PSYCHOLOGICAL CONSEQUENCES OF FINANCIAL SCARCITY

by

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A THESIS SUBMITTED IN PARTIAL FULFILLMENT OF
THE REQUIREMENTS FOR THE DEGREE OF

DOCTOR OF PHILOSOPHY

in

THE FACULTY OF GRADUATE AND POSTDOCTORAL STUDIES

(Psychology)

THE UNIVERSITY OF BRITISH COLUMBIA

(Vancouver)

June 2024

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Psychological consequences of financial scarcity

Submitted by Brandon M. Tomm in partial fulfillment of the requirements for

the degree of Doctor of Philosophy

in Psychology

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Abstract

Financial scarcity affects attention and decision making, but it is not known how these effects translate to behaviours which can make the condition of scarcity even worse. It is also not well understood which cognitive mechanisms are affected by scarcity. In 10 experiments, I used a variety of scarcity-induction methods and scarcity measurements to examine how scarcity can affect a variety of psychological processes. I found that scarcity induced an attentional bias such that people under an objective financial constraint were not able to adaptively up-regulate attention to useful information, resulting in a reduction in the use of a useful discount that would have alleviated the financial constraint in the first place (Chapter 2). Follow-up studies suggested that the attentional burden of scarcity can be partially alleviated by moving crucial information closer to the centre of focus (Chapter 3). Next, I used a numerical perception paradigm to investigate how both scarcity-scenario priming and cognitive load affect perception of hypothetical future income and future expenses (Chapter 4). This paradigm was extensively fruitful in showing how objective scarcity, subjective scarcity, and relative subjective scarcity can have independent effects on numerical perception. In general, people under objective scarcity estimate lower totals of future income and expenses while people under subjective scarcity estimated higher totals of future income and expenses. This is a novel finding with important theoretical implications for the scarcity literature: Scarcity is not a unitary construct and future research must account for the variety of ways scarcity can be experienced. Finally, I investigated how scarcity affects attention and decision making with regard to a job advertisement (Chapter 5). I found no evidence that scarcity affects how people attended to the job advertisement. These results support the need to differentiate the different varieties of scarcity in future research.
Lay Summary

Low-income people are sometimes stereotyped as unintelligent or foolish, but anyone who has experienced financial struggle can tell you that poverty brings its own set of challenges. My research explores how financial strain can affect our mental functioning. I showed that financial scarcity makes us focus more on dollars and cents and how this causes us to miss money-saving opportunities. I also found that scarcity can even affect our ability to do rough mental math. But most importantly, this work shows that there are different ways that people can experience financial scarcity – in our wallets, in our minds, or in our social life – and the way we experience scarcity can affect our mental functioning differently. This is a new finding that will improve future research because scientists now know how important it is to study multiple types of financial scarcity and not just what we see in our bank account.
Preface

All experiments reported in this dissertation were conducted in the Behavioural Sustainability Lab at the Department of Psychology at the University of British Columbia under the direction of Dr. Jiaying Zhao. Dr. Zhao and I designed the experiments together. I built all experiments, collected and analyzed all data, and wrote the manuscript. All data processing and analysis was done using R version 4.3.2 (R Core Team, 2023).

Portions of Chapter 1 are published as Zhao, J., & Tomm, B. M. (2018). Psychological responses to scarcity. In Oxford Research Encyclopedia of Psychology. Braddick, O. (Ed.), New York: Oxford University Press. Dr. Jiaying Zhao and I worked together on the outline and theoretical framework. I wrote the entirety of this Chapter while the published version contains edits by Dr. Zhao.

Portions of Chapter 2 have been submitted for publication as Tomm, B. M., Shafir, E., & Zhao, J. (submitted). Scarcity captures attention and induces neglect: Eyetracking and behavioral evidence. (Preprint: psyarxiv.com/c9jq6). The original idea for the experiments in Chapter 2 came from Dr. Eldar Shafir. I built all the experiments, collected and analyzed the data, and wrote the draft which appears in this dissertation. The version submitted for publication contains edits and additions written by Dr. Shafir and Dr. Zhao.

All data was collected following approval from the Behavioural Research Ethics Board at the University of British Columbia under the project title “The psychology of resource scarcity” (Certificate number H13-02686). No part of this work was created using generative artificial intelligence technology.
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List of Abbreviations

ERP  Event-related potential
FA   Financial Avoidance (scale)
fMRI Functional magnetic resonance imaging
GDP  Gross domestic product
IQ   Intelligence quotient
Mturk Amazon Mechanical Turk
OSF  Open Science Framework (osf.io)
PIFS Psychological Inventory of Financial Scarcity
RCT  Randomized controlled trial
SES  Socioeconomic status
US   The United States of America
USD  United States Dollars
List of Symbols

$d$  Cohen’s d
$F$  Fisher’s F test
$M$  Mean
$N$  Sample size
$p$  P value
$r$  Pearson’s correlation coefficient
$r_{pb}$  Point biserial correlation coefficient
$r_\phi$  Phi coefficient
$SD$  Standard deviation
$t$  Student’s t test
$U$  Mann-Whitney U test
$W$  Wilcoxon test
$\beta$  Regression coefficient
$\eta^2_p$  Partial eta-squared
$\phi_c$  Cramér’s V
$\chi^2$  Pearson’s Chi-squared test
$\omega^2$  Omega squared
Acknowledgements

I would first like to thank my supervisor, Dr. Jiaying Zhao, for the opportunities to work and learn at the Behavioural Sustainability Lab in the wonderful Department of Psychology at the University of British Columbia, and for her guidance through countless research projects, conference presentations, and manuscripts.

Next, I must thank the long list of undergraduate students who helped collect data over the years: Aaron Zhuo, Sherry Guo, Vincent Wang, Mark Ng Shun, Patricia Sun, Carly Chui, Ivy Tam, Justin Reed, Yimiao Gong, Lauren Duda, and Desmond Fung. A special thank-you to Victoria Li, who was extremely helpful in background literature searching and developing ideas together. I was also blessed to have many undergraduate students in my Cognitive Processes classes from 2021 – 2023 and in my Cognitive Systems seminars from 2022 – 2023. So many of you asked interesting questions and volunteered useful ideas. It was always a pleasure discussing them with you (I attempted to credit you by name in the footnotes where I discussed your ideas).

I also must thank my fellow graduate students who were colleagues who became friends. Thank you to Ru Qi Yu for our endless discussions and laughs in the lab which I will never forget. Thank you Yu Luo for the friendship and discussions, as well as the help with code; it was so fun working with you. Thank you Bram Scheerlinck for your help in collecting some of the original eye-tracking data that started this entire project, and thank you for being a great friend.

Thank you to my family for the constant love and support which enabled me to keep working through difficult times. Lastly, even though she is sitting next to me as I write, I must thank Marie for being so patient, dependable, and loving.
For Papa
Chapter 1: Introduction

Financial scarcity is a prevalent problem in the world today. An estimated 700 million people live in extreme poverty – defined by World Bank as living on less than $2.15 per day – and almost half of the global population lives on less than $6.85 per day (World Bank, 2023). In Canada, approximately 7% of people are classified as low income (Statistics Canada, 2023), and 18% of families reported that they were unable to access sufficient food due to financial limitations at least once in the past 12 months (Uppal, 2023). In the United States, 59% of people reported living paycheque to paycheque (Charles Schwab and Co., 2019). It is easy to see evidence of scarcity in many places – wealthy and poor countries alike. However, on the face of things, scarcity may look drastically different when comparing low-income people in Canada compared to low-income people in nations with low a national gross domestic product (GDP). In this introduction I will showcase multiple lines of research which show how the psychological consequences of scarcity can be quite similar for people in high- and low-GDP nations.

Definitions and the Study of Poverty

In the autumn of 1899, B. Seebohm Rountree began an intensive study of poverty which was remarkably comprehensive, ambitious, and insightful (eventually published as Rountree, 1901). He examined the state of poverty in the English town of York by going door to door on 388 separate streets and (with some help) making contact with 11,560 working-class families containing a total of 46,754 people (approximately two thirds of the city at the time). Though this extensive effort stands out in the published literature (Glennerster et al., 2004), there were others around the same time (e.g., Charles Booth’s similar study of London; see Booth, 1904). This study was a tremendous achievement not only for the insights it provided but for the future research it inspired. Rountree defined poverty by first investigating the minimum nutritional requirements for each family member, the cost of that minimum amount of food, the cost of the family’s rent, and other necessary expenses. From this baseline sum, he
constructed two definitions of poverty: primary poverty and secondary poverty. Families who did not earn enough money to afford the cost of the basic necessities were classified to be in “primary” poverty. Families whose total earnings was enough to afford the basic needs, but additional expenditures (wasteful or not) caused the funds to be insufficient for the basic needs were classified to be in “secondary” poverty. This study revealed that 9.91% of the city population met the criteria for “primary” poverty and a further 17.93% of the city population met the criteria for “secondary” poverty (pp. 297-298).

Around the same time of Rountree’s study of York, Thorstein Veblen, an American economist, further contributed to the discussion (1899). Although his work was more of a social critique than a scientific piece, it popularized the practice of defining economic classes according to their behaviour. For example, the wealthy class was defined as people who engage in “conspicuous consumption,” a term coined in this book (See Veblen, 1899, Chapter IV).

Much later, Haagenars and de Vos (1988) noted the difficulties of defining poverty in the preceding decades. It seemed that many governments used definitions which minimized the number of people considered to be impoverished. Regardless, these authors summarized the definitions in use by economists and policy-makers, which could be divided into three general definitions: (1) poverty is having less money than a specified minimum, (2) having less money than a specified percentage of society, and (3) poverty is feeling that you do not have enough money.

The definitions outlined by Haagenars and de Vos (1988) are close to those which will be used in the current dissertation, but there are some important differences. First, I will not use a pre-defined poverty line or minimum income standard. In fact, there will be no lines drawn to define where poverty starts and ends. Objective poverty will instead be indexed by people’s reported income. Relative poverty will be indexed as a subjective impression that a person has less money than other people (an important difference from the definition from Haagenars & de Vos because it is subjective
rather than objective). Finally, subjective poverty will be indexed by a scarcity scale (van Dijk et al., 2022) and is conceptually similar to definition 3 from Haagenars and de Vos.

The word ‘poverty’ is widely used in reference to financial insufficiency, so why deviate from this term and use the word scarcity? Scarcity is a word which also has a long history (well beyond the scope of this introduction) but it has recently been used extensively by psychological researchers. Scarcity is a convenient word to use because it lacks the financial connotations which poverty has. Because of this, psychological researchers can study the effects of a general lack of resources, the study of scarcity, without being constrained to a single resource domain. The seminal work which recently popularized the study of scarcity came from Mullainathan and Shafir (2013). In this book the authors discussed scarcity as a general phenomenon that can affect human thought and behaviour, regardless of whether the scarce domain is money, time, food, or friends. However, since the publication of this idea, the vast majority of scarcity research has centred on financial scarcity. The present dissertation also focuses how financial scarcity (i.e., poverty) can affect human cognition and behaviour.

**Scarcity Research**

The study of scarcity is everywhere. All economics research is a study of scarcity, since, without scarcity of resources, there would be no need to economize, and the field of economics would vanish. Similarly, the field of behavioural economics is the study of information scarcity and how people make judgments and decisions with limited information in their minds. In recent decades, there has also been a distinct rise in psychology research investigating scarcity. I cannot summarize the entire fields of economics and behavioural economics research in this single dissertation, so I will narrow my scope to the recent work primarily done by psychologists in the past two decades. Even with this limitation, the past 10 years has seen the psychological study of scarcity grow beyond what a single person can read.
The psychological study of scarcity itself does not have a unified approach, but there are common perspectives. Some researchers have studied the emotions and subjective experiences of people under scarcity (or people who feel like they are under scarcity; e.g., Goldsmith, 2017, Iles et al., 2021, Sharma et al., 2021). These studies often use imagery and thought-provoking scenarios in order to induce the feeling of scarcity (e.g., Roux et al., 2015). Other researchers seek to understand the content of thoughts of those under objective or subjective scarcity (e.g., Shah et al., 2018). Yet a different type of scarcity research has been a consistent voice in the literature, emphasizing the importance of objective scarcity – the quantifiable lack of resources or tangible constraints on resources which are necessary for people to use (e.g., Banerjee & Mullainathan, 2010, Bickel et al., 2016, Bogliacino et al., 2020, Breza et al., 2017, Carvalho et al., 2016, Fehr et al., 2019, Haushofer & Fehr, 2019, Lichand & Mani, 2020, Mani et al., 2013, Mani et al., 2020, Mullainathan & Shafir, 2013, Ong et al., 2019, Shah et al., 2012, Shah et al., 2019, Stephens, 2006, Szaszi et al., 2023, Tomm, 2017, Tomm & Zhao, 2016, Zhao & Tomm, 2018). This latter perspective is the one which the current thesis largely aligns with, especially at the beginning years of the course of my research. However, during my time doing research on scarcity, I found that a broad amalgamation of these perspectives was most useful. The reader will notice many occasions below in which the variety of perspectives on scarcity blend together and are included as much as possible. In fact, much evidence for the importance of multiple perspectives on scarcity will be found throughout this dissertation.

Before I begin to elaborate on the details of the relevant scarcity literature, I will make a few more brief notes about the field in general. Scarcity research tends to have relatively high public interest. Many results in scarcity research are relevant to public policy, which tends to generate even more interest. The field of scarcity has also caught the attention of researchers outside the field, who have subjected the field of scarcity to an “empirical audit” which failed to replicate many experiments that were previously published (see O’Donnel et al., 2021; see also Shah et al., 2023 for a substantive
rebuttal to the empirical audit). Not only is the field of scarcity generally interesting in society, but it has had a role in the development of science practices through the replication efforts. Below I will spend more time highlighting some of the stand-out findings of the scarcity literature.

As mentioned above, financial scarcity can be defined both as poverty in absolute terms, or as poverty relative to other people. Regardless of the definition, scarcity imposes significant psychological demands and requires people to adapt. For example, having a small budget requires the meticulous calculation of current and upcoming expenses and juggling of sporadic incomes in order to meet fiscal or social requirements. People may respond to scarcity in different ways. If people perceive that they are able to gather resources and reduce scarcity, they will likely be motivated work hard to better themselves, but if people perceive that they are not able to gather enough resources to resolve the situation, they may instead be motivated to restore a sense of personal control over the situation, which can involve gathering resources outside the domain of scarcity (Cannon et al., 2018). Sometimes the motivated focus on immediate finances can come with a cost, resulting in present-biased attention, over-borrowing, and disregarding future costs (Shah, Mullainathan, & Shafir, 2012). Financial scarcity may also directly impair cognitive performance and the ability to exert cognitive control (Mani, Mullainathan, Shafir, & Zhao, 2013). While this work primarily focuses on financial scarcity, scarcity is thought to elicit similar psychological consequences across different types of resources such as time scarcity or water scarcity.

In this chapter I will review literature that illustrates how people respond to scarcity, and the possible cognitive mechanisms thought to be involved. First, I will describe the many ways scarcity elicits adaptive responses. Next, I will describe the counter-productive responses to scarcity in light of a model I previously published in a review paper (Zhao & Tomm, 2018). There are also several key papers that have been published since this review paper that will also be included in this chapter.
Adaptive Responses to Scarcity

The most plainly adaptive response to scarcity is the motivation to protect what remains of the scarce resource and increase motivation to acquire more of the resources (Cannon et al., 2018). Evidence also shows that people begin to exhibit a mindset of competition and competitive behaviours when they are reminded of scarcity (Roux et al., 2015). At least in the short-term, increased motivation and competitive focus are likely adaptive responses to scarcity.

Many cognitive systems such as attention, working memory, and executive control are limited in capacity (Baddeley, 1992; Luck & Vogel, 1997; Miller, 1956; Pashler, Johnston, & Ruthruff, 2001; Rock & Gutman, 1981; Simons & Chabris, 1999). Sometimes the consumption of working memory resources can be beneficial for highly procedural functions (Beilock & Carr, 2001). Low-income people can perform better on procedural learning tasks after having been reminded of financial concerns, which consume working memory (Dang et al., 2016), showing that the limitations in working memory can benefit those under scarcity in certain circumstances. The attentional limitations can also lead to necessary adaptations when scarcity introduces critical demands. For example, someone living paycheque to paycheque must closely monitor spending habits and consumption near the end of the fiscal month. The additional efficiency resulting from scarcity drawing attention to a task is sometimes called the “focus dividend” (Mullainathan & Shafir, 2013). One classic example of the focus dividend was demonstrated by Gersick (1988) in the domain of time scarcity. Participants working in teams tended to show little productivity until the approximate midpoint in time between the start of a project and the deadline. After the midpoint, there was a surge in productivity as people drew each other’s attention to the looming deadline. In this example, the increased focus on the task at hand resulted in increased efficiency in the use of time. Therefore, under time scarcity with looming deadlines, people minimized time-wasting activity and surged in productivity. Scarcity causes people to be more efficient in the consumption of resources.
Another example from Shah, Mullainathan, and Shafir (2012) demonstrated the increased efficiency of resource consumption under resource scarcity. In a parody of the popular Angry Birds mobile game, participants played a game called “Angry Blueberries.” In this game, participants needed to use limited ammunition (blueberries) to hit targets and score points. To manipulate scarcity, some participants were given fewer blueberries and some participants were given a large amount of blueberries. The participants who had less blueberries available spent more time aiming each shot, and tended to score more points per shot than participants in the rich condition. The authors argued that the scarcity of ammunition caused participants to invest greater effort into making each blueberry count the most, while participants with abundant blueberries were more wasteful.

This finding was paralleled by Zhao and Luo (2015) who instructed participants to wash dirty dishes using a measured source of water. To manipulate scarcity, some participants were given a small amount of water while other participants were given a moderate amount of water. It was found that participants who started with a small amount of water used less water overall to complete the same task compared to participants who started with a moderate amount of water. These results show that scarcity tends to increase the efficiency of resource consumption, with particular respect to the resource that is scarce in the first place. This is not surprising since resources that are scarce are perceived as more valuable (Lynn, 1989; Lynn, 1992; Mittone & Savadori, 2009; Smith, 1776; Szybillo, 1975), even by children (Mittone et al., 2003).

Scarcity also increases the accuracy with which people perceptually represent quantities of the scarce resource. Thaler’s (1985) classic demonstration of value framing showed how people can perceive products as dramatically more or less valuable depending on the context in which it is offered. For example, people reported they would be willing to spend $2.65 on a beer that was to be purchased from a fancy resort hotel, but they would only be willing to spend $1.50 on the same beer that was to be purchased from a small, run-down grocery store. There are many cognitive heuristics that people
lean on when perceiving value (Kahneman & Tversky, 1979, 1984; Tversky & Kahneman, 1985). However, it is more crucial under scarcity to accurately perceive the value of scarce resources. Shah, Shafir, and Mullainathan (2015) experimented with Thaler’s beer value scenario (mentioned above) with low-income and higher-income participants. Among higher-income participants, the beer was valued differently depending on the context, replicating Thaler’s (1985) original finding. However, low-income participants did not differ in their willingness to pay for the beer depending on the context (a finding which has been further replicated by Isler et al., 2023). To explain this result, the authors asked participants to report which factors were important in their judgment of the beer’s value. Low-income participants were more likely to report that they considered what other purchases they would forego if they chose to buy the beer compared to higher-income income participants. Low-income participants also reported that the context of the beer purchase was less important to them compared to high-income participants. These findings show how financial scarcity may minimize the use of heuristics which can bias the perception of value. Therefore, scarcity seems to increase the precision of value perception. This represents a great adaptation people make under scarcity that helps to maintain a stable reference frame around the scarce resources.

Another crucial adaptation people show under scarcity is the tendency toward risk-aversion. When resources are precious, it is rational for people to defend their resources by minimizing risk. For people with limited time to make decisions, it is more difficult to evaluate the level of risk, and people tend to avoid risky gambles when under time pressure (Ben Zur & Breznitz, 1981). Similarly, people with limited or unstable incomes are more risk averse (Guiso & Paiella, 2008). Interestingly, risk aversion is increased by stressful situations (Cohn, Engelmann, Fehr, & Maréchal, 2015; Guiso et al., 2013). Haushofer and Fehr (2014) argued that the stress induced by financial scarcity may explain the risk aversion of people under financial scarcity. More recently, Bogliacino et al. (2021) found that labour shocks due to COVID-19 also predicted increased risk-aversion.
Temporal discounting also is a rational behavioural adaptation under scarcity. For people who have less resources, the possibility of unexpected negative income shocks means that it may not be possible to exchange current income for greater returns in the future. Because of this restriction, it is difficult to distinguish actual temporal discounting preferences from the limitations imposed by liquidity constraints (Epper, 2019). However, with a clever research design, Haushofer and Fehr (2019) used lab-induced negative income shocks to show that negative income shocks exacerbated temporal discounting and caused participants to show a bias for present resources. Interestingly, lower net worth is also associated with high temporal discounting among the elderly (Huffman et al., 2019). Despite the advantages of present bias under scarcity, this bias can also be problematic. This will be discussed further in the section below on counter-productive responses to scarcity.

