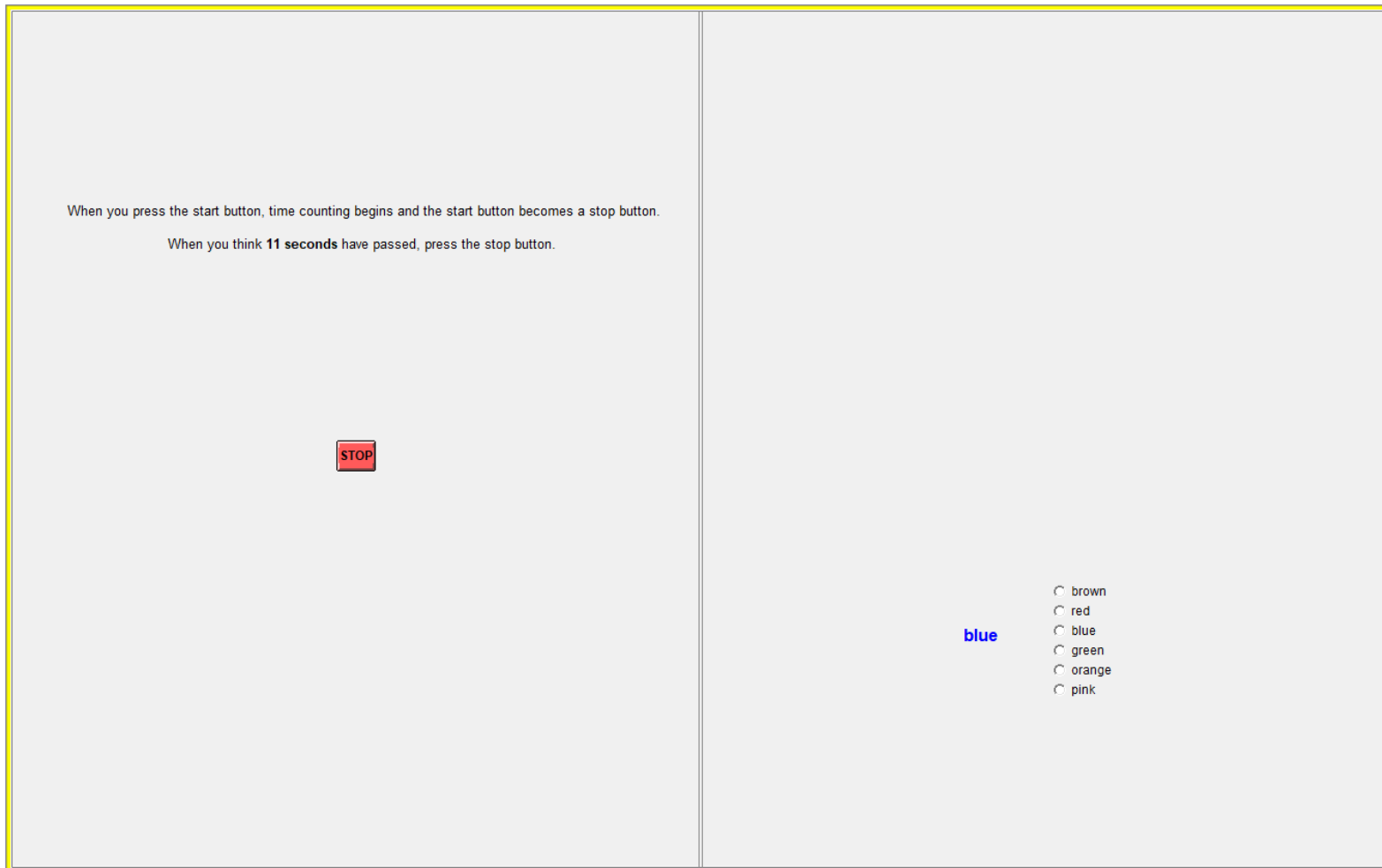
*Notes:* All variables are standardized. FTP is future time perspective, measured as the share of future oriented sentences in the scrambled sentence task. FTP correct is the number of grammatically correct sentences formed in the scrambled sentence task, FTP<sub>RT</sub> is the response time for the same task and Factor late is a factor variable of the number of late choices across all multiple price lists. \* $|\Delta\text{FTP}_{RT}| < 100$

### **9.3 Experiment screen shots**

Here, we present screen shots from both the multitasking experiment and the arousal experiment.



**Figure 18:** Time perception elicitation, first screen



**Figure 19:** Time perception elicitation, second screen in easy multitasking condition.



When you press the start button, time counting begins and the start button becomes a stop button.