**Counter-productive Responses to Scarcity**

Many of the adaptations discussed above do not come for free. Making adjustments to the way we attend or think can cause unintended consequences. The counter-productive responses to scarcity can be broadly summarized to two categories: attentional bias, and cognitive impairments.

**Attentional Bias**

Many lab experiments have shown how financial scarcity induces attentional focus on prices, and can induce deprioritization of surrounding information (Tomm, 2017; Tomm & Zhao, 2016; see also Chapter 2 below). The deprioritization induced by scarcity can sometimes cause participants to miss out on opportunities to save money. This attentional response to scarcity can be counter-productive not only because of the missed opportunities, but because memory for ignored information is reduced as well. In a series of restaurant-menu experiments (Tomm & Zhao, 2016) participants under financial scarcity were less likely to recall caloric information compared to the participants with larger budgets. This pattern of potentially counter-productive attentional bias under scarcity was termed “tunneling” (Mullainathan & Shafir, 2013).
Another possible counter-productive side-effect of focusing under scarcity is that it is fatiguing to focus intently on a task while managing scarce resources. Shah et al. (2012) found participants playing a repeated game with scarce resources showed more evidence of cognitive fatigue than participants who played the same game with abundant resources, despite that the resource-scarce participants played the game for a shorter amount of time overall. The attentional focus induced by scarcity can be taxing, and may cause further attentional bias over the long-term. However this particular finding failed to replicate in subsequent investigations (Camerer et al., 2018, Shah et al., 2019). Further research is needed to clarify the effect of scarcity-induced focus on cognitive fatigue.

**Cognitive impairments**

Scarcity may directly cause a reduction in cognitive performance by reducing working memory capacity or executive control. Mani et al. (2013) asked participants to think about either difficult or easy hypothetical financial scenarios. After considering these financial predicaments, participants were measured for cognitive performance (using Raven’s Matrices) and cognitive control. The authors found that lower-income participants scored lower on both measures of cognitive performance after considering the difficult financial scenarios, compared to higher-income participants. Interestingly, both higher-income and lower-income participants performed equally well on the cognitive performance measures after considering the easy financial scenarios. This suggests that lower-income participants had lower cognitive performance because they had been thinking about difficult financial scenarios. This pattern was replicated in a sample of Indian farmers who performed relatively poorly on cognitive measures before their harvest (when their finances were scarce), but performed relatively well after the harvest was sold (when their finances were abundant). Carvalho, Meier, and Wang (2016) failed to replicate this pattern of results in samples of American low-income earners before and after their pay-date, but there may have been methodological issues which damaged statistical power in their design (see Mani et al., 2020 for a rebuttal).
Recent evidence from Lichand and Mani (2020) suggested that income uncertainty is likely responsible for most of the variation in cognitive performance, while financial scarcity itself is primarily responsible for attentional bias. This result is supported by Bogliacino et al. (2021) who found that cognitive performance (measured using the cognitive reflection test) was reduced by unexpected labour market shocks and other stressful events. However, evidence from a dept-relief program suggests that financial debt in fact contributes significantly to cognitive performance decline (Ong et al., 2019). Iles et al. (2021) also presented some data suggesting that the subjective perception of financial well-being was predictive of working memory capacity.

Despite several studies finding evidence of IQ declines under financial scarcity or instability, this result only shows up in research sporadically and is a less reliable effect than the attentional effects described above. A recent meta-analysis concluded that the effect of scarcity on cognitive functioning is likely very small if there is an effect at all (Szecsi & Szaszi, 2022). These authors found that, in the published data on this topic, there is a high degree of variability which muddles any clarity on this subject. The same research group also conducted a pre-registered randomized controlled trial (RCT) which granted $200 to an extremely low-income group of 251 Liberians (the grant was around three times the average monthly income of these participants), while a control group of 222 people did not receive the money. After measuring a variety of cognitive functions at several time points after the cash transfer, the authors concluded that the alleviation of financial pressure may have had a small effect on some measures of cognitive function but not others. Though it is important to know how scarcity affects cognitive functioning, it appears as though reliable and large effects of scarcity on cognitive function are elusive.

Another possible mechanism that may link financial scarcity to reductions in cognitive performance is through negative emotion. There is evidence that people performed significantly worse on measures of memory performance and cognitive control immediately after recalling memories of
violence, and the reductions in performance can be caused by negative emotions alone (Bogliacino et al., 2017). However, the same authors were unable to link negative emotion with the reduction of cognitive performance following COVID-19 labour market shocks (Bogliacino et al., 2021). Mani et al. (2013) found that the cognitive decline in Indian farmers before their harvest season was not accounted for by anxiety. The possibility of negative emotion mediating the relationship between scarcity and cognitive impairment is interesting and more research is needed.

There may be a detrimental effect of scarcity on face processing. Rodeheffer et al (2012) found that scarcity priming increased the probability that racially ambiguous faces would be categorized as a racial out-group, but this finding more recently failed to replicate (Takebe et al., 2023). A different set of studies found that a simple (and quite artificial) scarcity prime caused differences in neurological processing of black but not white faces among white participants (differences in black face processing were observed in both ERP and fMRI data; Krosch & Amodio, 2019), suggesting that the scarcity prime reduced or delayed processing of black faces.

**Behavioural Impairments**

While little is known about direct relations between scarcity and behaviour, there are some findings worth noting. Some evidence suggests that people who have been exposed to scarcity for extended periods of time are more likely to engage in anti-social behaviour in a laboratory-based resource-allocation game (Prediger et al., 2014). At the macro level, scarcity is sometimes considered to be a driver of armed conflict between groups of people (Christie, 2006; Homer-Dixon, 1994). While much literature has studied the behaviour of low-income people, the matter of financial scarcity directly affecting behaviour remains relatively unstudied.

**Relevance to the Present Work**

Together these findings suggest that the precarious financial situations many low-income people encounter can cause attentional bias and possibly impair cognitive performance or decision
making. Because cognitive systems are limited, drawing cognitive and attentional resources to one task can lead to impairments in other domains. In turn, the cognitive impairments and attentional bias may cause counter-productive behaviours which perpetuate the condition of scarcity. This vicious cycle of scarcity is illustrated in the model below (Zhao & Tomm, 2018).

![Figure 1. Cycle of scarcity model.](image)

While prior research has suggested general cognitive impairment and attentional bias under scarcity, there has been a lack of work showing direct mechanisms how these effects may exacerbate scarcity or make scarcity more difficult to overcome. One goal of this work is to reveal applications of attentional bias and cognitive impairments and how they can specifically contribute to the vicious cycle of scarcity. It is important to understand which cognitive processes are affected by financial pressures, and how scarcity can lead to counter-productive behaviours. In the chapters below, I will describe three avenues of research, each targeting a different cognitive mechanism which can be affected by financial scarcity. In Chapter 2, I present data showing how attentional bias under financial scarcity leads to behavioural trade-offs that reinforce the vicious cycle of scarcity. In Chapter 3, I investigated
several attentional interventions to correct the behavioural trade-offs found in Chapter 2. In Chapter 4, I measured a variety of scarcity measures and examined their relation to numerical perception. In Chapter 5, I conducted a study of scarcity, attention, and decision making with regard to job advertisements. Finally, I conclude by offering some theoretical and practical conclusions in Chapter 6.
Attentional states determine what is seen. The Posner cueing paradigm demonstrated that covertly attending to a space causes reduced attention to adjacent stimuli (Posner, 1980). Similarly, hungry people are distracted by food (Piech, Pastorino, & Zald, 2010; Radel & Clément-Guillotin, 2012). This chapter presents evidence that financial scarcity alters the attentional state, and there are behavioural consequences that follow.

In my master’s thesis, I presented evidence that financial scarcity caused people to attend more to price-related information (Tomm, 2017). Participants were asked to look at a restaurant menu and decide what they would, hypothetically, like to order. To manipulate financial scarcity, participants were randomly assigned either a small budget or a large budget. To measure attention, eye-tracking equipment was used. Participants with a small budget (scarcity condition) looked at prices more than participants with a large budget (control condition). Participants in the scarcity condition also looked less at the names of the foods on the menu and the calorie information compared to participants in the control condition. Critically, participants in the scarcity condition also looked less at a discount clause at the bottom of the menu, which offered 18% off their selection. Ironically, these participants in the scarcity condition who needed the discount the most were less likely to attend to it compared to wealthy participants.

These results presented in my master’s thesis are convergent with other findings which also showed how scarcity affects attention. People who are hungry (food scarcity) are more likely to detect food-related stimuli compared to people who have recently eaten (Piech, Pastorino, & Zald, 2010; Radel & Clément-Guillotin, 2012). People who are thirsty (water scarcity) are more likely to focus on water-related cues than people who are not (Aarts, Dijksterhuis, & De Vries, 2001). Alcoholics and dieters are more likely to attend to alcohol and food-related cues, respectively (Stetter, Ackermann, Bizer, Straube, & Mann, 1995). People with retirement anxiety or financial anxiety attend more to
retirement or money-related cues (Gutierrez & Hershey, 2013; Shapiro & Burchell, 2012), and lower-income individuals are more likely to know the starting price of a taxi than higher-income individuals, despite how they take taxis less frequently than those with higher income (Mullainathan & Shafir, 2013).

These studies lead to many hypotheses about how scarcity itself may complicate the alleviation of scarcity. For example, dieters who voluntarily put themselves into calorie scarcity are more attentive to food in the environment. Therefore, calorie scarcity may increase temptation to eat impulsively, which is quite counter-productive to the original purpose of the diet. Similarly, my master’s thesis work may suggest that financial scarcity can also promote counter-productive behaviours because people under scarcity may focus on prices and consequently miss money-saving opportunities. However, the design of the prior experiments were not conducive to detecting instances of missing opportunities because of scarcity.

To investigate the behavioural consequences of attentional bias under scarcity, I conducted the following experiments. First, I conducted an online study to replicate the menu study in my master’s thesis with design modifications that probe the behavioural consequences of attentional bias (Experiment 1). Next, I conducted a pre-registered replication of Experiment 1 (Experiment 2). Finally, I designed a new version of the menu paradigm to test whether the attentional bias under scarcity is caused by reduced visual search area or reduced attentional flexibility (Experiment 3).

**Experiment 1**

The goal of this experiment was to examine how financial scarcity affects attentional bias and counterproductive behaviour. In particular, how do participants under financial scarcity make use of an opportunity to alleviate financial scarcity? This experiment is closely modelled after the previous menu study paradigm (Tomm, 2017, Experiment 1), but there are some important modifications. First, this experiment was conducted online instead of in a lab. Second, the available discount on the menu
was much larger. Third, there were more clear instructions on how to request the discount. Fourth, instead of using eye-tracking to measure attention, an online analog of eye-tracking was used. The methods are described in more detail below.

Participants

Participants were recruited online from Amazon Mechanical Turk (Mturk). All participants were from the United States (US), gave informed consent, and received USD$0.25 each as compensation for participation. A sample of n=429 participants was recruited from Mturk. Several exclusion criteria were applied to the online sample to ensure data quality. Participants who spent less than 10 seconds viewing the menu, who overspent their assigned budget, who responded through the same IP address as a previous participant, or who provided meaningless or unusable responses for all open-ended questions were excluded. Also, participants who were 2.5 times the standard deviation away from the mean of any particular measure were excluded from analyses involving that particular measure. After exclusions remained a sample of n=344 participants (185 female, 155 male, 4 unspecified; mean age=37.35 years, SD=12.33 years).

Stimuli and Procedure

Participants used their web browser to view a restaurant menu. The menu lists the names of dishes as well as the prices and calories associated with each dish. Importantly, there is a discount clause at the bottom of the menu that reads: “Type “Special” with your order to get your entire meal for free (up to $60)!”. Participants were then randomly assigned a budget of either $20 (scarcity condition) or $100 (control condition). All participants were instructed to decide on a selection of items from the menu that were within their budget.

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1 Exclusion based on deviation from the mean of more than 2.5 standard deviation is used consistently throughout the work presented here. This number was originally chosen to deal with attention-tracking data which can sometimes contain extreme outliers. Due to the presence of extreme outliers, outlier exclusion at larger standard deviations is sometimes insufficient because the exclusion of one extreme outlier can cause an extreme reduction in the standard deviation of the remaining sample, causing other true outliers to remain in the sample.
Figure 2. Experiment 1 – 2 stimuli. Left: Stimuli. Right: Participant view.

To measure participants’ attention, a novel online attention-tracking tool called BubbleView was used (adapted from Kim et al., 2017). The menu was covered by a black mask, and only a small circular area around the participant’s cursor was transparent where the participant could see the underlying menu. Participants were asked to move their mouse to see the content of the menu. The black mask was the same size as the menu. The transparent circular area was 40 pixels in diameter, which subtended approximately 1.2° of visual angle on a common 1080p 27 inch computer monitor. Note that the degrees of visual angle of the viewing circle and the menu itself depend on the screen size, resolution, and viewing distance of each individual participant. The participants’ mouse cursor location was tracked as a proxy for visual attention because the cursor location was the only part of the menu that was visible at a given time.

I thank Yu Luo greatly for finding this tool and helping me to adapt it to our countless Mturk studies.
After viewing the menu, participants typed their order on a separate page. Participants were then asked to complete a surprise memory test. They saw a version of the menu with all the food items, prices, and calories missing, and were asked to fill in as much information as possible based on their memory. Participants were required to enter both the price and calories for each food item they recalled, up to a maximum of 5 menu items. Afterwards, participants were asked to estimate the total cost of their order. Finally, participants reported demographic information including age, gender, personal income, and household income.

**Results and Discussion**

Participants in the control condition spent more time ($M=95.42$ seconds) viewing the menu than participants in the scarcity condition ($M=80.63$ seconds) [$t(330)=2.28$, $p=.023$, $d=0.26$]. Because of the variation in viewing time of the menu, we computed the proportional time spent looking at each area of interest on the menu as the primary of attention to each feature of the menu. All attentional results below reported are percentages of total menu viewing time. Therefore, dwell time is defined as the percentage of time looking at a particular feature of the menu relative to the total menu viewing time. The figure below shows a visual heatmap of cursor location in the scarcity condition and in the control condition. Participants in the control condition also spent more money ($M=$25.43) on their order than participants in the scarcity condition ($M=$15.22) [$t(338)=13.14$, $p<.001$, $d=1.52$].

**Attention Results**

Participants in the scarcity condition spent more time looking at prices ($M=16.56\%$ of dwell time) compared to participants in the control condition ($M=12.14\%$ of dwell time) [$t(333)=4.21$, $p<.001$, $d=0.46$], replicating prior findings. It was also found that participants in the scarcity condition looked less at the food item names ($M=47.27\%$ of dwell time) compared to participants in the control condition ($M=53.11\%$ of dwell time) [$t(338)=3.57$, $p<.001$, $d=0.39$], again replicating prior findings. There was no significant difference in attention to calorie information between participants in the
scarcity condition ($M=5.22\%$ of dwell time) and those in the control condition ($M=4.38\%$ of dwell time) \(t(334)=1.57, p=.118, d=0.17\). Critically, participants in the scarcity condition spent less time looking at the discount ($M=3.06\%$ of dwell time) compared to participants in the control condition ($M=4.80\%$ of dwell time) \(t(332)=2.95, p=.003, d=0.33\). These results showed that scarcity draws attention to prices and reduces attention to other information, such as the food items and the beneficial discount.

![Figure 3. Experiment 1 heat map. Left: scarcity condition. Right: control condition.](image)

3 Darker colours indicate higher density of cursor location.
Figure 4. Experiment 1 attention results. Note: * $p < .05$, ** $p < .01$, *** $p < .001$.

Discount Request Results

Significantly fewer participants in the scarcity condition requested the discount (15.86%) than participants in the control condition did (33.17%) [$\chi^2(1) = 13.10, p < .001, \phi_c = .20$]. This result demonstrates an important behavioural consequence of the attentional bias under scarcity, which is the missed opportunity to take advantage of the discount which can alleviate the budget constraints in the scarcity condition.

Discount Requesters in the Scarcity Condition. To further explore the effects of scarcity, I compared the results of participants in the scarcity condition who requested the discount ($n=23$) to all the participants in the control condition ($n=199$). Since these participants in the scarcity condition requested the discount, they effectively became control participants, because their budget constraints were largely eliminated. Thus, it was predicted that these participants should behave similarly to participants in the control condition. Indeed, discount-requesters in the scarcity condition looked at
prices for a similar proportion of time ($M=9.67\%$ of dwell time) as participants in the control condition ($M=12.14\%$ of dwell time) [$t(213)=1.34$, $p=.183$, $d=0.31$]. Discount-requesters in the scarcity condition also looked at the food items for a similar proportion of time ($M=48.96\%$ of dwell time) as participants in the control condition ($M=53.11\%$ of dwell time) [$t(218)=1.30$, $p=.194$, $d=0.29$]. In addition, discount-requesters in the scarcity condition looked at the caloric information for a similar proportion of time ($M=4.05\%$ of dwell time) as participants in the control condition ($M=4.38\%$ of dwell time) [$t(214)=0.33$, $p=.744$, $d=0.08$]. Unsurprisingly, discount-requesters in the scarcity condition spent a larger proportion of time ($M=14.53\%$ of dwell time) looking at the discount compared with the average participant in the control condition ($M=4.80\%$ of dwell time) [$t(215)=8.11$, $p<.001$, $d=1.83$]. Finally, discount-requesters in the scarcity condition recalled prices with equivalent accuracy ($mean absolute error=\$1.26$) compared to participants in the control condition ($mean absolute error=\$1.23$), showing that the attentional burden alleviated by noticing the discount allowed participants in the scarcity condition to retain information in memory with similar accuracy to participants in the control condition [$t(211)=0.12$, $p=.905$, $d=0.03$].

I also compared discount-requesters in the scarcity condition ($n=23$) to participants in the scarcity condition who did not request the discount ($n=122$). It was predicted that participants who requested the discount (to receive their entire meal free, up to a $60 value) would behave more like the control participants. Surprisingly, discount requesters in the scarcity condition did not spend more money ($M=\$14.74$) than non-requesters in the scarcity condition ($M=\$15.23$) [$t(143)=0.53$, $p=.596$, $d=0.12$]. However, these discount-requesters spent less time looking at prices ($M=9.67\%$ of dwell time) than non-requesters in the scarcity condition ($M=17.65\%$ of dwell time) [$t(139)=3.29$, $p=.001$, $d=0.85$]. Taken together, these results suggest that the attentional effects of scarcity were largely eliminated when the scarcity participants took advantage of the discount. This finding carries
implications for financial support programs. For example, benefit programs will improve cognitive functioning of people under scarcity only when they actually use the program.

**Figure 5.** Experiment 1 requester results showing behaviour of participants in the scarcity condition who requested the discount. Note: *** $p < .001.$

**Order Value Estimate Results**

Participants in the control condition made more expensive orders of their meals than those in the scarcity condition. When estimating the cost of their order, participants in the scarcity condition made smaller errors (*mean absolute error*=$2.07$) compared to participants in the control condition (*mean absolute error*=$6.73$) [$t(328)=6.50, p<.001, d=0.77$]. This difference could be driven by the higher total value of the orders made by participants in the control condition. To control for order value, I computed the proportional absolute error and did not find a significant difference between participants in the scarcity condition (*mean absolute proportional error*=$0.22$) and those in the control condition (*mean absolute proportional error*=$0.29$) [$t(336)=1.64, p=.102, d=0.18$]. Contrary to prior
literature, I am unable to conclude that participants in the scarcity condition carried more accurate knowledge of their spending than participants in the control condition.

**Memory Recall Results**

![Figure 6. Experiment 1 memory results. Note: * p < .05, *** p < .001.](image)

When recalling information from the menu, participants in the scarcity condition recalled fewer items ($M=4.11$ items) compared to participants in the control condition ($M=4.52$ items) $[t(330)=3.44, p<.001, d=0.37]$. The mean absolute error of price recall was computed by taking the mean of the absolute errors of each price recalled by each participant. Participants in the scarcity condition made smaller errors recalling the price information ($mean \ absolute \ error=$$0.95$) compared to participants in the control condition ($mean \ absolute \ error=$$1.23$) $[t(324)=2.54, p=.012, d=0.29]$. There was no difference in the recall accuracy of calories between participants in the scarcity condition ($mean \ absolute \ error=161.27$ calories) and control condition ($mean \ absolute \ error=143.94$ calories)
These results show that financial scarcity causes prioritization of price information and enhances memory recall of prices.

**Summary of Results and Discussion**

Most significantly, these results from Experiment 1 show that financial scarcity caused participants to look less at the available discount, and as a result, they were less likely to actually use the discount to alleviate the financial scarcity which constrained them in the first place. The participants in the scarcity condition who were fortunate enough to notice the discount did not dramatically increase their spending, but instead spent more time looking at the names of the items on the menu. These results are a novel empirical demonstration of the vicious cognitive cycle of scarcity, whereby scarcity causes counter-productive behaviours which perpetuate scarcity (Zhao & Tomm, 2018).