When you think **15 seconds** have passed, press the stop button.

**STOP**

Please type "X" in the box where the row above Asia intersects the column to the right of Mathematics

	English	Mathematics	Chemistry	Biology	Philosophy
Europe	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>
Asia	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>
Africa	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>
America	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>
Australia	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>

OK

Figure 20: Time perception elicitation, second screen in arousal experiment.

Payment Alternative A	Payment Alternative B	Choose
80 kr tomorrow	75 kr in 3 weeks	<input type="radio"/> A <input type="radio"/> B
80 kr tomorrow	80 kr in 3 weeks	<input type="radio"/> A <input type="radio"/> B
80 kr tomorrow	85 kr in 3 weeks	<input type="radio"/> A <input type="radio"/> B
80 kr tomorrow	90 kr in 3 weeks	<input type="radio"/> A <input type="radio"/> B
80 kr tomorrow	95 kr in 3 weeks	<input type="radio"/> A <input type="radio"/> B
80 kr tomorrow	100 kr in 3 weeks	<input type="radio"/> A <input type="radio"/> B
80 kr tomorrow	105 kr in 3 weeks	<input type="radio"/> A <input type="radio"/> B
80 kr tomorrow	110 kr in 3 weeks	<input type="radio"/> A <input type="radio"/> B
80 kr tomorrow	115 kr in 3 weeks	<input type="radio"/> A <input type="radio"/> B
80 kr tomorrow	120 kr in 3 weeks	<input type="radio"/> A <input type="radio"/> B

**Figure 21:** Time preferences elicitation, an example of a multiple price list.



**Figure 22:** Cognitive load during time preferences elicitation (pop-up).

A screenshot of a software interface for a scrambled sentence task. On the left side, there is a list of six words, each preceded by a number from 1 to 6. The words are: 1 seems, 2 be, 3 limited, 4 time, 5 infinite, and 6 to. In the center of the screen, there are five empty rectangular boxes arranged horizontally, intended for the user to drag and drop the words into. At the bottom center of the interface, there is a small rectangular button labeled "OK". The entire interface is enclosed in a yellow border.

**Figure 23:** An example of the future time perspective scrambled sentence task.

## 9.4 Questions used in the experiment

### 9.4.1 Sentences used in the scrambled sentence task to measure future time perspective

The following 10 scrambled sentences were used in the experiment.

1. is future the close far-away → “the future is close” (future-oriented) or “the future is far-away” (present-oriented)
2. ahead crucial planning unnecessary is → “planning ahead is crucial” (future-oriented) or “planning ahead is unnecessary” (present-oriented)
3. seems be limited time infinite to → “time seems to be infinite” (future-oriented) “time seems to be limited” (present-oriented)
4. act think then first → “think first then act” (“first think then act”) (future-oriented) or “act first then think ( “first act then think”) (present-oriented)
5. the focus present future on → “focus on the future” (future-oriented) or “focus on the present” (present-oriented)
6. rarely often the think future about I → “I often think about the future” (future-oriented) or “I rarely think about the future” (present-oriented)
7. detailed I plans loose make → “I make detailed plans” (future-oriented) or “I make loose plans” (present-oriented)
8. important present future the is → “the future is important” (future-oriented) or “the present is important” (present-oriented)
9. planning horizon I long short have a → “I have a long planning horizon” (future-oriented) or “I have a short planning horizon” (present-oriented)
10. imagine hard it’s easy to future the → “it’s easy to imagine the future” (future-oriented) or “it’s hard to imagine the future” (present-oriented)

### 9.4.2 Cognitive reflection questions

The following eight cognitive reflection questions were used in the experiment.

1. A bat and a ball cost 62 kr. in total. The bat costs 60 kr. more than the ball. How many kronor does the ball cost?

2. If it takes 5 machines 5 minutes to make 5 widgets, how many minutes would it take 100 machines to make 100 widgets?
3. In a lake, there is a patch of lily pads. Every day, the patch doubles in size. If it takes 48 days for the patch to cover the entire lake, how many days would it take for the patch to cover half of the lake?
4. If John can drink one barrel of water in 6 days, and Mary can drink one barrel of water in 12 days, how many days would it take them to drink one barrel of water together?
5. Jerry received both the 15th highest and the 15th lowest mark in the class. How many students are in the class?
6. If you're running a race and you pass the person in second place, what place are you in?
7. Simon decided to invest 8,000 kr. in the stock market one day early in 2008. Six months after he invested, on July 17, the stocks he had purchased were down 50%. Fortunately for Simon, from July 17 to October 17, the stocks he had purchased went up 75%. At this point, Simon has: 1: Broken even, 2: Gained money 3: Lost money
8. A farmer had 15 sheep and all but 8 died. How many are left?