**Experiment 2**

Participants in Experiment 1 used the discount less frequently when under financial scarcity, which is the first time this result was observed in any of my previous experiments. Because of the novelty and importance of this finding, the goal of Experiment 2 was to replicate the key findings of Experiment 1. In particular, there were three key findings to replicate: that scarcity participants looked more at prices than control participants (finding 1), that scarcity participants looked less at the discount than control participants (finding 2), and that scarcity participants would be less likely to request the discount than control participants (finding 3). This replication effort was pre-registered on the Open Science Foundation website (OSF; see the public preregistration page: https://osf.io/9j4hu). Based on power analyses using GPower (Faul, Erdfelder, Lang, & Buchner, 2007), a sample size of $N=182$ was required to replicate finding 1, a sample size of $N=452$ was required to replicate finding 2, and a sample size of $N=325$ was required to replicate finding 3, with 95% power. Based on this power analysis, I decided to recruit a minimum sample of $N=500$ (post-exclusion) to replicate the three key findings.
Participants

To meet the target sample size of $N=500$, $N=738$ participants were recruited from Mturk. Similar to Experiment 1, all participants were from the US. The same exclusion criteria as in Experiment 1 were applied. After exclusions, a sample of $N=552$ participants remained (280 female, 272 male, 0 unspecified; mean age=35.98 years, SD=11.29 years).

Stimuli and Procedure

The stimuli and procedure were identical to Experiment 1.

Results and Discussion

Participants in the control condition spent more time ($M=92.31$ seconds) viewing the menu compared to participants in the scarcity condition ($M=75.40$ seconds) [$t(531)=3.19$, $p=.002$, $d=0.28$]. Similar to Experiment 1, participants in the control condition spent more money ($M=$25.23) than participants in the scarcity condition ($M=$15.17) [$t(540)=13.10$, $p<.001$, $d=1.16$]. As in Experiment 1, I computed the proportional time spent looking at each region of the menu. The figure below shows a heat-map of mouse cursor location in the scarcity condition and in the control condition.

Pre-registered Results

All three key results strongly replicated the findings from Experiment 1. First, participants in the scarcity condition spent a larger proportion of time looking at prices ($M=16.36\%$ of dwell time) than participants in the control condition ($M=12.28\%$ of dwell time) [$t(538)=5.26$, $p<.001$, $d=0.45$]. This effect remained after controlling for age and gender [$F(1,548)=18.08$, $p<.001$]. Second, participants in the scarcity condition spent a smaller proportion of time looking at the discount ($M=2.29\%$ of dwell time) compared to participants in the control condition ($M=4.67\%$ of dwell time) [$t(534)=5.38$, $p<.001$, $d=0.48$], which was also significant after controlling for age and gender [$F(1,548)=15.30$, $p<.001$]. Third, participants in the scarcity condition were less likely to request the

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4 Covariates were added to increase confidence in these findings in particular because they are a replication of novel results from Experiment 1.
discount (11.11% of participants) than participants in the control condition (27.67% of participants) \[X^2=23.36, p<.001, \phi_c=.21\], even after controlling for age and gender (\(\beta=.17, t=5.01, p<.001\]).

**Figure 7.** Experiment 2 heat map. Left: scarcity condition. Right: control condition.\(^5\)

**Attention on the Menu**

As in Experiment 1, all attentional results reported are proportions of total viewing time.

While I found that participants in the scarcity condition looked more at prices and less at the discount than participants in the control condition, there were no significant differences between participants in the two conditions in the time viewing the food items (scarcity condition \(M=49.11\%\) of dwell time; control condition \(M=50.70\%\) of dwell time) \([t(541)=1.22, p=.224, d=0.11]\) or calories (scarcity condition \(M=4.25\%\) of dwell time; control condition \(M=4.47\%\) of dwell time) \([t(540)=0.56, p=.576, d=0.05]\).

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\(^5\) Darker colours indicate higher density of cursor location.
Figure 8. Experiment 2 attention results. Note: ** $p < .01$, *** $p < .001$.

**Requesting a Discount**

As found in Experiment 1, fewer participants in the scarcity condition requested the available discount compared with participants in the control condition, missing the chance to alleviate the financial constraint. See “Pre-registered Results” above for the statistics on discount requests.

**Discount Requesters in the Scarcity Condition**

As found in Experiment 1, discount-requesters in the scarcity condition performed similarly to participants in the control condition. Those in the scarcity condition who requested discounts spent comparable proportions of time looking at price information (scarcity condition $M=14.91\%$ of dwell time; control condition $M=12.28\%$ of dwell time) $[t(317)=1.59, p=.112, d=0.29]$, the food items (scarcity condition $M=45.11\%$ of dwell time; control condition $M=50.70\%$ of dwell time) $[t(323)=1.87, p=.062, d=0.41]$, and calories (scarcity condition $M=2.74\%$ of dwell time; control condition $M=4.47\%$ of dwell time) $[t(319)=1.87, p=.063, d=0.47]$ compared to the control condition. Discount-requesters in
the scarcity condition looked more at the discount ($M=12.78\%$ of dwell time) than the average participants in the control condition ($M=4.67\%$ of dwell time) [$t(319)=6.93$, $p<.001$, $d=1.48$]. As in Experiment 1, discount-requesters in the scarcity condition recalled prices with comparable accuracy ($mean\ absolute\ error=$$0.78) with participants in the control condition ($mean\ absolute\ error=$$1.07)$ [$t(296)=1.40$, $p=0.163$, $d=0.33$]. These results suggest that participants in the scarcity condition who took advantage of the discount behaved analogously to participants in the control condition.

Unsurprisingly, discount-requesters in the scarcity condition looked at the discount ($M=12.78\%$ of dwell time) more than those in the scarcity condition who did not request the discount ($M=1.05\%$ of dwell time) [$t(238)=23.83$, $p<.001$, $d=3.08$]. However, I did not find significant differences between discount-requesters and non-requesters in the scarcity condition in the time looking at prices (requesters $M=14.91\%$ of dwell time; non-requesters $M=16.54\%$ of dwell time) [$t(247)=0.82$, $p=.410$, $d=0.16$], the food items (requesters $M=45.11\%$ of dwell time; non-requesters}
$M=49.62\%$ of dwell time) \([t(244)=1.50, \ p=.134, \ d=0.33]\), or calories (requesters $M=2.74\%$ of dwell time; non-requesters $M=4.45\%$ of dwell time) \([t(246)=1.94, \ p=.054, \ d=0.48]\).

**Order Value Estimate Results**

As in Experiment 1, participants in the scarcity condition made smaller errors (*mean absolute error*=$1.36) when estimating the total value of their orders, compared to participants in the control condition (*mean absolute error*=$5.19) \([t(525)=7.46, \ p<.001, \ d=0.68]\). I also found that participants in the scarcity condition made smaller absolute proportional errors (*mean absolute proportional error*=0.12) compared to participants in the control condition (*mean absolute proportional error*=0.21) when recalling the total cost of their orders \([t(529)=3.68, \ p<.001, \ d=0.33]\). These results again replicated those found in Experiment 1.

**Memory Recall Results**

![Figure 10. Experiment 2 memory results. Note: *** p < .001.](image-url)
Participants in the scarcity condition made smaller errors recalling prices \((mean \text{ absolute error} = \$0.73)\) compared to participants in the control condition \((mean \text{ absolute error} = \$1.07)\) \([t(495) = 4.09, p < .001, d = 0.38]\). There was no significant difference in the errors recalling calorie information among participants in the scarcity condition \((mean \text{ absolute error} = 146.19 \text{ calories})\) and the control condition \((mean \text{ absolute error} = 136.92 \text{ calories})\) \([t(497) = 0.91, p = .361, d = 0.08]\). Replicating the findings in Experiment 1, these findings again demonstrate that scarcity draws attention to prices and enhances memory recall of prices (task-relevant information), but not of calories (task-irrelevant information).

**Summary of Results and Discussion**

Experiment 2 replicated the three key findings from Experiment 1, using a pre-registered protocol. Participants under financial scarcity looked less at a useful discount and most of them did not use the discount to alleviate their condition of scarcity. Interestingly, participants with large budgets still used the discount with greater frequency, despite the fact that they did not need the discount at all. This study adds empirical support to the idea that financial scarcity causes people to focus on immediate finances, at the expense of missing out on opportunities to escape poverty.

**Experiment 3**

It may be possible that the discount clause used in Experiments 1 and 2 reliably drew attention of participants in the control condition simply because it was there, and not because it was relevant to the task. If this is true, then it may be argued that the difference between control and scarcity participants’ attention to the discount is driven by control participants distributing attention more widely around the menu. To address this concern, I conducted a follow-up study with \(N=401\) participants from a US sample on Mturk. In this study, the methods and menu were identical to the methods and menu from Experiments 1 and 2, except the discount was replaced by an irrelevant sentence at the bottom of the menu (“This restaurant has served customers using local ingredients since
In this experiment, there was no difference in the amount of time spent looking at this irrelevant sentence between the scarcity condition ($M=1.66\%$ of dwell time) and the control condition ($M=1.82\%$ of dwell time) [$t(390)=0.83$, $p=.407$, $d=0.08$]. Combined with prior results, these results show that the control participants have a particular advantage over the scarcity participants when it comes to relevant information, but not with irrelevant information.

![Figure 11](image.png)

**Figure 11.** Experiment 3 attention results showing attention to the neutral statement where the discount had been in Experiments 1 and 2.

### General Discussion

#### Theoretical Considerations

The results of Experiment 3 suggest that participants under scarcity maintained a similar level of attentional dispersion or exploration about the menu, implying that participants under scarcity in Experiments 1 and 2 did not re-allocate attention when a discount appeared in the viewing circle. How could scarcity have suppressed attention and discount requests? There are several possible explanations.

First, it is possible that participants in the scarcity condition engaged in top-down allocation of attention in order to look specifically for prices. Attentional selection can occur prior to information processing (i.e., early selection; Broadbent, 1958; Kahneman, 1973; Neisser, 1967; Triesman, 1964). Early attentional selection can be highly efficient when participants know in advance what they are searching for, resulting in very little information processed outside the focus of attention (Yantis &
Johnston, 1990). Even if the discount passed through early attention selection, the discount could be quickly identified as non-price information during top-down search for price information. This would have resulted in the search redirecting elsewhere before the meaning of the text could be fully processed. This would be an example of reactive distractor suppression as the attentional systems quickly disengage from stimuli initially perceived to be irrelevant (see Geng, 2014, for further discussion of reactive vs. proactive distractor suppression).

Second, the condition of scarcity may have caused a reduction in the salience of non-price information. In other words, non-price information may be actively suppressed as distractors are suppressed during a visual search task. The combination of the amplification of price stimuli and suppression of non-price stimuli is also possible, resulting in a high degree of attentional selectivity. An increase in attentional selectivity is supported by the arousal-biased competition model (Mather & Sutherland, 2011) which predicts that selectivity of a perceptual system increases with arousal. However, it is not clear whether participants in Experiments 1-3 experienced arousal because of the condition of budget scarcity or if the price information increased arousal of participants under scarcity.

A third possible mechanism for scarcity to affect the function of attention is the effect of stress. Stress negatively affects attentional control in both humans (Liston et al., 2009) and rats (Liston et al., 2006). In theory, attentional control would be required in the menu experiments to shift from searching for price information to exploring other types of information, such as a discount. There is a clear association between financial scarcity and stress because cortisol levels decline after receiving large sums of money (Haushofer & Fehr, 2014). Evidence also supports a link between financial scarcity-induced stress and declines in executive functions, including attentional set-shifting (O’Neil et al., 2021). In the menu paradigm, a decline in set-shifting ability may result in participants being unable to shift from searching for prices to searching for other types of useful information. Unfortunately I do not have data to directly support this mechanism as I did not include a measure of stress in these
experiments. In order to clarify this possibility, future investigations should include measures of state stress when following up on this paradigm (e.g., the stress measure from Zsido et al., 2020).

Before concluding that participants under scarcity engage in “tunnelling” by increasing attentional selectivity and distractor suppression, there is an important caveat that must be considered. Some recent evidence suggests that people under financial scarcity are in fact more likely to notice unexpected events in an inattentional blindness task (Schmitt & Schlatterer, 2021). Schmitt and Schlatterer suggested that focusing on the primary task requires working memory, but the depletion of working memory capacity under scarcity leaves people less susceptible to inattentional blindness because they lack the working memory capacity required to avoid the unexpected stimuli. Why are people under scarcity less likely to notice the discount on the menu but more likely to notice unexpected events? I propose that the difference between these two findings comes from the focal task. In the menu experiments, the focal task was directly related to scarcity whereas in the inattentional blindness study from Schmitt and Schlatterer (2021), the focal task was not related to scarcity. Scarcity in the menu experiments draws attention toward the focal stimuli while scarcity in the inattentional blindness study draws attention away from the focal task.

While we do not yet understand the mechanism that explains why scarcity caused suppression of useful information, it is not the first finding of inattention among people experiencing scarcity. Kalil et al. (2023) found that parents of schoolchildren who reported more subjective financial scarcity (measured by a single item asking how much money participants had at the end of each month) were also more likely to be inattentive to information sent to them by school administrators. Based on my reading of the literature and my own results, I believe it is likely that people under scarcity are more likely to miss information not because their visual gaze did not meet the information, but because the information becomes filtered out before it reaches deep levels of perception. As a corollary to this, a mismatch between the effort spent looking for information and the amount of information retained in
memory may be part of the experience of scarcity. Even slight shifts in attentional selectivity may significantly affect the way people navigate information in their environments.

**Policy Implications**

These results demonstrate a potential systematic disadvantage to people who have restricted budgets compared to those with larger budgets. In a restaurant-menu paradigm, people with limited budgets prioritized the price information, but attended less to the useful discount that could have instantly solved the problem of budget constraints. In contrast, people with large budgets were afforded the attentional luxury of gathering useful information without the need to focus on prices as much as the scarcity participants. This implies that cash-poor diners may be trading away the cognitive capacity to attend to health information (such as calories or nutrition content) in order to attend to prices more. This could be resolved in several ways. First, food items could be sorted by price. This would simplify the task of selecting items within a budget, as the available options would be easier to find. Second, the calorie information can be simplified. Instead of listing numerical calorie information, which can be cognitively taxing to attend to or sum together, the menu could use categorical nutrition labels (such as “low-fat,” “low-salt,” “low-calorie,” etc.). Third, electronic food ordering systems are becoming more popular, and the user-interfaces can be updated with helpful features such as “search by budget” or “best nutritional value per dollar.” Fourth, attention-grabbing prompts can directly ask the user if they are eligible for available discounts, ensuring that all people have equal access to the discounts. These types of tools could alleviate the problems caused by attentional bias under scarcity.

These current findings may also help inform public policy and services targeting low-income populations. Among the OECD countries, enrolment in social assistance and public benefit programs is estimated to range between 40% and 80% (Hernanz, Malherbet, & Pellizzari, 2004; see also Bargain, Immervoll, & Viitamäki, 2012). The data presented in Chapter 1 can help to explain the low
participation rate. Specifically, the people who are eligible for these programs may tend not to participate because the attentional demands may be overwhelming. Low-income individuals may need to focus on their financial challenges and deadlines under scarcity, and perhaps may not be aware of these benefit programs and services, or they may not have time to pay attention to the details of the enrolment procedures. This attentional account is not the only factor that can explain the low participation rate. It is worth noting that in addition to the inherent cognitive and behavioural consequences that arise under the condition of scarcity, there are many social stigmas and stereotypes associated with poverty. Low-income individuals may be scorned, perceived as incompetent, or disrespected (Russel & Fiske, 2008), and this stigma may be discouraging for low-income people to seek help.

Given the attentional constraints under scarcity, social assistance and public benefit programs should be designed to avoid attentional bias under scarcity. Attentional bias under scarcity may make sign-up deadlines more difficult to remember. New social services and programs should use automatic enrolment systems to correct for the already demanding attentional challenges experienced by low-income individuals. It also may be helpful to streamline assistance applications and services to make them more salient, more accessible, and easier to process. The amount of effort and attention required should be minimized to increase or maintain participation. Benefit programs and social services can also be made more salient by using prompts and reminders. This could be done through any messaging medium such as text-message or email, and could be effective in catching the attention of those living under scarcity. Based on our current findings, future research can design interventions to avoid attentional bias in low-income people.
Chapter 3: Attentional Interventions to Alleviate Bias Under Scarcity

Attentional intervention has been a popular genre of research for more than fifteen years now. Since the publication of Nudge (Thaler & Sunstein, 2008) there have been countless efforts by researchers, governments, and employers to influence the behaviour of other people by bringing selected information into the focus of their attention, although the effectiveness of many of these “nudge” interventions is low (see Scaszi et al., 2022 for a sobering meta-analysis). Nonetheless it is worthwhile to test a variety of interventions to improve the cognitive and behavioural functioning of people under scarcity. The previous chapter showed that people under a simple condition of local budget scarcity are prone to attentional bias toward prices and frequently miss out on opportunities to use information which alleviates the budget scarcity conditions. In this case, the obvious intervention is to adjust the attentional availability of the discount information in order to bring people under scarcity up to a comparable level of functioning as people with large budgets. This chapter contains four experiments which follow up on the experimental paradigm introduced in Chapter 2.

Experiment 4

The goal of the Experiment 4 was to attempt to mitigate the reduced attention to the discount under scarcity found in prior Experiments. The strategy to mitigate this attentional bias was to make the discount more salient. I moved the position of the discount from the bottom of the menu to the top of the menu where it may be more likely to be noticed. It was predicted that participants under scarcity would be equally likely to notice and request the discount as participants who are not under scarcity when the discount is made salient.

Participants

Participants were again recruited from a US-based population on Mturk, and the same exclusion criteria as the prior online Experiments were used. After exclusions, a total of 433
participants remained as the final sample (249 female, 183 male, 1 unspecified; mean age=36.27 years, SD=12.67 years).

**Stimuli and Procedure**

The stimuli and procedure were identical to previous online menu experiments, with the exception of the modified location of the discount on the menu (now located at the top of the menu).

![Menu](image)

*Figure 12. Experiment 4 stimuli featuring the discount located at the top.*
Results and Discussion

Participants in the control condition (N=228) spent more time (M=92.80 seconds, SD=61.85 seconds) viewing the menu compared to participants in the scarcity condition (N=205) (M=76.41 seconds, SD=45.91 seconds) [t(421)=3.07, p=.002, d=0.30]. Similar to results in Chapter 2, participants in the control condition spent more money (M=$24.22, SD=$7.26) than participants in the scarcity condition (M=$18.77, SD=$4.96) [t(417)=8.88, p<.001, d=0.88].

![Graph showing results](image)

**Figure 13.** Experiment 4 results. Note: * p < .05, ** p < .01, *** p < .001.

Participants in the scarcity condition again spent more time (M=14.64 %, SD=9.76%) looking at prices compared to participants in the control condition (M=12.13%, SD=8.56%) [t(421)=2.83, p=.005, d=0.27]. Importantly, there was no significant difference in looking time at the discount (scarcity condition: M=4.54%, SD=6.22%; control condition: M=4.61%, SD=6.71%) [t(418)=0.12, p=.905, d=0.01]. Accordingly, there was no difference in the likelihood to request the discount (scarcity condition: 15.12%; control condition: 14.91%) [X²<0.001, p=.951, φc=0.00]. Since
participants in both conditions were equally likely to notice and request the discount, it is not surprising that there was no difference in looking time at the food items (scarcity condition: $M=48.37\%$, $SD=14.82\%$; control condition: $M=50.91\%, SD=16.82\%$) [$t(423)=1.64, p=.102, d=0.16$], or at the calorie information (scarcity condition: $M=3.82\%, SD=4.28\%$; control condition: $M=4.49\%, SD=4.36\%$) [$t(419)=1.58, p=.115, d=0.15$]. These results suggest that the attentional bias and counterproductive behaviour under scarcity can be successfully mitigated by making the discount more salient.

**Experiment 5**

Experiment 4 showed that the attentional bias under scarcity may be mitigated by changing the location of the critical information (i.e., the discount). In Experiment 5, I wanted to replicate this finding and expand the toolbox of attentional intervention to include colour salience. In particular, Experiment 5 was meant to examine whether changing the discount at the bottom of the menu to be written in bold red letters. At first this may seem like a trivial difference, but there are several theoretical reasons to warrant this test. First, automatic attentional capture due to colour contrast is a different cognitive mechanism than attentional capture due to visual proximity (i.e., Experiment 4). It may be useful to know that the type of attentional bias induced by scarcity can or cannot be overcome by colour contrast. Second, prior evidence suggests that people under scarcity are less able to up-regulate attention to information on the outside edges of the stimuli. The discount in Experiment 4 was quite close to the starting point of the task. In contrast, the discount in the present experiment is at the bottom of the menu, in roughly the same position as it was when it was deprioritized by participants under scarcity in Chapter 2. Therefore, the use of this experiment is to test whether participants under scarcity are able to overcome the previously found inability to up-regulate attention to information further away from the centre of the stimuli. In other words, this experiment is a more direct intervention to the paradigm used in Chapter 2. It may not always be possible to move critical
information into the central vision of people under scarcity. From this it follows that alternative strategies to alleviate scarcity-induced attentional burdens may be needed in the real world.

Participants

Participants were recruited from US-based Mturk workers. The same exclusion criteria as the prior online experiments were used. After exclusions, N=513 participants comprised the final sample (266 female, 245 male, 2 unspecified; mean age=38.05 years, SD=12.11 years).