## 9.5 Regression tables

### Regression tables corresponding to bar-figures in the paper

Here we present the regressions tables that correspond to the coefficient-plots in Section 6. While the results in the coefficient-plots are standardized, we do not standardize the coefficients in the regression tables presented here.

**Table 17:** Time perception when multitasking demands increase. Regressions corresponding to Figure 10.

	TR 7s	TR 11s	TR 15s	TR 23s	TR 34s	TR 45s	TR average
MD	0.0456 (0.035)	0.126* (0.069)	0.188** (0.075)	0.0516 (0.033)	0.0688** (0.029)	0.106*** (0.031)	0.0978*** (0.028)
Constant	1.333*** (0.055)	1.245*** (0.109)	1.145*** (0.118)	1.296*** (0.052)	1.199*** (0.045)	1.187*** (0.050)	1.234*** (0.044)
$N$	288	288	288	288	288	288	288
$R^2$	0.012	0.023	0.042	0.017	0.039	0.074	0.080
Subject FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes

	$\hat{a}$	$\hat{b}$
MD	0.435** (0.175)	0.0276* (0.014)
$\hat{b}$	-9.006*** (0.730)	
$\hat{a}$		-0.0574*** (0.005)
Constant	9.952*** (0.754)	1.035*** (0.023)
$N$	288	288
$R^2$	0.525	0.517
Subject FE	Yes	Yes

Standard errors in parentheses

\*  $p < 0.1$ , \*\*  $p < 0.05$ , \*\*\*  $p < 0.01$

Notes: MD = a dummy variable that takes the value 1 if multitasking demands are high and the value 0 if multitasking demands are low. TR Xs = Ratio of produced time over instructed time for time interval X=7, 11, 15, 23, 34, 45 seconds. TR average is the average of TR7s-TR45s.

**Table 18:** Cognitive reflection tasks when multitasking demands increase. Regression corresponding to Figure 11.

	(1) CR score	(2) CR score
MD	0.0972 (0.113)	0.0628 (0.114)
$CR_{RT}$		0.00289 (0.003)
$CR_{RT}^2$		0.000000821 (0.000)
Constant	1.785*** (0.178)	1.407*** (0.293)
$N$	288	288
$R^2$	0.005	0.058
Subject FE	Yes	Yes

Standard errors in parentheses

\*  $p < 0.1$ , \*\*  $p < 0.05$ , \*\*\*  $p < 0.01$

Notes: MD = a dummy variable that takes the value 1 if multitasking demands are high and the value 0 if multitasking demands are low, CR score = score on cognitive reflection questions,  $CR_{RT}$  = response time for cognitive reflection questions.

**Table 19:** Time preferences when multitasking demands increase. Regressions corresponding to Figure 12.

	Factor late	$\hat{\delta}$	$\hat{\beta}$
MD	0.00621 (0.045)	-0.0000309 (0.000)	0.00232 (0.005)
$\hat{\beta}$		-0.0186*** (0.003)	
$\hat{\delta}$			-9.343*** (1.709)
Constant	-0.00217 (0.071)	1.016*** (0.003)	10.25*** (1.706)
$N$	288	288	288
$R^2$	0.000	0.175	0.176
Subject FE	Yes	Yes	Yes

Standard errors in parentheses

\*  $p < 0.1$ , \*\*  $p < 0.05$ , \*\*\*  $p < 0.01$

Notes: Factor late = a factorization of the number of late choices in all multiple price lists, MD=a dummy variable that takes the value 1 if multitasking demands are high and the value 0 if multitasking demands are low.



**Table 20:** Differences in time preferences regressed on differences in time perception and cognitive performance when multitasking demands increase. Regressions corresponding to Figure 13.