Stimuli and Procedure

![Menu](image)

*Figure 14. Experiment 5 stimuli featuring a red coloured discount at the bottom.*
The stimuli and procedure were identical to Experiment 4 except the discount on the menu appeared at the bottom in bold, red letters.

Results and Discussion

Participants in the control condition (N=272) did not significantly differ in time spent viewing the menu (M=107.67 seconds, SD=101.42 seconds) compared to participants in the scarcity condition (N=241; M=91.68 seconds, SD=88.80 seconds) [t(492)=1.85, p=.064, d=0.17]. As usual, participants in the control condition spent more money (M=$21.23, SD=$11.28) than participants in the scarcity condition (M=$13.55, SD=$4.85) [t(501)=9.77, p<.001, d=0.88].

\[ \begin{align*}
\text{Discount Memory Recall} & \\
\text{Discount Request Rate} & \\
\text{Time Spent Viewing Menu} & \\
\text{Money Spent} & \\
\text{Prices} & \\
\text{Discount} & 
\end{align*} \]

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condition ($M=5.29\%$, $SD=6.39\%$) [$t(494)=4.98$, $p<.001$, $d=0.45$]. This difference is more agreeable
with results from Chapter 2 where the discount was in the same position at the bottom of the menu.
This result, combined with those of Experiment 4, together suggest that people under scarcity can be
helped to notice the discount by moving its location but not by increasing the colour salience.
Unsurprisingly, participants in the scarcity condition were far less likely to request the discount (8.71%
of participants requested) compared to the control condition (23.53% of participants requested)
[$\chi^2(1)=19.23$, $p<.001$, $\phi_c=0.19$]. Since the behavioural disadvantage of participants under scarcity was
persistent in this experiment, I believe I can conclude that this attentional intervention has failed.
Merely changing the colour of the text from black to bolded red is likely not a viable strategy to
alleviate the cognitive burdens of scarcity.

To deepen the understanding of the discount-request behaviour, I estimated the strength of the
relationship between attention to the discount (measured by proportional dwell time) and making a
request. In the control condition, there was a strong relationship between these two outcomes
[$r_{pb}(270)=.59$, $p<.001$]. There was also a strong relationship between correctly remembering the
discount and requesting it [$r_{\phi}(270)=.54$, $p<.001$]. These relationships were also significant in the
scarcity condition, where both attention to the discount [$r_{pb}(239)=.44$, $p<.001$] and memory of the
discount [$r_{\phi}(239)=.31$, $p<.001$] predicted requests. Participants in the scarcity condition were far less
likely to correctly recall the discount (23.65% correct recall) compared to participants in the control
condition (38% correct recall) [$\chi^2(1)=11.95$, $p=.001$, $\phi_c=0.15$], but memory had a strong relationship
with discount requests in both conditions. Using logistic regression I estimated the contribution of
attention and memory to predicting discount requesting in the same model. In the scarcity condition, a
one standard deviation increase in attention to the discount predicts an increase in probability of
requesting the discount by a factor of 2.36 [odds ratio=2.36, $p<.001$], and recalling the discount
correctly predicts an increase in the probability of requesting the discount by a factor of 5.96 [odds
ratio=5.96, p=.001]. These results make it clear that, in the scarcity condition, both attention and memory are strongly related to discount requesting. Participants are much more likely to request the discount when they looked at it longer, suggesting that patterns of attention are critical for noticing the beneficial discount. I also computed the same logistic regression model in the control condition. Among participants in the control condition, a one standard deviation increase in attention to the discount was associated with an increased probability of requesting the discount by a factor of 3.65 [odds ratio=3.65, \( p<.001 \)], and correctly recalling the discount was associated with an increased probability of requesting the discount by a factor of 10.68 [odds ratio=10.68, \( p<.001 \)]. These results support a conclusion made in the chapter above suggesting that participants in the scarcity condition were not able to usefully deploy their attention or memory compared to participants in the control condition. This trend in findings supports the view that financial scarcity may affect performance by changing the way attention is dynamically allocated or by affecting the perceptual efficiency which occurs during attentional deployment.

**Experiment 6**

Experiment 4 showed that moving the discount to the top of the menu reduced the difference in discount request rates across the scarcity and control conditions. Experiment 5 showed that changing the colour of the discount to a bold red colour at the bottom of the menu preserved the attentional and behavioural differences between the scarcity and control conditions. In Experiment 6 I examined the combination of these two approaches by moving the bolded red discount from Experiment 5 to the top of the menu in the same position as Experiment 4. While there are not many clear theoretical motivations for this experiment, I am reporting it for two reasons. First, it may be useful to know the limit of attentional intervention effectiveness. Is it possible to help most or all participants to request the discount? Secondly, this experiment offers the opportunity to replicate prior
findings with a new sample of participants. There are issues with generalizability within the scarcity literature, so it is important to replicate results when possible.

**Participants**

Participants were again recruited from US-based Mturkers. The same exclusion criteria as prior experiments were used. After exclusions, \( N=299 \) participants comprised the final sample (266 female, 245 male, 2 unspecified; mean age=38.05 years, SD=12.11 years). It is noteworthy that many more participants were excluded in this experiment compared to prior experiments. In this experiment, I collected 519 complete responses from Mturk, and excluded approximately 50% due to low data quality. Six participants were excluded for responding through the same IP address as a previous participant, 39 participants were excluded for overspending the budget, 110 participants were excluded for spending less than ten seconds viewing the menu, and a further 63 participants were excluded for not providing any usable data from the open-ended responses (such as their menu order, their memory recall of menu items, or their estimated value of their order). It appears that participants sampled from Mturk at this particular time were much more likely to provide low-quality data.

**Stimuli and Procedure**

The stimuli and procedure were identical to Experiment 4 where the discount appeared at the top of the menu except the discount was printed in bold red letters in order to maximize salience.
Results and Discussion

With respect to the overall menu viewing time, there was not a significant difference between subjects in the scarcity condition ($M=154.29$ seconds, $SD=173.57$ seconds) and participants in the control condition ($M=178.48$ seconds, $SD=188.36$ seconds) [$t(290)=1.14, p=.257, d=0.13$]. As expected, given their respective budget constraints, participants in the scarcity condition ($M=$12.57, $SD=$4.97) spent less money than participants in the control condition ($M=$23.37, $SD=$14.57) [$t(293)=8.37, p<.001, d=0.99$].
In this sample, the attentional data appeared broadly inconsistent with prior data. For example, attention to the price information was not significantly different between the scarcity condition ($M=12.54\%$ of dwell time, $SD=9.58\%$ of dwell time) and the control condition ($M=11.45\%$ of dwell time, $SD=9.58\%$ of dwell time) \[t(291)=0.97, p=.332, d=0.11\]. This is extremely unusual because I have used this paradigm with more than a dozen unique samples and I have never seen a non-significant difference in attention to prices when financial scarcity was manipulated. Attention to the discount information in the scarcity condition ($M=4.51\%$ of dwell time, $SD=6.78\%$ of dwell time) and the control condition ($M=4.28\%$ of dwell time, $SD=7.09\%$ of dwell time) was not significantly different \[t(288)=.27, p=.784, d=0.03\], which is not unexpected given the discount was at the top of the menu as in Experiment 4. There was, however, a significant difference in attention to the menu items as participants in the scarcity condition ($M=38.60\%$ of dwell time, $SD=19.41\%$ of dwell time) attended less to the item names than participants in the control condition ($M=44.35\%$ of dwell time, $SD=21.59\%$ of dwell time) \[t(296)=2.41, p=.017, d=0.28\], which is in the expected direction given participants under scarcity typically spend less time attending to the names of food items. However, this is interesting because participants in Experiment 4 (when the discount was also at the top of the menu) did not show a significant difference in attention to the menu item names. In Experiment 4, I suggested that this might be explained by participants noticing the discount at equal rates which alleviates scarcity for both conditions, negating the need for participants under scarcity to prioritize attention to price information. In Experiment 6 it seems that participants did spend similar proportions of dwell time attending to the discount as they did in the control condition of Experiment 4. However, both the scarcity and control conditions in Experiment 6 utilized this information at far lower rates. Only $4.96\%$ of participants in the scarcity condition requested the discount and only $5.06\%$ of participants in the control condition requested the discount, rates which are not significantly different from each other \[\chi^2(1)=0.00, p=1.000^6, \phi_c=0.00\], whereas they were different in prior experiments. In this sample there

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6 The $p$ value was forced to reach 1.00 due to Yates’ correction. The unadjusted $p = .969$. 

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seems to have been a floor effect in discount request data, which again is unusual given the amount of visual attention to the discount information.

Figure 17. Experiment 6 results. Note: * $p < .05$, *** $p < .001$.

**Experiment 7**

Since the results of Experiment 6 were striking and unusual, I decided to replicate the test with the exact same stimuli and procedure.

**Participants**

Participants were recruited from the population of US-based Mturk workers. The same exclusion criteria as prior experiments were used. After applying exclusions, a total of $N=262$ participants remained (132 female, 130 male, 0 unspecified; mean age = 36.53 years, $SD=11.85$ years). Just like Experiment 3, the sample drawn from Mturk was far lower quality than I have seen since I started collecting data online in 2016. I received 548 complete data sets from Mturk participants. Of these, 10 participants were excluded for responding through an IP address that matched the IP address of a previous participant. A further 59 participants were excluded for exceeding their assigned budget
in the menu task. After this, a staggering 188 participants were excluded for spending less than 10 seconds viewing the menu. This suggests that many participants on Mturk were rushing through studies. Unfortunately, participants who rushed through this paradigm would not provide high quality attention data because they did not sufficiently explore the menu. Finally, a further 29 participants were excluded for not providing usable data in at least one of the open-ended response sections, such as their menu order, menu recall, or total order value estimate.

**Stimuli and Procedure**

The stimuli and procedure were identical to Experiment 6. The discount was shown at the top of the menu and was printed in bold red letters.

**Results and Discussion**

In this sample, participants in the scarcity condition spent less time viewing the menu ($M=147.78$ seconds, $SD=170.88$ seconds) compared to participants in the control condition ($M=204.04$ seconds, $SD=200.26$ seconds) [$t(250)=2.38$, $p=.018$, $d=0.30$]. As usual, participants in the scarcity condition spent more money ($M=$12.68, $SD=$4.63) than participants in the control condition ($M=$23.02, $SD=$15.42) [$t(255)=7.09$, $p<.001$, $d=0.91$].

When I analyzed participants’ attention to the menu, I found that participants in the scarcity condition spent more time looking at the prices ($M=14.63\%$ of dwell time, $SD=12.22\%$ of dwell time) compared to participants in the control condition ($M=11.47\%$ of dwell time, $SD=10.03\%$ of dwell time) [$t(250)=2.25$, $p=.025$, $d=0.28$]. This finding suggests that the lack of a difference in attention to prices in Experiment 6 was likely a type II error. There was no statistically significant difference in attention to the item names across the scarcity condition ($M=34.42\%$ of dwell time, $SD=18.97\%$ of dwell time) and the control condition ($M=39.06\%$ of dwell time, $SD=22.70\%$ of dwell time) [$t(258)=1.77$, $p=.077$, $d=0.22$]. Similarly, participants in the scarcity condition did not attend differently to the calorie information ($M=5.02\%$ of dwell time, $SD=5.54\%$ of dwell time) compared to participants in the control
condition \( (M=6.37\% \text{ of dwell time, } SD=8.92\% \text{ of dwell time}) \) \( t(252)=1.42, p=.154, d=0.18 \). It is interesting to note that, while the calorie information a much larger part of the menu by area (23,001 pixels) compared to the discount information (16,378 pixels), the two areas received similar amounts of proportional dwell time.

There was no significant difference between attention to the discount in the scarcity condition \( (M=3.46\% \text{ of dwell time, } SD=7.89\% \text{ of dwell time}) \) and the control condition \( (M=4.39\% \text{ of dwell time, } SD=7.43\% \text{ of dwell time}) \) \( t(250)=0.96, p=.337, d=0.12 \), but these results are very similar to other version of this paradigm where the discount appeared on the top of the menu, such as Experiment 4. Despite the seemingly normal rates of attention to the discount, only one participant (in the control condition) requested the discount. Despite the near zero discount request rates, there was adequate discount memory recall accuracy, but recall accuracy of the discount information was not significantly different in the scarcity condition (19.01\% accuracy) compared to the control condition (27.66\% accuracy) \( \chi^2(1)=2.24, p=.134, \varphi_c=0.09 \).

It is difficult to explain why participants might not have requested the discount in Experiments 6 and 7, while the rates of discount requesting were much higher in previous iterations of the paradigm. One idea is that there was a decrement in the quality of participation during the time that Experiments 6 and 7 were collected. Data for Experiment 4 was collected in January 2020, data for Experiment 5 was collected on July 22nd, 2022, data for Experiment 6 (the first study which showed signs of low quality data) was collected on August 8th, 2022, and data for the current Experiment 7 was collected on September 13th, 2022. This decrement in participation quality was reflected in the extraordinarily high rates of participant exclusion which took place during this time. However, a large proportion of participants were also excluded from the Experiment 5 sample, which did not ultimately show abnormalities in their results. The data quality explanation may be supported by some other abnormalities in the data, such as the lack of a difference in attention to prices in Experiment 6, but this
argument is weakened by the lack of inconsistencies in other results, such as attention to item names, which was found in Experiment 6. It is possible that the discount request behaviour is one of the most sensitive measures in this paradigm and is vulnerable to subtle changes in the sample, while the attentional measures do not respond differentially among different samples.

![Graphs showing results from Experiment 7](image)

**Figure 18.** Experiment 7 results. Note: * $p < .05$, *** $p < .001$.

<table>
<thead>
<tr>
<th>Experiment</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
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<td>S</td>
<td>C</td>
<td>S</td>
<td>C</td>
<td>S</td>
<td>C</td>
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<tr>
<td>Items Dwell (%)</td>
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<tr>
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<td>4.47</td>
<td>4.25</td>
<td>4.44</td>
<td>3.54</td>
<td>4.49</td>
</tr>
<tr>
<td>Discount Dwell (%)</td>
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<td>3.06</td>
<td>4.67</td>
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<td>1.82</td>
<td>1.67</td>
<td>4.61</td>
</tr>
<tr>
<td>Discount Requests (%)</td>
<td>33.17</td>
<td>15.86</td>
<td>27.67</td>
<td>11.11</td>
<td>n/a</td>
<td>n/a</td>
<td>14.91</td>
</tr>
</tbody>
</table>

**Table 1.** Summary of results from Experiments 1 – 7. Dwell time values represent the percentage of time looking relative to the total menu viewing time. Discount request values represent the percentage of participants who requested the discount. Note: C = control condition; S = scarcity condition. Note: Experiment 6 used a neutral phrase instead of a discount.
General Discussion

The present chapter made several attempts to circumvent the attentional tax of scarcity shown in Chapter 2. The interventions straightforwardly counteracted the attentional constraints to price information under scarcity by moving the important discount information to a region of the menu where participants of all budget conditions would be likely to see it. In addition, moving the discount to the top of the menu may have the benefit of introducing the discount information before participants, particularly those under scarcity, started engaging with the numerical information. In Experiment 4, this intervention appeared successful as participants in both conditions began requesting the discount at similar rates. However, the way in which this intervention was successful is still uncertain. In Chapter 2, rates of discount requesting in the control condition were frequently close to 30%, while discount request rates were close to 10% in the scarcity condition. In the intervention of Experiment 4, both conditions were close to 15% request rates. It is difficult to interpret these results clearly. On one hand, these results could suggest that the intervention made a small improvement to the function of the scarcity condition participants, but made even larger decrements to the function of the control condition participants. This explanation seems unlikely because it would suggest an inverse relationship between attentional availability of the discount and discount requests. However, there was a locally positive relationship between attention to the discount and discount requesting behaviour, suggesting that the increased attentional availability of the discount did not decrease discount request behaviour on its own. An alternative explanation for these results may suggest that participants on Mturk have on average become less attentive to the instructions of the experiments over time. This explanation would account for not only the decreasing rates of discount requests from Experiments 4 through Experiment 7, but it would also agree with the extremely high exclusion rates in these studies. Recent publications have noted a decline in data quality from Mturk samples that is characterized by low attentiveness among participants (Chmielewski & Kucker, 2020; Douglas et al., 2023).
Despite the low quality data, this chapter presents attentional interventions which may help participants under scarcity improve their performance by noticing a previously under-utilized discount. Even though discount requesting behaviour was on the decline among the Mturk population, Experiment 4 showed a modest increase in discount requesting. The size of this effect is not clear because there was no control group with the discount at the bottom of the menu that was collected at the same time.

This chapter also showed that moving the critical information closer to central vision was a more effective intervention compared to increasing the colour salience of the critical information. Participants were more likely to notice and use the discount when it was closer to the top of the menu (where all participants started their menu viewing task) compared to when the discount was in red letters at the bottom of the menu. However, the relative effectiveness of these interventions cannot be conclusively stated because the quality of data seemed to be in flux, and these data were not all collected at the same time. It is a strong possibility that these samples of participants were not equivalent in quality, which may have driven at least part of the difference in intervention effectiveness. Future studies using a higher quality sample of participants will add confidence to the present findings.

The above data demonstrated that people under budget constraints not only had a reduced scope of their spatial attention during visual search of the menu (Chapter 2, Experiments 1-2) but they also had less flexibility with their allocation of attention to the information near the edge of the stimuli, meaning that they were less likely to dynamically reallocate their attention to the discount when it was seen (Chapter 2, Experiment 3). In the present chapter, data showed that the attentional rigidity of people under scarcity is more effectively corrected by changing the spatial location of the discount rather than increasing the colour salience of the discount (Experiments 4-7). The relative effectiveness of spatial salience over colour salience is a novel finding in the scarcity literature and it corroborates new evidence suggesting that vivid colour saturation is beneficial in advertising for most people, but
not for people under scarcity (Kim et al., 2024). It seems as though people under scarcity may be less responsive to vivid colour. However, the present results are limited in their ability to fully characterize this attention deficit under scarcity. On one hand, it is possible that the spatial intervention was conflated with time, causing participants to see the discount before significantly engaging with the prices in the budgeting task. On the other hand, it is possible that scarcity causes a type of cognitive inertia such that they are less able to on-board new information after having engaged in a cognitively demanding budget task. Future research can disentangle these possibilities.

The present results have some implications for public policy implementations. In this chapter I showed that cognitive and behavioural deficits under financial scarcity can sometimes be mitigated with attentional interventions. Many people under financial scarcity do not enrol in programs such as financial assistance (Bouckaert & Schokkaert, 2011; Dubois & Ludwinek, 2015; Hernanz et al., 2004) or food assistance (FNS, 2020). Scarcity may even limit decisions to use contraception (Norris et al., 2019). The results of the present chapter suggest that the use of these resources can be improved by bringing the resources into the centre of attention. This can be done by reducing the spatial distance between the opt-in of the new resource and a resource which a person is already using. For example, the opt-in form for a utility subsidy program can be placed on a utility bill. This can also be done by providing text-message reminders for programs to eligible users which include a direct link to the sign-up page. Regardless of the program type, the key insight of this chapter is to bring the relevant information into close spatial proximity to information that people under scarcity are already attending to.
Chapter 4: Perception of Expenses and Income Under Financial Scarcity

High quality financial decisions depend on accurate perception of available resources and upcoming costs. However, there may be perceptual biases under scarcity which can undermine accurate judgments and decision making. For example, increased attentional and working memory load are correlated with longer estimations of time duration (Block, Hancock, & Zakay, 2010). Perhaps the cognitive demands associated with financial strain can also bias estimation of time duration, but a more important question is how cognitive demands under scarcity may bias the estimation of future income and upcoming expenses. The mental accounting of finances must become more precise as the gap between one’s income and expenses narrows. Therefore, errors in estimation under financial scarcity could be disastrous. For example, a single parent who overestimates their income over the upcoming month is at risk of overspending without realizing that more money must be preserved for upcoming bills. This could cause debt to accumulate, further exacerbating the cycle of poverty. Furthermore, a university student may underestimate the summed cost of textbooks, food, rent, and tuition, risking an insufficient amount of paid work scheduled to cover the costs. This chapter investigates how financial scarcity affects the estimation of future income and future expenses.

Before asking the question of whether or not financial scarcity affects estimation of income or expenses, the following assumption is a temptation: Since people under financial scarcity focus more on financially crucial information (as demonstrated in the above chapter on financial scarcity and visual attention), people should be expected to focus on income streams and track expenses with an accuracy proportional to the seriousness of their financial situation. In other words, people under scarcity would be expected to prioritize their finances in their minds more than people not under scarcity. For example, someone who has recently sustained financial losses would be expected to increase their focus on their income and expenses. Not only is this type of cognitive adaptation a promising prediction based on prior research on scarcity and attention (Tomm, 2017), but it is also the rational
behaviour which would be expected if we assume people are motivated to re-balance their finances when things go wrong. Unfortunately this is not the case, as evidenced recently by data showing that measures of financial scarcity are positively correlated with financial avoidance (Hilbert et al., 2022b). A recent study from Hilbert et al., (2022b) showed that people under financial scarcity report higher incidence of avoiding thinking about their finances or looking at their budget. Using survey methods, these authors also found that avoiding thinking about or looking at finances predicted subsequent worsening of financial scarcity – a finding which adds additional support to my account of the vicious cycle of scarcity.

Thus, it seems we have prior evidence in this dissertation suggesting that financial scarcity will cause people to up-regulate their attention to financial information, and other evidence in the literature suggesting that financial scarcity causes people to down-regulate their attention to financial information. This chapter will attempt to resolve these conflicting predictions in the domain of numerical estimation. How does financial scarcity affect estimation of future income and future expenses? I conducted two experiments to measure the perceived estimates of sums.

**Numerosity**

When people estimate the sum of a set of numbers, the sum is usually estimated to be larger when there are more numbers being summed compared to when there are less numbers being summed, even when the total quantity of both number sets is equal. In other words, people use the number of units to help infer the total quantity. This phenomenon is known as the numerosity heuristic (Bagchi & Davis, 2016). Overestimation of quantities due to the over-reliance on the numerosity heuristic will be called numerosity bias in this chapter (note: this definition of the term “numerosity bias” varies slightly from usage elsewhere, e.g.: Shrivastava et al., 2017). Prior research has shown that people under cognitive load or time pressure exhibit a greater reliance on the numerosity heuristic when estimating quantities (Pelham, Sumarta, & Myaskovsky, 1994). In other words, people tend to overestimate total
quantities when there are more numbers to add together, and this bias increases in magnitude under
cognitive load. Moreover, it has been shown that people under financial scarcity have increased
cognitive load, as there are excess demands on the attentional and executive control systems (Iles et al.,
2021; Mani, Mullainathan, Shafir, & Zhao, 2013; Shah, Zhao, Mullainathan, & Shafir, 2018). The
potential for interplay between scarcity-induced cognitive impairment and numerosity heuristic is one
motivating factor for the current chapter.

The goal of this chapter is to investigate how scarcity affects estimation of numerical sums
representing future income and future expenses. One possible connection between scarcity and
numerical estimation accuracy is that the cognitive demands of scarcity may exacerbate the numerosity
bias. A second possibility is that scarcity affects numerical estimation via another mechanism not yet
specified in this chapter – either a mechanism to enhance or impair numerical estimation accuracy. For
example, people might respond to scarcity by adopting a conservative perception of numbers
(underestimating income and overestimating expenses). These possibilities carry implications for
people under financial scarcity because it could be problematic to overestimate the total expected
income or expenses. To examine the possible mechanisms by which scarcity affects numerical
estimation, I conducted two online experiments. The experiments in this chapter evaluate how scarcity
affects the perception of income (Experiment 8), and how scarcity affects the perception of expenses
(Experiment 9). Based on prior findings that financial scarcity increases attentional and working
memory load, it was predicted that participants under financial scarcity would overestimate numerical
quantities more than participants not under financial scarcity.

**Methodological Background**

The basic paradigm used in this chapter is adapted from Pelham et al., which was created to
demonstrate the numerosity bias (1994; Experiment 2 in particular). The authors asked participants to
solve repeated addition problems. For each problem, a group of numbers was presented on a screen for
two seconds. Following the presentation interval, participants were allowed up to seven seconds to verbally report their best estimate of the sum of the previously presented numbers. Participants were instructed to guess the sum if they were not able to precisely calculate the answer. There were 24 problems to solve in total. Of these problems, there were twelve pairs of problems that summed to the same number. However, within each pair of problems, one had “few-elements” and one had “many-elements.” Overall, the “few-element” problems had an average of 4.75 numbers to sum, while the “many-element” problems had an average of 8.41 problems to sum. The existence of pairs of problems with the same solution but with varied amounts of elements was helpful to infer the use of the numerosity heuristic. The authors always presented these pairs of problems back-to-back, but this method was not necessary for the purposes of the current chapter. I used this paradigm during pilot testing without using paired problems. Instead, I used randomly generated problems presented in a random order. Thus, all problems were independent.

To induce cognitive load during the summation task, Pelham et al. (1994) asked half of the participants to complete a concurrent digit-detection task. This dual task required participants to report the presence or absence of the digit “4” anywhere in the set of numbers to sum. Participants in the dual-task condition were required to report the presence or absence of this digit before reporting the sum of the numbers. In the current chapter, I used a different dual task designed to induce working memory load which will be described in more detail below.

I selected this design by Pelham et al. (1994) because of its flexibility in that are several ways that the numerosity heuristic can be detected. First, within-subject comparisons can be made to check the degree to which participants estimate a larger sum for the “many-element” trials compared to the “few-element trials.” This method yields an average estimation bias score for each participant. Second, the correlation between estimation accuracy and the number of elements within each trial can be used. This method yields a correlation coefficient for each participant that indicates the degree to
which the numerosity heuristic has been used. Participants with high sum estimates in trials with many
elements and low sum estimates with few elements are likely making use of the numerosity heuristic.
For these reasons this is a suitable design for the investigation of numerical estimation under the
cognitive load of scarcity.

In addition to the measurement of the use of the numerosity heuristic, this paradigm
straightforwardly measures several key indications of numerical estimation accuracy. First, this
paradigm yields a measure of trial-level accuracy. Specifically, as participants reported estimates of
sums of numbers, the deviation from the true sums can show whether participants under or
overestimated the numbers they saw in front of them. Secondly, this paradigm yields a measure of
block-level accuracy. After participants complete several trials, they were asked to report the overall
sum of the last four blocks. This measure of accuracy over an entire block of four trials gives an
indication of whether participants are able to hold their trial sum estimates in mind and accurately
compute global sums over multiple trials, which is more difficult than reporting trial-by-trial sums.
This block-level measure of estimation accuracy may reveal how participants are able to store
quantitative information in working memory under the cognitive load of still completing trial sums, and
also under the cognitive load induced by scarcity.

Experiment 8

The purpose of Experiment 8 was to investigate how lab-induced scarcity affects the use of the
numerosity heuristic during a summation task. The methods and hypotheses for this experiment were
pre-registered on OSF (see https://osf.io/hq3d5).

Methods

In this experiment, participants were asked to estimate the sum of sets of numbers which
represented future income. Each number represented a dollar amount earned in one day, and a set of
numbers represented one week of income earned. For example “$100 + $70 + $60” represents three
days of work, and “$40 + $40 + $50 + $80 + $20” represents five days of work. After four trials (four “weeks” of income), participants were asked if they earned enough to cover a quantity of monthly expenses, which is given as one single number before the start of the four trials.

**Financial Scarcity Manipulation**

In this experiment I manipulated financial scarcity using both a within-subjects independent variable and a between-subjects independent variable. For the within-subjects manipulation of financial scarcity, participants were given a figure representing the amount of monthly expenses for that particular block of trials. Participants were told that they had to keep track of the overall sum of all four trials (i.e., “weeks” of income) and be prepared to judge whether or not the income was sufficient to cover the nominal expenses by the end of the four trials for that block. Scarcity was manipulated by varying the distance between the nominal expenses and the actual total of the upcoming four weeks of income. There were two conditions: the scarcity-expense condition and the control-expense condition. In the scarcity-expense condition, the nominal expenses figure was either 10% higher or 10% lower than the true sum of the upcoming four trials of income. For each participant, whether the expenses were higher or lower than the total of income was determined by a random number generator implemented in JavaScript running on participants’ computers. This is a scarcity condition because the difference between income and overall expenses is always relatively small, so participants needed to track their income closely in order to correctly determine whether their budget balances or not. In the control-expense condition, the amount of overall expenses was substantially lower than the total of upcoming income. At the start of each block, the amount of expenses was determined by summing all four trials of upcoming income and dividing the overall sum by four. This number was then rounded down to the nearest integer to remove decimal values. Therefore, the amount of expenses in the control-expense condition were approximately one quarter of the overall income budget. Participants in the control-expense condition had little difficulty in determining whether their income was sufficient
to cover their monthly budget because their expenses were approximately equal to the income shown in the first trial. In contrast, it was more difficult for participants in the scarcity-expense condition to determine whether their total of income was sufficient to cover their nominal expenses because the difference between these two quantities was relatively small.

Scarcity was also manipulated between participants using a scenario-priming procedure. There were two conditions: the scarcity-scenario condition and the control-scenario condition.

Participants in both conditions were asked to read a scenario about hypothetical job salary cuts. In the scarcity-scenario condition, participants read a scenario describing general economic difficulties that result in their employer needing to make a 15% cut to the participant’s salary. The participants were then asked to write about how they would respond to this hypothetical salary cut in their actual lives.

Participants were prompted to think about what changes to their lifestyle they would need to make. Participants in the control-scenario condition were given the exact same scenario and prompts, except they were assigned a 5% pay cut instead of a 15% pay cut.

The economy is going through difficult times; suppose your employer needs to make substantial budget cuts. Imagine a scenario in which you received a [15%/5%] cut in your salary. Given your situation, would you be able to maintain roughly your same lifestyle under those new circumstances? If not, what changes would you need to make? Would it impact your leisure, housing, or travel plans? Please write your responses in the text box below.

**Figure 19.** Experiment 8 scenario-priming stimuli.

**Participants**

Participants (N=892) were recruited from a US-only population on Mturk. To enhance the quality of the sample, I excluded 117 participants who failed the practice block of trials, which is easy to pass if the directions are understood (see a more detailed description of the practice block below). To help prevent duplicate participants, I excluded seven participants who responded through an IP
address matching a previous participant in this sample. After these exclusions, a final sample of $N=768$
participants remained ($mean$ $age$=$37.38$ $years$, $SD$=$11.62$ $years$).

Since this study focused on lab-induced scarcity, no participants were recruited or excluded based on their income. However, the standard battery of demographic information still included information pertaining to income in order to be used as a covariate in exploratory analyses. I would suggest to any researcher interested in scarcity research to always include measures of subjective socioeconomic status and financial stress, as these simple variables are often more predictive than objective financial indicators.

**Stimuli and Procedure**

**Number Estimation Task.** Participants were asked to imagine that they were looking ahead on their work-schedule to check if they have enough hours of work scheduled in order to pay some bills at the end of the month. Each month consisted of four weeks, and represented a block of four trials. Each trial represented one week of future earnings. Each “week” contained between three to seven numbers. The sets of numbers were displayed for two seconds at the centre of the participants’ screens. After the numbers disappeared, a prompt asked participants to type their estimate of the total of the set of numbers. Participants were given unlimited time to respond to each trial. All participants were instructed to guess if they did not know the precise sum. After each trial response was entered, there was a one-second break before the next trial. To ensure that participants were familiar and comfortable with the interface, they were given one block of practice trials before starting the experimental blocks. Participants completed a total of two experimental blocks of trials, yielding 8 trials per participant.

**Dual Task.** During the summation task, all participants completed a concurrent dual task. Participants were asked to keep track of the grand total of earnings across the four “weeks” within each block of trials. At the beginning of each block, participants were informed of the grand total of their monthly expenses, and instructed that they were to be asked whether or not the forthcoming earnings
over the next four weeks would satisfy the expenses. In addition to being asked whether or not the earnings cover the expenses, participants were also asked for their estimate of the total earnings for that block of trials. The purpose of the dual task was to manipulate cognitive load during the summation task by inducing financial scarcity. To manipulate scarcity, participants were assigned either a large amount of expenses (scarcity-expense condition) or a small amount of expenses (control-expense condition). As mentioned above, expenses in the scarcity-expense condition were either 10% above or 10% below the actual total of all four weeks of income. Therefore, participants in the scarcity-expense condition needed to track income closely in order to successfully complete the dual-task of deciding whether or not their income in a given block was sufficient. In contrast, participants in the control-expense condition were assigned expenses close to one quarter of the total income in a given block. In this condition, the cognitive load induced by the dual-task was low because participants did not need to closely monitor expenses in order to successfully judge the adequacy of their income. In theory, participants in the scarcity-expense condition experienced a relatively high working memory load compared to participants in the control-expense condition.

Figure 20. Experiment 8 control-income condition experimental flow.
Hypotheses

There were three pre-registered hypotheses. First, I hypothesized that participants in the scarcity-prime condition would underestimate the sum of four weeks of income (i.e., the block total) significantly more than participants in the control-prime condition (main effect of scarcity mindset). Second, I hypothesized that participants’ reported confidence that they would be able to cover the expenses of the current month with their current income ("budget confidence") would positively correlate with signed block estimation error (error estimating the total of four weeks of income). In other words, participants with few immediate financial concerns in their real life would be less conservative with their estimates of the future income (to be conservative with budget estimates means to anticipate lower income). People with less financial worry should not need to be as conservative with their estimates of future income, so I wanted to detect this shift in conservatism in this paradigm. My third hypothesis was that participants' real life budget confidence would negatively correlate with absolute block estimation error (error estimating the total of four weeks of income). In other words, people with few immediate real-world financial concerns will be more accurate in estimating the total future income. This third hypothesis is contrary to the prior literature which predicts that financial scarcity makes people attend more to financial information (see the above chapter on scarcity and
attention) and financial scarcity also makes people frame value more precisely (Shah et al., 2015; Isler et al., 2023). However, I made this prediction because the block-level estimation is a secondary task (dual task). Therefore, scarcity should be expected to draw attention to the immediate task of estimating the trial-by-trial sums of income, which may reduce attention to the overall monthly budget.

**Results and Discussion**

**Pre-registered Analyses**

To analyze the errors in estimating the total of income, I collapsed the budget scarcity conditions together. This was done for each participant by taking an average of estimation error from the control-expense and scarcity-expense conditions. Although I pre-registered a directional hypothesis for this comparison, I used a two-tailed t-test for the analysis. Participants in the scarcity-scenario condition underestimated income significantly more ($Mean estimation error=-$1677.05, $SD=$1151.89) compared to participants in the control-scenario condition ($Mean estimation error=-$1397.50, $SD=$1185.90) [t(752)=3.28, p=.001, $d=0.24$]. This result suggests that the scarcity scenario caused participants to estimate lower sums of income over the course of the experimental blocks. In other words, the scarcity scenario caused participants to become more conservative in their estimates of the future income, supporting my first hypothesis.

To test my second hypothesis, I estimated the relationship between participants’ confidence in their real-world budget and the signed block estimation error. While I hypothesized a negative relationship between budget confidence and estimation error (this tests whether participants who feel good about their personal finances estimate higher amounts of income in the estimation task), I did not find any significant relationship between budget confidence and error in the estimation of four weeks of income [r(766)=0.03, $p=.435$]. These results fail to support my second hypothesis. There seems to be no clear linear relationship between budget confidence and signed block estimation error.
For hypothesis three, I estimated the relationship between budget confidence and absolute block estimation error. This comparison is intended to capture an effect of real-world financial scarcity on accuracy estimating the block totals, which was the secondary component of the dual-task in this experiment. Under real-world scarcity (low budget confidence), I expected participant to be more attentive to the trial-by-trial income estimation, and therefore deprioritize the block-level totals, resulting in higher absolute estimation error. However, I found no significant relationship between my measure of budget confidence and absolute block income estimation error \( r(766)=0.03, p=.471 \), so my third hypothesis remains unsupported.

**Exploratory Analyses**

In the following analyses I will explain that, while I failed to find evidence of numerosity bias, these data were more rich with insights than expected. First I will describe the analyses which correspond to predictions from prior numerosity literature, and then I will report the comparatively informative exploratory results.

**Numerosity Bias.** The present study was inspired by an original paradigm which used pairs of sum-matched trials in order to compare estimation error across trials with few and trials with many elements (Pelham et al., 1994). This was useful because comparing trials of different set size with the same sum can provide evidence of numerosity bias. In the present study, there were no pairs of trials with matching sums. Instead, trials were constructed by first choosing a random number of elements (between three and seven) and then choosing random values for each element (between 60 and 200). Therefore, the trial sums were dependent on the set size.

Instead of comparing trials with few versus many elements, I explored for numerosity bias using correlations. For each trial, I computed the distance between the estimated trial sum and the objective trial sum and divided the difference by the objective trial sum. This yielded a measurement of proportional estimation error where positive values reflect overestimation and negative values reflect
underestimation. It was necessary to use proportional error because the objective sums are solely
determined by the set size and some random error variance, which means that some of the information
from set size is likely built in to the estimation errors. For example, participants may make larger
estimation errors for larger objective sums simply because the scale of the numerical values are larger.
Using proportional errors is a way to remove this bias from the correlation between error and set size.

I used the proportional trial estimation and trial set size data to estimate Pearson correlations.
This resulted in a correlation coefficient for each participant (note that five participants were excluded
from these correlation analyses as I could not estimate a correlation coefficient due to a lack of variance
in their trial estimates). The correlations were notably negative (mean $r=-.39$, $SD=.41$) and the median
of correlation estimates was significantly different from zero [Wilcoxon statistic = 29266, $p<.001$]
(95% CI: [-.45, -.38]; Note: non-parametric tests were used because the distribution of correlations was
highly skewed). There were significantly more estimates below zero ($n=613$) than estimates at zero or
above ($n=147$) [$\chi^2(1)=285.73$, $p<.001$, $\phi=0.38$]. Although only 220 of these 760 coefficients are
statistically significant, this strong general tendency toward negative correlations across participants
suggests that numerosity heuristic is not the primary factor driving estimations. In fact, participants
were likely to estimate higher sums for trials containing fewer elements compared to trials containing
more elements. Participants appear to have systematically estimated lower income totals when trials
contained more elements compared to when they contained fewer elements.

The initial thought behind this paradigm was to use it to investigate whether scarcity
exacerbates the use of the numerosity heuristic (since earlier studies found that cognitive load increased
reliance on the numerosity heuristic). Although there seems to be little evidence from the current data
showing the use of the numerosity heuristic, I decided it would be worthwhile to check whether the
relationship between set size and proportional estimation error was significantly different between
participants in the scarcity-scenario condition and participants in the control-scenario condition. Is the
numerosity heuristic only used among those under scarcity? Using a Mann-Whitney test I found no
significant difference between the median correlations of participants in the scarcity-scenario
(median=-.48) condition and participants in the control-scenario condition (median=-.47) \([U=72652, p=.873]\). Unlike the predictions from my original theory, these data fail to suggest any effect of
scarcity on the use of the numerosity heuristic.

This analysis does not rule out the use of the numerosity heuristic in this paradigm (it simply
fails to reveal it). However, since the numerosity heuristic seems not to have been a major factor
driving sum estimations, I will focus on other findings for the remainder of the analyses.

**Trial Income Estimates.** To compute the income estimation error scores, I summed together
the trial error scores within each block. This was done separately for the scarcity-expense condition
and the control-expense conditions, yielding trial income estimation scores for each block. Since each
block contained four trials, the average error can be obtained by dividing the estimation scores by four.
However, I decided to keep the trial estimation scores as the sum of the four trial errors per block.

Participants generally underestimated the sums of income on most trials. However, there was
no significant difference between trial income estimation in the scarcity-expense condition \((Mean\ income\ estimation\ error=-732.40, SD=828.58)\) compared to the control-expense condition \((Mean\ income\ estimation\ error=-748.51, SD=830.37; note: this is a within-subject comparison; note: 20\)
participants had difference scores more than 2.5 times the standard deviation of difference scores and
were excluded from this test and from the means reported above) \([paired t(747)=0.97, p=.334, d=0.02]\).

Looking at only the trials completed in the scarcity-expense condition, there was no difference
in income estimation error between participants in the scarcity-scenario condition \((Mean\ income\ estimation\ error=-757.55, SD=845.97)\) and participants in the control-scenario condition \((Mean\ income\ estimation\ error=-694.12, SD=810.63)\) \([t(760)=1.06, p=.292, d=0.08]\). In addition, looking
at only the trials completed in the control-expense condition, there was no difference in income
estimation error between participants in the scarcity-scenario condition (Mean income estimation error = -$807.78, SD = 822.29) and participants in the control-scenario condition (Mean income estimation error = -$723.21, SD = 802.20) [t(762) = 1.44, p = .151, d = 0.10].

The analysis of the trial income estimates shows that while participants generally underestimate the sums of the stimuli immediately after their presentation and disappearance, neither the scarcity scenario conditions nor the scarcity budget conditions had a measurable effect on estimation. However, there were some interesting factors which predicted participants’ trial income estimates. First, there may have been some relation between personal income and trial income estimation [r(766) = -.10, p = .005], although this small correlation did not remain when using my measure of household income [r(766) = .04, p = .283] (the measure of household income factors in the number of household occupants). Given the present data there is very weak evidence for this relationship, but if it holds in future research, this would be interesting because it could suggest that lower income individuals are more likely to estimate higher incomes in this paradigm – an example of lower income people being more accurate in their estimations of income. A follow-up correlation between personal income and absolute income estimation error confirms that lower income people were slightly more accurate in this experiment [r(766) = .15, p < .001] (note: here, accuracy was defined as the absolute value of trial income estimation error).

A second set of interesting correlations are those between the subjective measures of scarcity and trial income estimation. While reported financial stress did not seem to have a significant relation to trial income estimation accuracy [r(766) = -.02, p = .567], relative SES did [r(766) = -.10, p = .008]. This correlation may suggest that people who felt financially worse off than other people may have estimated slightly higher incomes in this experiment. This is a weak result on its own, and it is not supported by findings from the scarcity index and financial avoidance index data. The scarcity index used was the Psychological Inventory of Financial Scarcity (PIFS; van Dijk et al., 2022) and financial
avoidance was measured using the Financial Avoidance scale (FA; Hilbert et al., 2022b). While participants who reported personal income to be lower tended to report slightly higher (more accurate) income estimates, participants with high subjective scarcity (measured via the PIFS) tended to report lower income estimates \( r(766)=-.18, p<.001 \) and their trial income estimates were less accurate overall when crossed with the absolute trial income estimation error data \( r(766)=.24, p<.001 \) (note: higher scores on the scarcity index correspond to stronger feelings of subjective scarcity).