	(1)	(2)	(3)	(4)	(5)	(6)
	$\Delta$ Factor late	$\Delta$ Factor late	$\Delta\hat{\delta}$	$\Delta\hat{\delta}$	$\Delta\hat{\beta}$	$\Delta\hat{\beta}$
$\Delta$ TR average	0.359* (0.209)		0.000411 (0.001)			0.0453*** (0.017)
$\Delta$ CR score	0.0204 (0.025)	0.0134 (0.025)	-0.000267* (0.000)	-0.000235 (0.000)	-0.00460 (0.004)	-0.00341 (0.004)
$\Delta$ CR <sub>RT</sub>	0.000472 (0.001)	0.000530 (0.001)	0.0000291 (0.000)	0.00000302 (0.000)	0.000130** (0.000)	0.000128** (0.000)
$\Delta$ CR <sub>RT</sub> <sup>2</sup>	0.0000206* (0.000)	0.0000203* (0.000)	1.36e-08** (0.000)	1.33e-08** (0.000)	0.000000191 (0.000)	0.000000201 (0.000)
$\Delta\hat{b}$		0.204 (0.223)	0.0000649 (0.001)		0.00170 (0.027)	
$\Delta\hat{a}$		0.0322 (0.030)	-0.0000707 (0.000)		0.00165 (0.003)	
$\Delta\hat{\beta}$			-0.0181* (0.010)			
$\Delta\hat{\delta}$				-0.0189* (0.010)		
Constant	-0.0192 (0.077)	-0.0112 (0.079)	0.000607** (0.000)	0.000432* (0.000)	-8.704*** (2.368)	-8.590*** (2.330)
$N$	144	144	144	144	144	144
$R^2$	0.157	0.128	0.230	0.227	0.262	0.302
Session FE	Yes	Yes	Yes	Yes	Yes	Yes

Standard errors in parentheses

\*  $p < 0.1$ , \*\*  $p < 0.05$ , \*\*\*  $p < 0.01$

Notes:  $\Delta$  indicates different in the corresponding variable between the high and low cognitive load conditions. TR average is the average of the ratio of produced time to instructed time across all six time intervals, CR score is performance on the cognitive reflection tasks, CR<sub>RT</sub> is response time on the cognitive reflection questions.

**Table 21:** Between subjects, given low multitasking demands. Regressions corresponding to Figure 14

	(1)	(2)	(3)	(4)	(5)	(6)
	Factor late	Factor late	$\hat{\delta}$	$\hat{\delta}$	$\hat{\beta}$	$\hat{\beta}$
TR average	0.727*** (0.206)		0.00107** (0.001)		0.0201 (0.017)	
CR score	0.139** (0.061)	0.152** (0.062)	-0.0000836 (0.000)	-0.0000818 (0.000)	0.0130** (0.005)	0.0138*** (0.005)
CR <sub>RT</sub>	0.00502** (0.002)	0.00515** (0.002)	0.00000879 (0.000)	0.00000898 (0.000)	0.000286 (0.000)	0.000272 (0.000)
CR <sub>RT</sub> <sup>2</sup>	-0.00000873*** (0.000)	-0.00000856*** (0.000)	-1.91e-08** (0.000)	-1.84e-08** (0.000)	-0.000000356 (0.000)	-0.000000342 (0.000)
Woman	-0.0816 (0.061)	-0.0752 (0.059)	-0.000180 (0.000)	-0.000171 (0.000)	-0.00171 (0.007)	-0.00163 (0.007)
Age	0.135 (0.156)	0.117 (0.163)	0.000327 (0.000)	0.000303 (0.000)	0.00142 (0.013)	0.000411 (0.013)
Age <sup>2</sup>	-0.00218 (0.003)	-0.00188 (0.003)	-0.00000589 (0.000)	-0.00000546 (0.000)	0.00000409 (0.000)	0.0000212 (0.000)
Risk preferences	0.0486 (0.043)	0.0469 (0.043)	0.000191** (0.000)	0.000183** (0.000)	-0.0000631 (0.003)	-0.000591 (0.003)
$\hat{a}$		0.185*** (0.066)		0.000152 (0.000)		0.00291 (0.006)
$\hat{b}$		0.177 (0.757)		0.000473 (0.001)		-0.0504 (0.062)
$\hat{\beta}$			0.00381 (0.002)	0.00410* (0.002)		
$\hat{\delta}$					7.572* (4.463)	7.820* (4.384)
Constant	-3.863* (2.159)	-3.116 (2.289)	0.987*** (0.005)	0.988*** (0.005)	-6.750 (4.470)	-6.915 (4.400)
N	144	144	144	144	144	144
R <sup>2</sup>	0.210	0.204	0.251	0.229	0.170	0.179
Session FE	Yes	Yes	Yes	Yes	Yes	Yes

Standard errors in parentheses

\*  $p < 0.1$ , \*\*  $p < 0.05$ , \*\*\*  $p < 0.01$

Notes: TR average is the average of the ratio of produced time to instructed time across all six time intervals, CR score is performance on the cognitive reflection tasks, CR<sub>RT</sub> is response time on the cognitive reflection questions. Risk Preferences are a survey measure of risk attitudes, increasing in risk tolerance.