Figure 22. Experiment 8 trial estimation scatter-plots.\(^7\)

Figure 23. Experiment 8 trial estimation results by expense condition and by scenario condition.

This seems paradoxical since objective and subjective scarcity seem to have opposite relations with performance in this task. However, there is an explanation worth consideration. There is a tendency for researchers to think of demographic data as stable, since it often reflects people who are

\(^7\) Note: uniform dithering was added to relative wealth and personal income data for visual clarity.
stable over time. However, some of this demographic data, particularly the subjective scarcity measures, may be dependent on the way that participants responded to the experimental paradigm itself. The scarcity index data was recorded after the experimental trial blocks. Therefore, instead of concluding that people who feel subjective scarcity will perform worse on this task, we may consider the possibility that people who estimated low incomes in this experiment developed a local state of subjective scarcity. Finding acute feelings of scarcity would not be surprising to the wider scarcity literature because it is common to acutely manipulate feelings of scarcity through simple laboratory manipulations. In fact, the scarcity scenario manipulation in this experiment systematically affected participants’ reported subjective scarcity (even though this measure was intended to capture their feelings about their real-world finances). Participants in the scarcity-scenario condition reported higher subjective scarcity (Mean subjective scarcity=4.30, SD=1.44) compared to participants in the control-scenario condition (Mean subjective scarcity=4.05, SD=1.44) [t(766)=2.41, p=.016, d=0.17].

Figure 24. Experiment 8 subjective scarcity results. Note: * p < .05.

**Block Income Estimates.** After participants completed four trials in a block, they were asked to estimate the grand total of all the income values they had seen in that block. This was intended to be a relatively difficult secondary task that required participants to make estimates from their memories of the previous four trials. Each participant made two block income estimates: one for the trials in the scarcity-expense condition and one for trials in the control-expense condition (in addition to these two,
participants also made a block-level income estimate for trials in the practice block). Similar to the
trial income estimations, participants generally underestimated the true sum of the four blocks of trials.
However, I found that participants estimated higher block income totals in the scarcity-expense
condition (Mean block income estimation error=-\$863.55, SD=\$956.65) compared to when they were in the control-expense condition (Mean block income estimation error=-\$1078.67, SD=\$923.28; note: these means reported here were computed after exclusion of difference scores greater than 2.5 times the standard deviation from the mean difference score) [paired \(t(749)=7.62, p<.001, d=0.23\)].

This is unexpected because, when looking at the trial income estimates, I did not find any difference between the scarcity-expense condition and the control-expense condition (see above). However, this result could be explained by an anchoring effect caused by the expenses figure which was manipulated for each condition. Specifically, participants were shown a much larger expenses figure before the start of the scarcity-expense condition block compared to the expenses figure shown before the start of the control-expense condition block. Participants may have anchored their estimates of the total block income on the nominal block expenses, resulting in participants in the scarcity-expense condition estimating slightly higher income totals compared to when they were in the control-expense condition. Independently of any anchoring effects, the difference in block income estimation may also be explained by prior literature which shows that people under scarcity have a more stable frame of numerical value and may be expected to be more accurate in estimating numerical figures such as these (Shah et al., 2015; Isler et al., 2023). However, this explanation has limited power in the current paradigm because the stabilized perception of value under scarcity is thought to be accounted for by reduced reliance on contextual information (people under scarcity are less likely to have their estimates of value biased by contextual information), of which there is little in the current paradigm. A more likely explanation for the difference in block income estimation between expense-conditions (aside from the powerful anchoring explanation) may be related to accuracy of value estimation driven by a
more general scarcity mindset. Since participants were more accurate in estimating income totals in the scarcity-expense condition than in the control-expense condition, perhaps there is something about the scarcity mindset which increases precision of income estimation. The expense-conditions were not intended to manipulate scarcity mindset per se. Therefore, this possibility can be better tested by looking at the difference in block income estimation across the scarcity-scenario and control-scenario conditions, which were intended to manipulate scarcity mindset.

Figure 25. Experiment 8 block estimation and decision results. Note: ** p < .01, *** p < .001.

In the scarcity-expense block, participants in the scarcity-scenario condition (Mean block income estimation error = $-1007.48, SD = $863.28) underestimated the block income significantly more than participants in the control-scenario condition (Mean block income estimation error = $-802.15, SD = $971.41) [t(751) = 3.18, p = .002, d = 0.23]. Similarly, in the control-expense block, participants in the scarcity-scenario condition (Mean block income estimation error = $-1212.45, SD = $971.41) underestimated the block income significantly more than participants in the control-scenario condition.
(Mean block income estimation error=$-1027.11, SD=852.33) [t(749)=3.09, p=.002, d=0.23]. In general, it seems that participants in the scarcity-scenario condition systematically estimate lower income totals in each block type. This result is corroborated by the scarcity index data, which correlates negatively with block income estimation error in both the scarcity-expense condition \[ r(766)=-.21, p<.001 \] and the control-expense condition \[ r(766)=-.19, p<.001 \]. In other words, people who feel more scarcity in their daily life tended to estimate lower monthly income totals. This may be an adaptation of the scarcity mindset: more financial worries should equate to more conservative projections of future income. This could be a pragmatic strategy, implicitly or explicitly executed, intended to ‘play it safe’ when economic times are tough. Alternatively, this type of conservatism under scarcity may be linked to a temporal discounting mechanism, possibly induced by stress, which causes people to undervalue future quantities (Haushofer & Fehr, 2019). In this case, I am not currently aware of a mechanism which connects temporal discounting to changes in perceived quantity. Future research should investigate this possibility as it has significant implications for the present results and also for temporal discounting research in general (a perceptual explanation of temporal discounting could be quite powerful). The present paradigm could be adapted to answer this very question by shifting the temporal framing around when participants can expect to receive the future income.

These results are in contrast to a prior finding above. I previously found that participants estimated higher block income totals when expenses were high (budget scarcity), and lower block income totals when expenses were low (no budget scarcity). Here, I also found that participants estimated lower block income totals after reading the scarcity scenario (scarcity mindset) and higher block income totals after reading the control scenario (no scarcity mindset). Since these patterns of results are in opposite directions, it is most likely that the block income estimation differences across expense conditions is driven by something other than scarcity, and is best accounted for by anchoring.
To check whether the effect of the expense-conditions and the scenario-conditions are independent, I used a 2 (expense condition; within subjects) x 2 (scenario condition; between subjects) mixed ANOVA. This ANOVA was computed after excluding outliers on the block-level estimation errors who were more than 2.5 standard deviations from the mean in either the scarcity-expense condition or the control-expense condition. With this methodology, there was a main effect of expense condition \[ F(1,742)=54.79, \ p<.001, \ \omega^2=0.07 \], a main effect of scenario condition \[ F(1,742)=11.54, \ p=.001, \ \omega^2=0.01 \], and no significant interaction \[ F(1,742)=0.02, \ p=.878, \ \omega^2=0.00 \]. The lack of interaction here suggests that the observed effect of expense condition is likely different (likely simply an anchoring effect) than the observed effect of scenario condition, which seems to be best explained by participants becoming more financially scrupulous under scarcity.

![Figure 26](image)

**Figure 26.** Experiment 8 block estimation scatter-plots.\(^9\)

It is interesting that while there were no differences by condition for the trial-level data, block-level data revealed some notable patterns. Why might the block estimations have been affected by the scarcity conditions but the trial-by-trial estimations were not? I can think of two reasons. Firstly, anchoring is likely to play a larger role in block income estimation than trial income estimation because

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8 Omega squared was used here due to the tendency of partial eta squared to overestimate the effect sizes in designs with within-subject factors (Kroes & Finley, 2023; Olejnik & Algina, 2003). However, in this case the omega squared estimates were nearly identical to the partial eta squared estimates.

9 Note: uniform dithering was added to relative wealth and personal income data for visual clarity.
the expenses figure is a monthly one, similar to the block income estimate (and unlike the weekly trial figures). Secondly, the block estimation task is more difficult than the trial estimation task. Estimating the block totals involves fuzzy estimation from more distant memories. The increased uncertainty in the block estimation task means that there is more room for variability, such as improvement of accuracy, caused either by increased effort or improved numerical ability under scarcity. The dual-task element of this study (the block estimation task) has turned out to be a valuable tool in measuring numerical estimation performance under scarcity.

**Decision Accuracy.** The final round of exploratory analysis for this experiment concerns the accuracy of participants’ decisions on whether or not their total income from the four trials was sufficient to pay for the nominal expenses in the respective block. Each participant made two such decisions, one for the scarcity-expense condition block and one for the control-expense condition block, and the decision was made on a separate page immediately after estimating the block sum of income. All participants also made a decision after the practice block, and this decision was used as an attention check (only participants who responded correctly were retained in the sample). However, this attention check is far from perfect because it is a binary answer. We can assume, of the participants who did not pay attention to the instructions and who guessed on the attention check, 50% of the participants who did not attend to the instructions passed the attention check by chance. Since 117 participants were excluded based on the attention check, we may assume that a similar number of participants in the final sample did not understand the instructions correctly. This assumption is supported by the 78 participants (10.16% of the final sample) who made an incorrect decision in the control-expense block, which was designed to be extremely easy for those who understood the instructions correctly.

As a reminder to the reader, there were two expense conditions: the scarcity-expense condition and the control-expense condition. In the scarcity expense condition, participants were assigned an
expense budget which was close to the actual sum of all their income in that block (expenses were either 10% higher or 10% lower than the total of income from all four trials). In this condition it is difficult to make a correct decision at the end because participants need to pay close attention to all four trials in order to have an estimate of their income total which is accurate enough to make a decision. In the control-expense condition, however, the expenses were always one quarter of the total income for the four trials. In this condition it is easy to make a correct decision at the end because participants simply need to notice that their income already exceeded the expenses before the fourth trial. The difference in difficulty of the two conditions is illustrated by the percentages of participants responding correctly. Participants in the scarcity-expense condition were barely above chance performance (54.82% correct responses) \( \chi^2(1)=7.13, p=.008, \phi_c=0.10 \), and were significantly less accurate than they were in the control-expense condition (89.84% correct responses) \( \chi^2(1)=65.13, p<.001, \phi_c=0.29 \). This shows that decision making in the scarcity-expense condition was significantly more difficult than the control-expense condition.

To check whether the two scenario conditions differed in decision accuracy, I examined the decision accuracy performance in the scarcity-expense block. This block is ideal for this analysis because it was relatively difficult compared to the control-expense block, in which accuracy was near ceiling. I tested whether accuracy was independent of scenario condition using a chi-squared test of independence. This type of test was used (instead of a goodness-of-fit test with two conditions) because the sample sizes were slightly unequal. I found no strong evidence that decision accuracy in the scarcity-scenario condition (51.53% correct responses) was any different than accuracy in the control-scenario condition (58.24% correct responses) \( \chi^2(1)=3.23, p=.072, \phi_c=0.06 \). However, participants in the control-scenario condition were significantly above chance-level decision accuracy \( \chi^2(1)=10.23, p=.001, \phi_c=0.16 \) while the participants in the scarcity-scenario condition were not significantly above chance-level decision accuracy \( \chi^2(1)=0.37, p=.545, \phi_c=0.03 \). While this is not
strong evidence for an effect of scarcity on decision accuracy, it may suggest that scarcity impairs the ability of people to make accurate decisions about their finances. This is an interesting possibility that warrants further study. A follow-up study should replicate this paradigm with a larger sample size and a stronger scarcity scenario manipulation procedure.

If the participants under scarcity were making less accurate decisions, what decisions were they actually making? I examined the responses to the budget decision in the scarcity-expense condition and found that the “yes” responses were significantly over-represented. In this condition, 72.53% of participants said that they earned enough income to cover the expenses, whereas this number should approximate 50% under optimal performance. Participants in this condition were clearly biased in favour of satisfying the budget. Next, I checked whether this bias differed across the scenario conditions. The proportion of participants who said “yes” in the scarcity-scenario condition (72.04% “yes” responses) was not significantly different from the proportion of participants who said “yes” in the control-scenario condition (69.94% “yes” responses) [$\chi^2(1)=1.01, p=.316, \phi_c=0.04$]. It is interesting to note that, while participants in the scarcity-scenario condition may have been less accurate than participants in the control-scenario condition, this potential drop in accuracy is not explained by any measurable decision bias. This is surprising given the above finding which showed that participants in the scarcity-scenario condition are more likely to underestimate their income to a greater degree. Greater underestimation of income would presumably lead to a systematic bias in favour of the “no” response, relative to the control condition. However, these findings do agree to the extent that they both represent reductions in accuracy under scarcity. Scarcity seems to cause both reduced accuracy of income estimation and reduced accuracy in decisions about income.

To satisfy my own curiosity, and for the sake of completion, I also analyzed decision results for the control-expense condition, which were predictably less interesting. Participants in both the scarcity-scenario condition (89.29% correct responses) [$\chi^2(1)=242.00, p<.001, \phi_c=0.79$] and the
control-scenario condition (90.43% correct responses) \( \chi^2(1)=245.79, p<.001, \phi_c=0.81 \) were significantly above chance-level performance and were not different from each other \( \chi^2(1)=0.16, p=.687, \phi_c=0.01 \). I would have liked to see the accuracy of participants in the control-expense condition to be closer to 100%. Future versions of this paradigm may try to achieve better performance using a more thorough practice session.

**Experiment 9**

Experiment 8 showed evidence suggesting that people estimate future income (monthly income) differently depending on which scarcity scenario they had been exposed to (scarcity vs. control scenarios). In this experiment I wanted to extend the findings of Experiment 8 to the domain of expenses. When mentally forecasting financial budgets, people need to accurately project estimated income and expenses in the future. Experiment 8 showed that people under financial scarcity become more conservative with their estimates of income by estimating lower total income at the end of the month. How does this finding generalize to the domain of expenses? On one hand, we may expect that people under scarcity will continue to underestimate expenses more than those in the control condition. In this case, the findings of Experiment 8 can be understood purely as an effect of scarcity on numerical estimation ability. An alternative prediction may suggest that people under scarcity will become more conservative with their expense estimates and underestimate their expenses less than participants in the control condition. If this is the case, then, we may understand the findings of Experiment 8 as an adaptive response under scarcity, because people are making practical adjustments to their estimates in order to more safely manage their budgets under scarcity. The pre-registered methods and hypotheses for Experiment 9 are available on OSF (see https://osf.io/hg29v).

**Methods**

The methods for Experiment 9 were exactly the same as Experiment 8 except the framing of the numbers was changed from estimating future income to estimating future expenses. At the start of
each block, participants were informed of the monthly income they were to receive, and needed to estimate the sums of expenses in order to know if their budget is satisfied or not.

**Financial Scarcity Manipulation**

Financial scarcity was manipulated in the exact same way as Experiment 8. Participants were randomly assigned to either the scarcity-scenario condition or the control-scenario condition. As a reminder to the reader, participants in the scarcity-scenario condition read and responded to a hypothetical situation in which they were receiving a 15% pay cut, while participants in the control-scenario condition were given the same scenario with only a 5% pay cut.

There was also a within-subjects scarcity manipulation. However, this variable does not map to scarcity and control conditions as in the previous experiment. Participants each completed two blocks of trials: one scarcity-income block and one control-income block. In the scarcity-income condition, participants were assigned an income which was exactly one quarter of the total value of the upcoming expenses. In this condition it was easy for participants to know whether or not their budget was satisfied at the end of the month because the monthly income was roughly equal to the first week of expenses. This is in contrast to the scarcity-expense condition in Experiment 8, in which it was relatively difficult to make a correct budget decision. In the control-income condition, participants were given an income which was either 10% above or 10% below the actual sum of the expenses they were going to estimate. This condition was difficult because the income value was close to the actual total of their upcoming expenses. The only way for participants to determine whether or not their budget was satisfied was to closely monitor the expenses week-by-week and accurately sum their estimates at the end of the block. This condition is very similar to scarcity-expense condition from Experiment 8, except the framing of the income and expenses are reversed. These between-subjects conditions in Experiment 9 are interesting because they effectively counter-balance the conditions of task difficulty and scarcity. In other words, the scarcity-expense condition in Experiment 8 was
difficult, while the scarcity-income condition in Experiment 9 was easy. In addition, the control-expense condition in Experiment 8 was easy, while the control-income condition in Experiment 9 was difficult. This difference between experiments enables contrasting the effect of budget scarcity and the effect of task difficulty.

**Practice Block Validation**

One more difference between this experiment and Experiment 8 was the addition of validation to the practice block of trials. Each started by completing the practice block, which was a scarcity-income block (their assigned income was 25% of their upcoming expenses). At the end of this block, participants should have known that their income was too low to cover the expenses. Any participant who said “yes” to the decision question at the end of the block, indicating that they believed their income was sufficient to cover the expenses, was given corrective feedback and was redirected to complete the practice block again. The corrective feedback was: "Your response is incorrect. Please try the practice section again.” Therefore, only participants who eventually completed the practice block correctly were able to proceed to the experimental blocks.

**Participants**

I recruited 600 US-based participants on Mturk and received 569 complete responses. No exclusions for failing the practice block were necessary, since participants who failed the practice block were not allowed to continue until they made a correct budget decision. Two participants were excluded for responding through the same IP address as a previous participant, leaving a sample of N=567 participants.

**Stimuli and Procedure**

The stimuli and procedures were nearly identical to those in Experiment 8, except the words “income” and “expenses” were swapped.
Hypotheses

There was only one pre-registered hypothesis for this study. I hypothesized that participants in the scarcity-scenario condition will significantly underestimate the sum of four weeks of expenses (i.e., the block total) more than participants in the control-scenario condition. In other words, estimates of the total of expenses will be negative in both conditions (both conditions will underestimate the total of expenses), but the estimates of total expenses will be lower in the scarcity-scenario condition compared to the control-scenario condition. This hypothesis was motivated by the results from Experiment 8. In
Experiment 8, results showed that participants underestimated the block income totals more in the scarcity-scenario condition than in the control-scenario condition. I suspected this effect was due to a decrement in numerical processing accuracy under scarcity, or a systematic underestimation bias under scarcity. If either of these was true, I would expect to see the same pattern of results in Experiment 9.

An alternative hypothesis could have also been made based on findings of Experiment 8. The finding that participants underestimated income more under scarcity could be interpreted as an adaptive response toward conservative budgeting under scarcity. In other words, participants may have been erring on the safe side in their estimations of income, because it is better to underestimate income than to overestimate income, especially under scarcity. If this is true, then we may predict that participants in Experiment 9 would also show a conservative estimation bias. This could lead to the hypothesis that participants in the scarcity-scenario condition will estimate higher expense totals than participants in the control-scenario condition (because it is better to overestimate expenses than underestimate them). The results of Experiment 9 will help disentangle these opposing predictions.

Results and Discussion

Pre-registered Analyses

Similar to Experiment 8, I collapsed the block expense estimates from the two budget conditions together. This was done by taking the average of the block expense estimates from the scarcity-income condition and the control-income condition for each participant. I found that the mean block expense estimation error was not significantly different in the scarcity-scenario condition (Mean estimation error=$-1375.10, SD=$1158.53) compared to the control-scenario condition (Mean estimation error=$-1271.72, SD=$1233.85) [t(556)=1.02, p=.308, d=0.09]. To follow up on this analysis I examined the scarcity-income and control-income conditions separately. When only looking at the scarcity-income condition, block expense estimation in the scarcity-scenario condition (Mean estimation error=$-980.76, SD=$837.34) was not significantly different from block expense estimation...
in the control-scenario condition \( (Mean \text{ estimation error} = -\$941.95, SD = \$863.82) \) \( [t(557) = 0.54, p = .590, d = 0.05] \). Similarly, when only looking at the control-income condition, block expense estimation in the scarcity-scenario condition \( (Mean \text{ estimation error} = -\$775.70, SD = \$884.78) \) was not significantly different from block expense estimation in the control-scenario condition \( (Mean \text{ estimation error} = -\$760.92, SD = \$871.50) \) \( [t(554) = 0.20, p = .843, d = 0.02] \).

These data fail to support the primary hypothesis for Experiment 9, suggesting that participants did not change their expense estimation behaviour depending on the scenario conditions. This result may suggest a pattern of maladaptive behaviour whereby people under scarcity do not adapt their perceptions of upcoming expenses, even when such adaptations are available to them. It should be noted that underestimation of expenses is problematic because it could lead to monthly deficits, regardless of whether someone is under scarcity or not, but the situation gets significantly worse under scarcity: If people under scarcity do not change the way they perceive upcoming expenses, they risk underestimating upcoming expenses which need to be eliminated before they are incurred. Some may argue that people under scarcity have already cut costs as much as possible, so it is not as important to closely monitor the remaining expenses. However, US bank account holders earning between $12,000 and $27,707 annually reduced their spending by 32% from February to March 2020, when the COVID-19 pandemic lock-down policies came into effect (Cox et al., 2020), showing that even people in lower income brackets can reduce their expenses when necessitated by external circumstances. I generally avoid prescribing ‘correct’ or ‘rational’ behaviour, but in this situation I would suggest that the optimal behaviour under scarcity is to strategically overestimate expenses in order to proactively identify opportunities to cut costs when finances are strained.

There is an interesting asymmetry between the results of Experiments 1 and 2. Unlike participants in Experiment 8, participants in Experiment 9 did not show signs of budget conservatism under scarcity, nor did they show signs of exacerbated numerical bias under scarcity. It is interesting
that participants under scarcity underestimated their income compared to the control group (in Experiment 8) but did not change their estimation of expenses (in Experiment 9). I conducted a follow-up 2 (scenario condition: scarcity-scenario vs. control-scenario; between subjects) by 2 (task type: income estimation vs. expenses estimation; between subjects) ANOVA to probe this interaction. While there was a significant main effect of scenario condition \([F(1,1310)=8.15, p=.004, \eta^2=0.01]\) and a significant main effect of task type \([F(1,1310)=12.82, p<.001, \eta^2=0.01]\), the interaction term was not statistically significant \([F(1,1310)=2.32, p=.128, \eta^2=0.00]\).

Why did income estimation change under scarcity in Experiment 8, but expenses estimation did not change under scarcity in Experiment 9? There are several possible explanations\(^{10}\). First, it is possible that, in real-world situations, people are more likely to think about increasing income under scarcity than reducing expenses under scarcity. This makes sense because people probably enjoy thinking about earning more money than they enjoy thinking about reducing expenses. Also, for some people, it may be more difficult to reduce expenses than it is to increase income (for example, some people may be able to schedule more work hours, but cannot easily reduce their non-discretionary spending\(^{11}\)). The ease of thinking about adjusting income over adjusting expenses may contribute to the asymmetric findings.

Secondly, it is possible that people believe their expenses are fixed and more difficult to change compared to their income\(^{12}\). People may believe that expenses are necessary, and therefore immutable. Whether or not this belief is really true does not matter in the minds of people under scarcity. If people believe their expenses are less flexible than their income, we may expect scarcity to change the way people attend to income, not expenses.

Thirdly, while it is adaptive to underestimate income under conditions of reduced income, it may not be adaptive to overestimate expenses under reduced income. Instead, it may more more

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\(^{10}\) I discussed this issue with many students from my Cognitive Systems Seminar (COGS 401) classes, many of whom wrote papers on this subject. I will do my best to assign credit for their ideas accordingly.

\(^{11}\) I credit Rishika Aggarwal for this idea.

\(^{12}\) I credit Emily Huynh for this idea.
adaptive to overestimate expenses in response to a decline in purchasing power or savings. When resources are scarce, it is adaptive to adjust decision making strategies by reducing the number of factors in each decision because this simplifies the cognitive processes required (see Wright, 1974). In the case of scarcity caused by reduced income, perhaps the most cognitively simple process is to adjust the perception of income, or perhaps thinking about expenses is too cognitively taxing (this latter point would be supported by the findings of Hilbert et al., 2022b showing that scarcity correlates with reports of avoiding thinking about finances). There is a straightforward mental connection between income reduction and income estimation strategies, but the connection between income reduction and expense estimation strategies may require more mental effort, which is not an adaptive process to be engaging in under scarcity. This leads nicely to the fourth explanation.

Fourthly, the present experiments manipulated scarcity through a scenario procedure which centred on hypothetical income. Because the scenario procedure was focused on income, there was likely a priming effect which lasted well into the number estimation task. If participants are primed to think about income during the number estimation task, it is not surprising that income estimation would be more affected than would expense estimation. To address this possibility, follow-up studies should repeat Experiments 1 and 2 with one critical modification to the scenario procedure: Instead of manipulating scarcity by varying the levels of a reduction in income (5% vs. 15% reduction in income), scarcity can be manipulated by varying the levels of an increase in expenses, such as an increase in rental fees (5% vs. 15% increase in expenses). If the differential results in block estimation between Experiments 1 and 2 are caused by a priming effect, this modification may cause a reversed pattern of results: Participants may respond to scarcity by making higher estimates of future expenses but not changing the way they estimate future income, compared to the respective control groups. I suggest that priming is the most likely explanation for the stronger results in Experiment 8 compared to

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13 I credit Siddarth Aanandi for this idea.
14 This was independently communicated to me by Christopher Anstis, Shaun Olafson, Cher Peng, and Lyla Yu, all of whom deserve equal credit for this idea.
Experiment 9. Therefore, conducting a follow-up study that manipulates increases in expenses instead of decreases in income is suggested for future research.

Another possible explanation could be that the difference in exclusion methodology between Experiments 1 and 2 caused the lack of effect of scenario condition on block estimation. More poorly performing participants were allowed into Experiment 9, which might cause an effect of scenario condition on block estimation to be too difficult to detect. However, excluding the poorly performing participants from Experiment 9 does not change the pattern of results, so this explanation is unsupported.

Finally, there is the possibility that income is more positively valenced than expenses are, and this changes the way this information is processed. In the case of expenses, which are of more potent valence, perception of numerical value is stabilized. If perception of value is stabilized, heuristics such as conservative underestimation are no longer needed, as they are with income. While this explanation is highly speculative, it can be easily tested by repeating this paradigm but instead of framing the number stimuli as income or expenses, the valence of the number framing can be directly manipulated (e.g., counting the number of daily acts of kindness vs. counting the number of daily crimes).

**Exploratory Analyses**

In this section I will describe results which parallel the exploratory analyses conducted in Experiment 8.

**Trial Expense Estimates.** For each block, trial errors were summed together to produce signed trial expense estimation accuracy scores for each participant. Like the previous experiment, participants generally underestimated the trial sums. Participants did not differ in trial expense estimation accuracy when they were in the scarcity-income condition (Mean estimation error= -$729.01, SD=$785.42) compared to when they were in the control-income condition (Mean estimation error=-$708.24, SD=785.42) \[t(544)=1.12, p=.263, d=0.03].
Next I examined whether trial estimation error varied by scenario condition. First, I looked at responses in the scarcity-income block. In this block, participants in the scarcity-scenario condition ($\text{Mean estimation error}=-\$727.54, \text{SD}=\$805.39$) did not differ in trial income estimation accuracy compared with participants in the control-scenario condition ($\text{Mean estimation error}=-\$739.26, \text{SD}=\$804.09$) [$t(564)=0.17, p=.863, d=0.01$]. Similarly, when only looking at the control-income block, participants in the scarcity-scenario condition ($\text{Mean estimation error}=-\$715.46, \text{SD}=\$789.22$) did not estimate trial income sums differently compared to participants in the control-scenario condition ($\text{Mean estimation error}=-\$678.53, \text{SD}=\$830.40$) [$t(562)=0.54, p=.589, d=0.05$]. These results parallel those of Experiment 8, and fail to suggest the scenario manipulation or the budget conditions had any effect on trial expense estimation.

The following analyses of trial estimation error use the sum of each participant’s trial expense estimates across both experimental blocks. When I turned to the demographic data, I found a small negative correlation between personal income and trial expense estimation, suggesting that lower-income participants tended to estimate higher values for the expenses [$r(565)=-.11, p=.011$]. These results corroborate the nearly identical correlation found in Experiment 8. It is still not clear to me whether this result suggests that people under real-world financial scarcity are more accurate in their estimates of numerical information, or if these results suggest that people under real-world financial...
scarcity have a generalized over-estimation bias with numerical information. In an attempt to answer this question, I looked at the correlation between personal income and absolute trial expense estimation error, which is an index of accuracy on the trial estimation task \(r(565)=.12, p=.003\]. This correlation is similar in magnitude, suggesting that a simple over-estimation bias under scarcity is more likely than the idea of increased numerical estimation accuracy under scarcity (in the latter case, I would expect to see a significantly larger correlation relative to the correlation between income and signed estimation error).

When looking at the relation between subjective measures of scarcity and estimation errors, I found a pattern of results nearly identical to the results found in Experiment 8. Specifically, there was no significant correlation between financial stress and trial estimation errors \(r(565)=.01, p=.747\], but there was a significant correlation between relative SES and trial estimation error \(r(565)=-.11, p=.010\]. This negative correlation suggests that people who felt relatively poor were more likely to estimate higher sums of expenses at the trial level. Although these correlations are small in magnitude, all the correlations reported so far are strikingly similar to their counterparts in Experiment 8 which corroborate these results.

![Trial Error by PIFS](image1.png) ![Trial Error by Relative Wealth](image2.png) ![Trial Error by Personal Income](image3.png)

**Figure 30.** Experiment 9 trial estimation scatter-plots.\(^{15}\)

\(^{15}\) Note: uniform dithering was added to relative wealth and personal income data for visual clarity.
When examining the subjective scarcity data, the PIFS shows a reversed pattern compared with the objective scarcity data and compared with the relative scarcity data. People who reported higher levels of subjective scarcity reported lower sums of expenses during the trial estimation task \[ r(565)=-.18, p<.001 \]. This paradoxical result was also present in Experiment 8, however, the convenient explanation available for the Experiment 8 results does not hold with the current paradigm. In Experiment 8, I suggested that people might have caused themselves to feel subjective scarcity by estimating low sums of income. If this mechanism was true, I would have expected people who reported higher sums of expenses to have reported higher subjective scarcity. Since the opposite is true (and the numerical pattern is the same as Experiment 8, despite the reversed framing of the task), I will tentatively propose the conclusion that people who feel subjectively scarce have a general bias toward perceiving lower numerical sums, regardless of whether these values represent income or expenses\(^\text{16}\).

In addition, it seems that people with objectively lower personal income have a general bias toward perceiving higher numerical sums. The divergent patterns of results between subjective and objective scarcity is an interesting avenue worth further exploration. In particular, future studies should investigate which stage of cognition these divergent biases emerge. Is this a perceptual bias, or is this a bias in subsequent judgment processes? If this is a bias at a judgment stage, do people under objective versus subjective scarcity have differential dependence on anchoring, or do they use different information to make their judgments? There are no studies I am currently aware of which can inform predictions on these questions, which makes these even more interesting.

**Block Expense Estimates.** As expected, participants widely underestimated the block totals of expenses. Participants in the scarcity-income condition estimated lower block-level sums of expenses \((\text{Mean estimation error}=-939.98, \text{SD}=881.07)\) compared to when participants were in the control-income condition \((\text{Mean estimation error}=-748.24, \text{SD}=901.32)\) \([\text{paired } t(552)=6.47, p<.001,\]

\(^{16}\) However, given the possibility that the experimental procedures may affect measures of scarcity, future studies should replicate these findings using scarcity measurements preceding the experimental procedures.
This pattern was also found in Experiment 8 and I believe it is best explained by anchoring on the assigned income at the beginning of the block: participants likely used information from the prescribed monthly income in their estimates of the block total of expenses.

\[d=0.22\].

**Figure 31.** Experiment 9 block estimation and decision results. Note: *** \(p < .001\).

In the pre-registered analyses I found no significant difference between the scenario conditions in the block estimation task. This was somewhat surprising because this contrast was significant in Experiment 8. Although I provided several explanations for the lack of an effect in the present experiment, there are still several exploratory analyses which may be informative. While the scarcity scenario was meant to induce scarcity, there was no significant difference in the reported subjective scarcity when measured by the scarcity index across the scarcity-scenario condition (Mean subjective scarcity=4.20, SD=1.50) and the control-scenario condition (Mean subjective scarcity=4.11, SD=1.48) \([t(565)=0.71, p=.475, d=0.06]\). However, there was significant variability in the subjective scarcity index scores, allowing me to probe for relations between subjective scarcity and block expense
estimation. In the scarcity-income condition, there was a small correlation between subjective scarcity and block expense estimation error, such that people who felt more subjective scarcity tended to underestimate the expenses more \[ r(565)=-.12, p=.005 \]. A similar pattern was found among participants in the control-income condition \[ r(565)=-.13, p=.002 \]. Larger correlations were found between subjective scarcity and absolute error (the absolute distance between the estimated block expenses total and the true block expenses total). In the scarcity-income block, participants who reported higher subjective scarcity made larger absolute errors in the block expenses estimation task \[ r(565)=.23, p<.001 \]. Similarly, in the control-income block, participants who reported higher subjective scarcity made larger absolute errors in the block expenses estimation task \[ r(565)=.22, p<.001 \]. Taken together, these results may suggest that scarcity does have some relation to numerical estimation (it reduces numerical estimation accuracy), but the scarcity scenario induction was not strong enough to produce this effect on its own. Alternatively, participants who felt their block estimation performance was poor may have been made to feel a subjective feeling of scarcity, due to the financial theme of the task. Despite the unclarity in the meaning of these results, I am more confident in concluding that there is some connection between scarcity and numerical estimation, whether the scarcity is induced by some element of my independent variables or some other aspect of the task. It does appear that wherever there is variability in feelings of financial scarcity, we will be able to predict at least a small amount of variability in numerical estimation accuracy.

*Figure 32. Experiment 9 subjective scarcity results.*
Decision Accuracy. The final set of exploratory analyses for this chapter concerns the decision accuracy of participants who were asked, at the end of each block, whether or not their expenses (which they had to estimate) were lower or higher than the prescribed amount of income (given at the start of the block). Participants were well above chance-level accuracy in the scarcity-income condition (74.60% correct responses) \(\chi^2(1)=137.29, p<.001, \phi_C=0.49\), which is not surprising because it is easy to see that the income is much lower than the grand total of expenses in this block. On the other hand, participants were close to chance-level accuracy in the control-income condition (54.14% correct responses), which can only be considered above chance by a marginal degree of statistical significance \(\chi^2(1)=3.90, p=.048, \phi_C=0.08\).

Overall, participants were more accurate decision makers in the scarcity-income block than they were in the control-income block \(\chi^2(1)=18.43, p<.001, \phi_C=0.18\), which is to be expected given the relative difficulty of the two conditions. I found it interesting, however, that accuracy in the scarcity-income condition (74.60% correct responses) was lower than that of the control-expense condition of Experiment 8 (89.84% correct responses), even despite the sample in Experiment 9 having

\[\text{Note: uniform dithering was added to relative wealth and personal income data for visual clarity.}\]
been given multiple blocks of practice trials (for those who failed the practice block) [$\chi^2(1)=53.56$, $p<.001$, $\phi_c=0.20$]. The scarcity-income condition of Experiment 9 and the control-expense condition of Experiment 8 were numerically identical and equal in difficulty, so I was surprised to see a difference of this magnitude. This difference in accuracy across otherwise equivalent conditions might be explained by the different exclusion methods because participants who failed the practice block in Experiment 8 were excluded completely, while participants who failed the practice block in Experiment 9 were allowed to stay in the final sample, provided they eventually answered the practice block correctly. This procedure may have allowed participants into the final sample who still did not attend sufficiently to the task. Ironically, my attempt at improving the quality of responses may have reduced the quality of the data. Future studies should consider excluding participants based on their first attempt in the practice block to improve sample quality.

An alternative explanation for the drop in decision accuracy could be related to the bias toward “yes” responses found in Experiment 8. If there is a general “yes” bias among participants in this task, this bias would increase accuracy in the control-expense condition of Experiment 8 and reduce accuracy in the scarcity-income condition of Experiment 9. In the control-income of Experiment 9, I indeed found evidence of a bias toward “yes” responses, as these responses outnumbered the “no” responses (58.38% “yes”; 41.62% “no”) [$\chi^2(1)=15.92$, $p<.001$, $\phi_c=0.17$], when the proportions should be equal to each other in the absence of bias. This suggests an additional explanation for why participants in the scarcity-income condition were worse decision-makers than participants in the control-expense condition.

Similar to the results of Experiment 8, there was no difference in decision accuracy across scenario conditions in either the scarcity-income block [$\chi^2(1)=0.05$, $p=.827$, $\phi_c=0.01$] or the control-income block [$\chi^2(1)=1.54$, $p=.215$, $\phi_c=0.05$]. However, here I found another result which differed from Experiment 8. When looking only at decisions from the control-income block, participants in the
scarcity-scenario condition were slightly above chance-level performance (56.94% accuracy) \([χ^2(1)=5.41, p=.020, φ_c=0.10]\), while participants in the control-scenario condition were not significantly different from chance-level performance (51.40% accuracy) \([χ^2(1)=0.22, p=.636, φ_c=0.02]\). This is the opposite pattern seen in Experiment 8, where the control-scenario participants were above chance, while the scarcity-scenario participants were not above chance. In both cases, the difference between scenario conditions did not reach statistical significance, so it may not be worth speculating on these findings at this stage. Future studies should note this comparison for further examination in new data sets, however, I do not find it appropriate to discuss experimental effects at this stage because the data do not support them.

**General Discussion**

This chapter is full of surprising results\(^\text{18}\) which deviated from the original purpose of the experiments. This chapter started as an investigation of how people may use the numerosity heuristic in their estimations of income and expenses under scarcity. However, I quickly found that there was no evidence for the numerosity heuristic in this paradigm. In fact, the opposite effect was found: participants tended to estimate larger numerical sums when there were fewer numbers shown to them. I believe experts the field of numerosity may be able to reconcile the results presented here, but I will first suggest that this heuristic may not be as robust or generalizable as currently believed.

Broadly speaking, I did not find any evidence for scarcity scenario priming affecting trial-by-trial estimation of income or expenses. Based on my observations, it seems that local estimates of numerical quantities were not affected by hypothetical scenarios. In addition, I did not find any evidence of the budget conditions affecting trial estimation for income or expenses. However, I did find that the actual reported personal income of participants had a negative relationship with estimation of numerical quantities at the trial level. People with lower incomes tended to estimate slightly higher

\(^{18}\) Many research papers today are adverse to surprises, perhaps because this improves the logical flow of ideas which is easier to read (and also blandishes the author’s foresight, skill, or intelligence). I hope the reader will forgive me for the often difficult flow of this chapter.
sums for both income and expenses, causing them to be more accurate overall in the trial estimation tasks. Subjective measures of financial well-being (i.e., relative SES, self-reported scarcity, & self-reported financial avoidance) also tended to predict numerical estimation. With these measures, however, the patterns of results were more complex. People with lower perceived relative SES tended to have estimated higher sums at the trial level, but people who self-reported higher levels of financial scarcity tended to have estimated lower sums, regardless of whether the numbers represented income or expenses. In other words, people who felt like others have more money than them report estimated higher numbers, but people who felt like they do not have enough money estimated lower numbers. I do not have a satisfying explanation for this pattern of results. The most I can speculate at this point is that both objective financial scarcity and relative SES cause a bias in numerical estimation toward higher numbers while explicit subjective financial scarcity biases numerical estimation toward lower numbers, but these conclusions remain weakly supported. I do not believe these results are spurious because they were consistent across two pre-registered studies with large sample sizes, but much more data is needed to unpack this covariance structure. There are remaining subtleties in numerical estimation and scarcity which are not well understood.

Interestingly, the link between scarcity and numerical estimation extends to the domain of block-level estimation. Like the trial-by-trial estimates, I found that people who reported higher levels of subjective scarcity – that they did not have enough money for themselves – tended to estimate lower sums at the end of each block, making them less accurate in their estimates of both income and expenses. This is a consistent theme across these experiments that is reliably found with a variety of measurement instruments.

Another noteworthy result here is the effect of the scarcity scenario conditions on block-level estimation. In Experiment 8, participants in the scarcity-scenario condition underestimated income more than participants in the control condition. The effect size for this comparison was $d = 0.23$, which
is small, but it stands out given the simplicity of the independent variable. The change from a 5% pay cut to a 15% pay cut in a hypothetical scenario may seem trivial, but the effect was reliably found in both blocks. However, this effect seemed to disappear in Experiment 9, when participants were estimating expenses instead of income. After consideration of all this data, I believe there are two plausible explanations for this pattern which are not mutually exclusive. First, the independent variable had a stronger effect on the sample in Experiment 8 compared to the sample in Experiment 9. This conclusion is supported by the difference in self-reported subjective scarcity in Experiment 8 (participants assigned the 15% pay cut reported more subjective scarcity than participants assigned the 5% pay cut) which was not found in Experiment 9. If this is true, more follow-up studies can easily resolve this mystery and clarify the results. A second plausible explanation is that people under scarcity become more conservative in their estimates of income but do not adjust their estimates of future expenses. Since expense estimation at the block-level correlated negatively with subjective scarcity, I believe the first explanation for this lack of difference to be the most likely.

To round off my summaries of the results presented in this chapter, I will briefly note the important findings from the decision-making element of this paradigm. There were some data suggesting that participants in the scarcity-scenario condition were not above chance-level decision-making accuracy while participants in the control-scenario condition were above chance-level decision-making accuracy (Experiment 8). However, this pattern of results was reversed in Experiment 9, where participants in the scarcity-scenario condition performed significantly above chance while participants in the control-scenario condition did not. These effects are not large enough to warrant speculation on their explanation at this stage (since, in both experiments, the two scenario conditions were not significantly different from each other in decision-making performance). I encourage the reader to view these results as warranting further study, but not to draw conclusions from them.
The decision-making data in the present study showed a general trend toward optimistic decision making. In conditions where it was difficult to know whether income was sufficient to cover the expenses, participants said the budget would be balanced more often than not. This bias appeared consistent across the scarcity scenario conditions, and there was no evidence that bias was dependent on condition $[\chi^2(1)=1.21, p=.271, \varphi_c=0.05]$ (Note: this test only included data from Experiment 9). It is noteworthy that the optimistic bias observed here likely contributed a substantial proportion of error in responses, particularly in conditions where the total income and expenses were close together.