**Table 22:** Between subjects, survey based measure of time preferences given low multitasking demands. Regressions corresponding to Figure 15

	(1)	(2)	(3)
	TimePref, survey	TimePref, survey	TimePref, survey
TR average	1.014*	0.967*	
	(0.515)	(0.499)	
CR score	0.141	0.136	0.140
	(0.112)	(0.110)	(0.115)
CR <sub>RT</sub>	0.00396		0.00404
	(0.005)		(0.005)
CR <sub>RT</sub> <sup>2</sup>	-0.00000757		-0.00000672
	(0.000)		(0.000)
Woman	-0.0505	-0.0653	-0.0470
	(0.128)	(0.127)	(0.145)
Age	-0.143	-0.171	-0.168
	(0.344)	(0.349)	(0.362)
Age <sup>2</sup>	0.00190	0.00242	0.00244
	(0.006)	(0.007)	(0.007)
Risk preferences	0.202**	0.201**	0.193**
	(0.080)	(0.080)	(0.085)
$\hat{a}$			-0.0271
			(0.137)
$\hat{b}$			-0.444
			(1.461)
Constant	6.812	7.604	9.074*
	(4.628)	(4.674)	(5.118)
<i>N</i>	144	144	144
<i>R</i> <sup>2</sup>	0.131	0.124	0.101
Session FE	Yes	Yes	Yes

Standard errors in parentheses

\*  $p < 0.1$ , \*\*  $p < 0.05$ , \*\*\*  $p < 0.01$

*Notes:* TR average is the average of the ratio of produced time to instructed time across all six time intervals, CR score is performance on the cognitive reflection tasks, CR<sub>RT</sub> is response time on the cognitive reflection questions. Risk Preferences are a survey measure of risk attitudes, increasing in risk tolerance.

### Regressions including measures of time preferences, with a control for response time

Here, we present variants of Tables 23 and 20 with a control for response time on the multiple price lists. The control we use is a proxy of response time based on the number of Stroop tasks subjects answered during the time they were answering the multiple price lists. Since the Stroop tasks arrived with the expected delay of 7 seconds, we can calculate a proxy for the average number of seconds used on each multiple price list of the time preferences elicitation.

**Table 23:** Time preferences when multitasking demands increase, controlling for answering time on multiple price lists.

	Factor late	$\hat{\delta}$	$\hat{\beta}$
MD	-0.0149 (0.054)	-0.000169 (0.000)	0.00212 (0.006)
MPL-time-Proxy	0.00619 (0.009)	0.0000243 (0.000)	-0.0000817 (0.001)
MPL-time-Proxy <sup>2</sup>	-0.0000214 (0.000)	-3.29e-08 (0.000)	-0.000000169 (0.000)
$\hat{\beta}$		-0.0186*** (0.004)	
$\hat{\delta}$			-9.267*** (1.804)
Constant	-0.132 (0.181)	1.015*** (0.003)	10.17*** (1.800)
$N$	275	275	275
$R^2$	0.005	0.179	0.175
Subject FE	Yes	Yes	Yes

Standard errors in parentheses

\*  $p < 0.1$ , \*\*  $p < 0.05$ , \*\*\*  $p < 0.01$

Notes: Factor late = a factorization of the number of late choices in all multiple price lists, MD=a dummy variable that takes the value 1 if multitasking demands are high and the value 0 if multitasking demands are low.

**Table 24:** Differences in time preferences regressed on differences in time perception and cognitive performance, controlling for difference in answering time on the multiple price lists.

	(1)	(2)	(3)	(4)	(5)	(6)
	$\Delta$ Factor late	$\Delta$ Factor late	$\Delta\hat{\delta}$	$\Delta\hat{\beta}$	$\Delta\hat{\delta}$	$\Delta\hat{\beta}$
$\Delta$ TR average	0.414* (0.228)				0.000481 (0.001)	0.0533*** (0.017)
$\Delta$ CR score	0.0175 (0.028)	0.00999 (0.028)	-0.000323* (0.000)	-0.00616 (0.004)	-0.000303* (0.000)	-0.00520 (0.004)
$\Delta$ CR <sub>RT</sub>	0.000303 (0.001)	0.000427 (0.001)	0.00000356 (0.000)	0.000161** (0.000)	0.00000378 (0.000)	0.000149** (0.000)
$\Delta$ CR <sub>RT</sub> <sup>2</sup>	0.00000158 (0.000)	0.00000171 (0.000)	1.39e-08** (0.000)	0.000000228 (0.000)	1.39e-08** (0.000)	0.000000214 (0.000)
$\Delta$ MPL-time-Proxy	0.00620 (0.008)	0.00631 (0.008)	-0.0000301 (0.000)	-0.000525 (0.001)	-0.0000229 (0.000)	-0.000510 (0.001)
$\Delta$ MPL-time-Proxy <sup>2</sup>	-0.0000815 (0.000)	-0.000111 (0.000)	0.000000764 (0.000)	0.00000657 (0.000)	0.000000481 (0.000)	0.0000117 (0.000)
$\Delta\hat{b}$		0.303 (0.275)	0.0000428 (0.001)	0.0139 (0.028)		
$\Delta\hat{a}$		0.0485 (0.041)	-0.0000991 (0.000)	0.00425 (0.003)		
$\Delta\hat{\beta}$			-0.0180* (0.011)		-0.0193* (0.011)	
$\Delta\hat{\delta}$				-8.385*** (2.464)		-8.456*** (2.372)
Constant	-0.0268 (0.142)	-0.0197 (0.149)	-0.000136 (0.001)	-0.00144 (0.018)	-0.000164 (0.001)	-0.00359 (0.017)
N	131	131	131	131	131	131
R <sup>2</sup>	0.169	0.140	0.232	0.279	0.228	0.320
Session FE	Yes	Yes	Yes	Yes	Yes	Yes

Standard errors in parentheses

\*  $p < 0.1$ , \*\*  $p < 0.05$ , \*\*\*  $p < 0.01$

Notes:  $\Delta$  indicates different in the corresponding variable between the high and low cognitive load conditions. TR average is the average of produced time to instructed time across all six time intervals, CR score is performance on the cognitive reflection tasks, CR<sub>RT</sub> is response time on the cognitive reflection questions and MPL-time-Proxy is a proxy of the response time for the time preference elicitation. Due to missing data in the variable MPLtime proxy, 11 observations have been eliminated from the original dataset.

## Regression tables with a reduced sample

Here, we present variants of the results in Figures 10 to 13 in which extreme outliers in terms of the difference in time measure between the two multitasking conditions are excluded. The extreme outliers are observations that lie outside the interval  $[Q1 - 3IQR, Q3 + 3IQR]$ , where  $Q1$  and  $Q3$  are the first and the third quartile, respectively, and  $IQR = Q3 - Q1$ . Hence, we excluded observations that fulfilled any of the following constraints:  $\Delta TR_{average} < -0.85$ ,  $\Delta TR_{average} > 1.01$ ,  $\Delta \hat{a} < -2.94$ ,  $\Delta \hat{a} > 3.14$ ,  $\Delta \hat{b} < -0.324$ ,  $\Delta \hat{b} > 0.74$ ,  $\Delta CR_{RT} < -316$  or  $\Delta CR_{RT} > 356$ . The remaining sample consists of 130 subjects. The reduced sample within regressions are presented in Figures 25-28.

For the between subject regressions presented in Figures 14 and 15, we redo the regressions excluding outliers in terms of time measure in the low multitasking demand conditions. Hence, we excluded observations that fulfilled any of the following constraints:  $TR_{average} > 2.64$ ,  $a > 4.35$ ,  $b < 0.4$ ,  $b > 1.52$  and  $CR_{RT} > 329$ . The remaining sample consists of 136 subjects. The reduced sample between regressions are presented in Figures 29 and 30.

**Table 25:** Time perception when multitasking demands increase. Excluding extreme outliers.

	TR 7s	TR 11s	TR 15s	TR 23s	TR 34s	TR 45s	TR average
MD	0.0538 (0.035)	0.0972*** (0.032)	0.0641** (0.031)	0.0615* (0.033)	0.0794*** (0.028)	0.0856*** (0.027)	0.0736*** (0.021)
Constant	1.285*** (0.055)	1.220*** (0.051)	1.243*** (0.049)	1.251*** (0.052)	1.169*** (0.044)	1.195*** (0.042)	1.227*** (0.033)
$N$	260	260	260	260	260	260	260
$R^2$	0.018	0.065	0.032	0.026	0.059	0.073	0.089
Subject FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes

	$\hat{a}$	$\hat{b}$
MD	0.127*** (0.036)	0.0246*** (0.007)
$\hat{b}$	-4.474*** (0.224)	
$\hat{a}$		-0.169*** (0.008)
Constant	5.739*** (0.222)	1.205*** (0.016)
$N$	260	260
$R^2$	0.759	0.759
Subject FE	Yes	Yes

Standard errors in parentheses

\*  $p < 0.1$ , \*\*  $p < 0.05$ , \*\*\*  $p < 0.01$

Notes: MD = Multitasking demands. TR Xs = Ratio of produced time over instructed time for time interval X=7, 11, 15, 23, 34, 45 seconds. TR average is the average of TR7s-TR45s.

**Table 26:** Cognitive reflection tasks when multitasking demands increase. Excluding extreme outliers.

	(1) CR score	(2) CR score
MD	0.169 (0.118)	0.101 (0.123)
$CR_{RT}$		0.00461 (0.007)
$CR_{RT}^2$		-0.00000408 (0.000)
Constant	1.723*** (0.187)	1.292** (0.521)
$N$	260	260
$R^2$	0.016	0.045
Subject FE	Yes	Yes

Standard errors in parentheses

\*  $p < 0.1$ , \*\*  $p < 0.05$ , \*\*\*  $p < 0.01$

Notes: MD = multitasking demands, CR score = score on cognitive reflection questions,  $CR_{RT}$  = response time for cognitive reflection questions.

**Table 27:** Time preferences under multitasking demands. Extreme outliers are excluded from the sample.

	Factor late	$\hat{\delta}$	$\hat{\beta}$
MD	0.0242 (0.045)	-0.0000414 (0.000)	0.00199 (0.005)
$\hat{\beta}$		-0.0176*** (0.004)	
$\hat{\delta}$			-8.485*** (1.790)
Constant	0.00439 (0.070)	1.015*** (0.003)	9.394*** (1.787)
$N$	260	260	260
$R^2$	0.002	0.150	0.151
Subject FE	Yes	Yes	Yes

Standard errors in parentheses

\*  $p < 0.1$ , \*\*  $p < 0.05$ , \*\*\*  $p < 0.01$

Notes: Factor late = a factorization of the number of late choices in all multiple price lists, MD=multitasking demands.



**Table 28:** Differences in time preferences regressed on differences in time perception and cognitive performance. Extreme outliers are excluded from the sample.

	(1)	(2)	(3)	(4)	(5)	(6)
	$\Delta$ Factor late	$\Delta$ Factor late	$\Delta\hat{\delta}$	$\Delta\hat{\delta}$	$\Delta\hat{\beta}$	$\Delta\hat{\beta}$
$\Delta$ TR average	0.276 (0.180)			0.00160 (0.001)		0.0507** (0.024)
$\Delta$ CR score	0.0130 (0.027)	0.00432 (0.027)	-0.000273 (0.000)	-0.000236 (0.000)	-0.00723* (0.004)	-0.00636 (0.004)
$\Delta$ CR <sub>RT</sub>	-0.000258 (0.001)	-0.000196 (0.001)	0.00000361 (0.000)	0.00000282 (0.000)	0.000101 (0.000)	0.0000795 (0.000)
$\Delta$ CR <sub>RT</sub> <sup>2</sup>	0.0000852** (0.000)	0.00000872** (0.000)	-2.50e-09 (0.000)	5.12e-09 (0.000)	0.00000124** (0.000)	0.00000146** (0.000)
$\Delta\hat{b}$		0.464 (0.508)	-0.000879 (0.003)		-0.00335 (0.064)	
$\Delta\hat{a}$		0.0106 (0.086)	-0.000360 (0.000)		-0.000193 (0.010)	
$\Delta\hat{\beta}$			-0.0172 (0.012)	-0.0182 (0.012)		
$\Delta\hat{\delta}$					-7.526*** (2.800)	-7.753*** (2.592)
Constant	0.0219 (0.069)	0.0407 (0.079)	0.000656* (0.000)	0.000451 (0.000)	0.00980 (0.008)	0.00622 (0.008)
$N$	130	130	130	130	130	130
$R^2$	0.135	0.136	0.196	0.206	0.272	0.299
Session FE	Yes	Yes	Yes	Yes	Yes	Yes

Standard errors in parentheses

\*  $p < 0.1$ , \*\*  $p < 0.05$ , \*\*\*  $p < 0.01$

Notes:  $\Delta$  indicates different in the corresponding variable between the high and low cognitive load conditions. TR average is the average of the ratio of produced time to instructed time across all six time intervals, CR score is performance on the cognitive reflection tasks, CR<sub>RT</sub> is response time on the cognitive reflection questions.

**Table 29:** Between subjects, given low multitasking demands. Extreme outliers are excluded from the sample-

	(1)	(2)	(3)	(4)	(5)	(6)
	Factor late	Factor late	$\hat{\delta}$	$\hat{\delta}$	$\hat{\beta}$	$\hat{\beta}$
TR average	0.507 (0.313)		0.00142** (0.001)		-0.00280 (0.025)	
CR score	0.152** (0.066)	0.158** (0.065)	-0.000106 (0.000)	-0.0000924 (0.000)	0.0153*** (0.005)	0.0156*** (0.005)
CR <sub>RT</sub>	0.00244 (0.007)	0.00277 (0.007)	-0.00000333 (0.000)	-0.00000375 (0.000)	-0.0000704 (0.001)	-0.0000773 (0.001)
CR <sub>RT</sub> <sup>2</sup>	1.01e-08 (0.000)	-0.00000135 (0.000)	1.76e-08 (0.000)	2.09e-08 (0.000)	0.00000102 (0.000)	0.000000969 (0.000)
Woman	-0.0744 (0.062)	-0.0719 (0.062)	-0.000198 (0.000)	-0.000185 (0.000)	-0.00135 (0.007)	-0.00135 (0.007)
Age	0.171 (0.174)	0.165 (0.176)	0.000440 (0.000)	0.000441 (0.000)	0.00119 (0.014)	-0.0000804 (0.014)
Age <sup>2</sup>	-0.00288 (0.003)	-0.00277 (0.003)	-0.00000797 (0.000)	-0.00000801 (0.000)	0.0000102 (0.000)	0.0000348 (0.000)
Risk preferences	0.0444 (0.044)	0.0472 (0.045)	0.000177** (0.000)	0.000180** (0.000)	-0.000979 (0.004)	-0.000990 (0.004)
$\hat{a}$		0.237 (0.218)		0.000627 (0.000)		-0.000793 (0.017)
$\hat{b}$		0.330 (1.295)		0.00294 (0.002)		-0.105 (0.106)
$\hat{\beta}$			0.00362 (0.002)	0.00378 (0.002)		
$\hat{\delta}$					7.396 (4.732)	7.430 (4.629)
Constant	-3.828 (2.527)	-3.857 (2.982)	0.987*** (0.006)	0.984*** (0.007)	-6.520 (4.737)	-6.430 (4.640)
$N$	136	136	136	136	136	136
$R^2$	0.200	0.198	0.223	0.202	0.183	0.192
Session FE	Yes	Yes	Yes	Yes	Yes	Yes

Standard errors in parentheses

\*  $p < 0.1$ , \*\*  $p < 0.05$ , \*\*\*  $p < 0.01$

Notes: TR average is the average of the ratio of produced time to instructed time across all six time intervals, CR score is performance on the cognitive reflection tasks, CR<sub>RT</sub> is response time on the cognitive reflection questions. Risk Preferences are a survey measure of risk attitudes, increasing in risk tolerance.

**Table 30:** Between subjects, survey based measure of time preferences given low multitasking demands. Extreme outliers are excluded from the sample.

	(1)	(2)	(3)
	TimePref, survey	TimePref, survey	TimePref, survey
TR average	1.658** (0.654)	1.749*** (0.633)	
CR score	0.0893 (0.113)	0.0695 (0.108)	0.114 (0.115)
CR <sub>RT</sub>	-0.0130 (0.013)		-0.0142 (0.014)
CR <sub>RT</sub> <sup>2</sup>	0.0000419 (0.000)		0.0000480 (0.000)
Woman	-0.0906 (0.129)	-0.0850 (0.127)	-0.0728 (0.137)
Age	0.0323 (0.340)	0.0812 (0.326)	0.0131 (0.367)
Age <sup>2</sup>	-0.00165 (0.006)	-0.00254 (0.006)	-0.00130 (0.007)
Risk preferences	0.191** (0.078)	0.195** (0.078)	0.193** (0.084)
$\hat{a}$			0.559 (0.466)
$\hat{b}$			1.970 (2.343)
Constant	5.219 (4.867)	3.574 (4.479)	4.921 (5.842)
$N$	136	136	136
$R^2$	0.185	0.178	0.144
Session FE	Yes	Yes	Yes

Standard errors in parentheses

\*  $p < 0.1$ , \*\*  $p < 0.05$ , \*\*\*  $p < 0.01$

*Notes:* TR average is the average of the ratio of produced time to instructed time across all six time intervals, CR score is performance on the cognitive reflection tasks, CR<sub>RT</sub> is response time on the cognitive reflection questions. Risk Preferences are a survey measure of risk attitudes, increasing in risk tolerance.