One of the more interesting takeaways from the present study concerns diverging effects of subjective scarcity and objective personal income on numerical estimation. I consistently found that objective scarcity (having low personal income) predicted higher numerical estimates. On the other hand, I consistently found that subjective scarcity (participants reporting the feeling that they do not have enough money or that other people have more money than them) predicted lower numerical estimates. In both cases, these patterns were found regardless of whether the numerical information represented income or expenses. Distinctions between subjective and objective scarcity in the research literature are rare, especially within a single study. The findings of this chapter suggest refinement of the scarcity constructs under study and the methods used to study them. Researchers and policy makers should consider the type of scarcity, objective or subjective, when collecting data or making predictions about behaviour. One implication they should consider is that there may be debiasing effects of objective scarcity, leading to more accurate numerical estimations of money (again, income or expenses) for people under scarcity. Another implication is the possibility for people of all objective income levels to experience detrimental cognitive effects of scarcity. Subjective scarcity may affect people of any objective income level. Therefore researchers should attend to the measures of subjective scarcity (the PIFS was excellent for this) and should also study possible interactions between objective and subjective scarcity.
Chapter 5: Decision-making Under Scarcity

People who live in poverty are often stereotyped as incompetent and faulty decision-makers (Russel & Fiske, 2008). What are the characteristics of a faulty decision? One possibility reduced attention to long-term consequences of a decision in favour of short-term consequences. Indeed, people under financial strain are more prone to temporal discounting, prioritizing short-term gains over long-term interests (Bickel et al., 2016; Griskevicius et al., 2013; Haushofer & Fehr, 2014; Lawrence, 1991), although the increases in temporal discounting may be primarily related to anticipated future financial problems and not necessarily related to current financial scarcity (Hilbert, Noordewier, & van Dijk, 2022a). In addition, people who grew up in low SES environments respond to financial recession-related stimuli by taking more risks and increasing their temporal discounting (Griskevicius et al., 2013). Previous studies have found that physiological stress also increases temporal discounting (Lerner, Li, & Weber, 2012), and stress is associated with shifting from goal-directed behaviours to habitual behaviours (Schwabe & Wolf, 2009). Combined with the results given in Chapter 1, these studies illustrate how people under financial scarcity may be reducing the quality of their decisions by focusing too much on short-term aspects of their decision at the expense of long-term considerations.

Wright (1974) studied how people make decisions under time pressure. Participants were asked to choose the best car from the options available. Each car had a set of multiple attributes, such as price, comfort, and handling. To manipulate time scarcity, some participants were rushed through their decision while others had ample time. Wright generally found that participants under time scarcity weighed negative attributes more heavily in their decisions. It was also observed that participants under time scarcity tended to use fewer attributes to make decisions compared to participants with more time. In this example, people substituted a complex task involving multiple attributes for a simple task involving a smaller set of information when they had limited time. This substitution would later become recognized as an important element of availability and
representativeness heuristics (Kahneman & Frederick, 2002). How do people under financial scarcity adjust their decision-making?

Given that people under financial scarcity are more likely to focus on current prices and expenses, and may discount matters in the distant future, scarcity may directly affect decision making. Importantly, this chapter does not aim to discuss temporal discounting under scarcity as an irrational or maladaptive response to scarcity (see Sharma et al., 2019, for an excellent demonstration of conditions under which temporal discounting is reduced by scarcity, and how this is a rational process). As noted in the prior literature above, limitations in time or money tend to shift priorities to the immediate situations. With regard to decision making, these shifts may entail a reduction in the amount of information used or a qualitative shift in the type of information used. The purpose of this chapter is to clarify this and investigate decision making under financial scarcity. Using an online experimental design, I investigated how a simulated scarcity mindset affects hypothetical decisions about job advertisements. This was done by manipulating the scarcity mindset using a common scenario priming procedure, and then showing participants a generic job advertisement. I measured attention to the job advertisement using a combination of masking and dynamic mouse tracking. Importantly, the job advertisement contained salary information, retirement benefits information, health benefits information, and long-term career potential information.

The experiment that follows was pre-registered on OSF prior to data collection (link to pre-registration: osf.io/gpjvs). Detailed methodological information and pre-registered hypotheses are available there. There were four primary hypotheses. First, I hypothesized that participants in the scarcity condition will look more at the salary information compared to participants in the control condition. This is what I expected to happen if the scarcity priming procedure increases attention to financial information. This may be expected based on the findings of the chapter on scarcity and attention above. Second, I hypothesized that participants in the scarcity condition will look less at the
retirement benefits information compared to participants in the control condition. Third, I hypothesized that participants in the scarcity condition will look less at the health benefits information compared to participants in the control condition. Fourth, I hypothesized that participants in the scarcity condition will look less at the long-term career advancement information compared to participants in the control condition. Hypotheses two, three, and four must be tested in order to contribute to the existing literature on scarcity and temporal discounting. As discussed above, some evidence suggests that financial scarcity is related to prioritizing current concerns at the expense of future concerns (Lawrence, 1991; Haushofer & Fehr, 2014). The current study may contribute to this evidence by showing how participants under scarcity pay less attention to long-term benefits such as retirement, health, and job security benefits compared to control participants.

**Experiment 10**

To start this experiment, I randomly assigned participants to complete a scarcity mindset induction procedure. This was intended to simulate the way that finances are at the top of mind under real financial scarcity. Following this mindset induction, participants viewed a job advertisement and their attention to various features of the job advertisement was measured. After viewing the job advertisement, participants reported whether or not they would be interested in applying for the job, and then reported the importance of various features of the job ad in terms of their importance in making the participants’ decisions. After this self-reporting procedure, participants completed a series of demographic questions highly similar to those used throughout this dissertation.

**Methods**

**Participants**

Online participants were recruited from Mturk, and were only drawn from the US population ($N=881; \text{mean age}=38.14\ \text{years, SD}=11.17\ \text{years}; 461\ \text{male, 416\ female, 4\ other\ gender}$). Due to
exclusions, N=802 participants remained in the final sample (exclusion reasons are discussed in the Results and Discussion section below).

**Stimuli and Procedure**

**Scarcity Mindset Induction**

To simulate scarcity, participants were randomly assigned to the scarcity mindset induction procedure. Simulated scarcity was manipulated by asking participants to read and respond to a hypothetical financial scenario. The scenario described tough economic conditions which required the participant’s employer to make budget cuts and to cut employee wages. All participants read this hypothetical financial scenario, but participants in the scarcity condition were given a 15% pay cut while participants in the control condition were given a 5% pay cut. All participants were prompted to think about how such a scenario would impact their actual real-world finances and what type of lifestyle changes they would need to make in order to cope with this situation. Participants were given a text box in which they could respond to this scenario, and they were not permitted to advance to the next stage of the experiment unless they had written something in the box.

**Job Advertisement Task**

Next, participants were shown an advertisement for a generic job posting and were asked to read it. The instructions suggested to participants that they should read enough of the advertisement to be able to make decisions about whether or not to apply for the job at a later time, as they would not be able to refer back to the advertisement when answering questions about it. The job advertisement included several attributes about the job such as the monthly salary, retirement contributions, health benefits, and long-term advancement potential. The salary in the job ad was listed as “Your current salary plus 20%” smooth the attractiveness of the advertisement for the varied income levels among participants.
To measure attention on the job advertisement, the same BubbleView technique as in Chapter 1 was used. The job advertisement was covered by a black mask which required participants to move their cursor to reveal the stimuli behind. Attention to the job advertisement was defined as the amount of total dwell time spent looking at each particular feature on the job advertisement divided by the total

<table>
<thead>
<tr>
<th>New Job Position Available</th>
<th>Annual Salary: Your current salary plus 20%</th>
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<tbody>
<tr>
<td>Job Title: Manager</td>
<td>Retirement benefits: 401k match up to 8%</td>
</tr>
<tr>
<td>Job Description:</td>
<td>Health benefits: Insurance for health, dental, and eye-care will be provided.</td>
</tr>
<tr>
<td>The successful applicant will manage clients and staff, and coordinate services and schedules to ensure customer satisfaction.</td>
<td>Long-term career potential: Promotion to higher-pay general manager position available after 5 years.</td>
</tr>
<tr>
<td>Hours:</td>
<td></td>
</tr>
<tr>
<td>Monday – Friday, 8am – 4pm</td>
<td></td>
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</tbody>
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time spent looking at the job advertisement. This accounts for potential variation in total amount of
time participants spend looking at the advertisement.

After participants were finished reading the job advertisement, they proceeded to a second
page where they were asked to self-report their likelihood of applying for the job. Participants reported
their likelihood to apply on a 7-point scale from “Not likely at all” to “Very likely.”

After deciding how likely they would be to apply, participants were asked to self-report the
importance of each attribute in their decision. Participants were asked to rate the importance of the
starting salary, retirement benefits, health benefits, and long-term career potential. Each attribute was
probed separately using a 7-point scale from “Not important at all” to “Very important.”

**Demographics and Covariates**

Following the job advertisement task, participants completed measures of confidence in their
actual financial budget (budget confidence), financial stress, and relative socioeconomic status (relative
SES). Budget confidence was measured by asking participants “How confident are you that your
income this month will cover your expenses?” on a 7-point scale from “Not confident at all” to “Very
confident.” Financial stress was measured by asking participants “In general, how much financial
stress do you feel on a day-to-day basis?” on a 7-point scale from “No financial stress at all” to “A
considerable amount of financial stress.” Subjective SES was measured by asking participants
“Financially speaking, how well off do you feel compared to others?” on a 7-point scale from “I feel
much worse off than most people” to “I feel better off than most people.”

Next, participants responded to two measures of objective income: annual personal income
and annual household income. Next participants were asked for the number of people living in their
household. This information was used to create an improved measure of objective household income.
This was done by dividing the reported household income by the square root of the reported household
occupancy. This is a superior measure of objective household income because the amount of expenses
incurred by a household does not scale linearly with the number of people in the household. Resources and therefore costs are shared more efficiently in larger households compared with smaller ones.

Standard demographic information including participant age, gender, and ethnicity were also collected.

**Results and Discussion**

While 881 participants completed the experimental protocol, 63 participants were removed from the sample for spending either less than two seconds or more than five minutes viewing the job advertisement. In addition, 16 participants were removed for responding through the same IP address as another participant, leaving a final sample of 802 participants for analysis.

All t-tests reported below were done using an outlier-trimming procedure. For each t-test, outliers beyond 2.5 standard deviations from the mean of the participants in each condition were excluded.

Participants spent an average of 41.15 seconds viewing the job advertisement ($SD=48.32$ seconds). The distribution of viewing time shows a strong positive skew; the median viewing time was 24.87 seconds. Even after excluding outliers beyond 2.5 standard deviations I did not find a significant difference between the viewing time of the scarcity condition ($M=34.51$ seconds, $SD=35.32$ seconds) and the control condition ($M=32.87$ seconds, $SD=32.44$) [$t(765)=0.67$, $p=.501$, $d=0.05$]. Even though there do not appear to be systematic differences in viewing time across conditions, attentional data below were analyzed as proportions of total viewing time in order to reduce variability related to overall viewing time. This is my standard practice for attentional data which yields more sensitive and statistically powerful analyses.

**Pre-registered Analyses**

All four pre-registered hypotheses were directional. However, all four hypotheses were tested using non-directional two-tailed t-tests.
To test hypothesis one, I compared attention to the salary information across scarcity conditions. Time spent viewing any part of the salary information was tabulated in this analysis (this includes the entire line: “Annual Salary: Your current salary plus 20%”). The proportion of time spent looking at the salary component was not significantly different between participants in the scarcity condition ($M=4.27\%, \ SD=4.94\%$) and participants in the control condition ($M=4.85\%, \ SD=5.23\%$) [$t(777)=1.58, \ p=.115, \ d=0.11$]. This result may suggest that scarcity has little effect on attention to salary when looking at job advertisements. Alternatively, this result may be explained by the low baseline levels of attention to the salary information in this task. It is possible that this paradigm is not sensitive to attentional prioritization to salary information because of a floor effect. Regardless of the explanation, these data fail to support hypothesis one.

To test hypotheses two, three, and four, I compared attention to the retirement benefits, health benefits, and long-term career advancement information across the scarcity and control conditions. Participants in the scarcity condition did not look significantly less at the retirement benefits ($M=5.61\%, \ SD=5.58\%$) compared with participants in the control condition ($M=5.68\%, \ SD=5.30\%$) [$t(777)=0.17, \ p=.865, \ d=0.01$]. Participants in the scarcity condition also did not look significantly less at the health benefits ($M=6.69\%, \ SD=6.07\%$) compared to participants in the control condition ($M=6.18\%, \ SD=5.44\%$) [$t(781)=1.25, \ p=.212, \ d=0.09$]. Finally, I found that participants in the scarcity condition did not look significantly less at the long-term career advancement information ($M=8.64\%, \ SD=7.69\%$) compared to participants in the control condition ($M=8.32\%, \ SD=7.01\%$) [$t(776)=0.60, \ p=.550, \ d=0.04$]. Together these results suggest that the scarcity-mindset induction did not change attentional priority to information pertaining to long-term concerns. As mentioned above, it is possible that these results could be accounted for by a floor effect. It appears that interest in these elements of the job advertisement is generally low. Whether or not there was a floor effect, these data fail to support hypotheses two, three, and four.
Based on the analyses above it appears that participants did not spend very much of their time looking at important features of the job advertisement. I was particularly surprised at the low attention to the salary information ($M=5.40\%$, $SD=7.20\%$). To examine this, I found that out of 802 participants in the sample, 293 participants spent 0% of their time looking at the salary. Since there was a large sub-population of participants who did not even look at the salary, I looked at the difference in attention to salary information across conditions while excluding all participants who spent zero time looking at the salary information. With this exclusion, I still found no difference between the time spent looking at salary information between participants in the scarcity condition ($M=7.44\%$, $SD=5.17\%$) and participants in the control condition ($M=7.59\%$, $SD=4.85\%$) [$t(489)=0.33$, $p=.741$, $d=0.03$]. Based on the results so far, the scarcity-mindset induction appears not to have any effect on attention to salary information, or any other type of information in job advertisements.

**Figure 36. Experiment 10 attention results.**
Following the attention measurements, participants were asked how likely they would be to apply for the job shown to them. There was no significant difference in reported likelihood between participants in the scarcity condition ($M=5.23$, $SD=1.35$) and participants in the control condition ($M=5.36$, $SD=1.39$) [$t(782)=1.33$, $p=.183$, $d=0.10$]. While scarcity may not have affected reported likelihood of applying for this job, it is important to notice that participants were broadly likely to consider applying for this job. I suspect that interest in the job advertisement is necessary to gather meaningful attentional data. For this reason, I will rule out a lack of interest as an explanation for the null attentional results discussed above. In fact, reported interest in this job advertisement correlates modestly with total amount of time spent looking at the job advertisement [$r(800)=.10$, $p=.003$] and time spent looking at the salary information within it [$r(800)=.12$, $p=.001$].

With the decision about whether or not to apply for the job in mind, participants also reported the importance of the salary, retirement, health, and advancement information as factors in their
decisions. All four of these measures were responded to on a 7-point scale described above. Participants in the scarcity and control conditions did not differ in reported importance of the salary information \([t(788)=0.73, p=.464, d=0.05]\), the retirement benefits information \([t(783)=0.39, p=.694, d=0.03]\), the health benefits information \([t(786)=1.64, p=.101, d=0.12]\), or the career advancement information \([t(789)=1.72, p=.085, d=0.12]\). Although self-reported scales tend to be less veridical compared to attentional measures, such findings are not uncommon in the scarcity literature. For example, Shah, et al. (2018, study 1) found that lower income participants were more likely to report that they would think about a series of cost-related statements in response to hypothetical scenarios compared to higher income participants. The authors suggested that scarcity increases the frequency of cost-related thoughts, bringing money-related concerns to the top of their minds. Given these previous results, I would have predicted that participants in the current study would rate the importance of salary as a more significant factor in their thoughts when under scarcity.

**Subjective SES.** There is one more analysis I would like to contribute to this chapter concerning a pattern of results I have never made hypotheses about, but have consistently observed in my data over many years. I am writing about a distinction between subjective SES and objective income in their ability to predict a variety of outcome measures in my studies of scarcity. In countless cases I have seen objective income fail to account for significant variance in models while subjective measures of financial status tend to be more informative than objective income. In the present study, subjective SES did not significantly account for much variability in attentional data (all correlation magnitudes <.06), but it did significantly correlate with self-reported likelihood of applying for the job \([r(800)=.29, p<.001]\), as well as the self-reported importance of the attributes of the job advertisement. Subjective SES showed significant correlational relationships with reported importance of the salary information \([r(800)=.19, p<.001]\), the retirement benefits information \([r(800)=.29, p<.001]\), the health benefits information \([r(800)=.19, p<.001]\), and the career advancement information \([r(800)=.29,\)

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Financial stress also showed significant correlational relationships with the reported likelihood of applying for the job \[ r(800)=.36, \ p<.001 \], the reported importance of the salary information \[ r(800)=.30, \ p<.001 \], the retirement benefits information \[ r(800)=.22, \ p<.001 \], the health benefits information \[ r(800)=.27, \ p<.001 \], and the career advancement information \[ r(800)=.27, \ p<.001 \]. These correlations seem to suggest that real-world financial stress and feelings of low relative SES are related to higher willingness to apply for jobs, and seem to predict higher perceived importance of the information on job advertisements.

While these subjective measures of financial stress and relative wealth contained useful insights into the participants’ responses, the objective measures of wealth were minimally informative. Objective income did not significantly correlate with reported likelihood of applying for the job \[ r(800)=-.02, \ p=.637 \], the importance of the salary information \[ r(800)=-.02, \ p=.558 \], the health benefits information \[ r(800)=.04, \ p=.298 \], or the career advancement information \[ r(800)=.06, \ p=.095 \]. However, there was a small positive correlation between objective income and the reported importance of the retirement benefits information \[ r(800)=.10, \ p=.007 \]. Overall, the objective measures of income add relatively little to our knowledge of the way people value information in job advertisements compared to the subjective measures of income, which are generally more informative.

**General Discussion**

Unfortunately the results reported in this chapter are unable to reveal much about cognitive function under scarcity. While I found that people who are more interested in a job advertisement will look at it more, the amount of attention appears not to relate to the condition of financial scarcity. On one hand, this may be seen as an optimistic outcome, since people under scarcity may not be subject to problematic attentional biases when job searching (this may even be predicted by the results from the chapter above on attention under scarcity). On the other hand, the results shown here may reflect an attentional misprioritization of those under scarcity. In particular, people under scarcity should
prioritize salary-related information. The tendency not to up-regulate attention to the job advertisement in response to scarcity may reflect inflexibility of attention, similar to the one discovered in Chapter 2. Moreover, participants in this study did not increase their reports of the importance of salary information in response to scarcity. Since prior literature suggests that money-related thoughts spontaneously spring forward under scarcity, the results of the present study may suggest caution before generalizing these effects to job-seeking behaviour.

In the current state of scarcity-related literature, the role of attention in decision making under scarcity is not well understood. There are several possible mechanisms by which scarcity affects decision-making. It is possible that scarcity overloads working memory with financial concerns, and this causes fewer attributes to be weighed during decision-making, reducing the overall quality of a decision. Alternatively, scarcity may draw attention to the most immediately important attributes, and induce a deprioritization of long-term attributes, reducing the overall quality of a decision. The present findings fail to support the attentional account. It remains unclear whether scarcity-related effects on attention can affect decision making about future job opportunities. It also remains possible that the cognitive load account may play a role in decision making about jobs under scarcity.

To conclude this chapter I will make some recommendations for future investigations of scarcity and decision making. There are many situations in which immediate financial concerns may preclude or interfere with important future considerations. There are many situations in which time, money, or effort must be invested upfront in order to yield long-term benefits. Replacing a vehicle headlight is an investment with upfront time, effort, and financial costs, but yields returns safety which accrues over the long-term. Continued study of the potential trade-offs between short-term and long-term concerns may be important for explaining a range of existing maladaptive behaviours seen among low-income individuals. For example, children growing up in low-income neighbourhoods may become fixated on acquiring cash quickly, and criminal methods are frequently available.
Understanding the effects of scarcity on the weight of short-term versus long-term concerns may help to understand how financial scarcity causes children to underestimate both the long-term consequences of crime, but also the long-term benefits of low-wage work (development of responsibility, maturity, & good habit formation, etc.). It is adaptive to imagine the long-term possibilities under scarcity, not just short-term solutions. Future research can test whether long-term plan-making interventions reduce the fixation on short-term cash-gains, and increase the weight of long-term benefits in the decision-making process. Another speculative line of research may investigate new practices for policy-makers and how legislative bills are crafted. It is important for policy-makers to look past immediate constraints such as political will or immediate revenues in order to form sound long-term plans for their jurisdiction. An intervention to balance the policy-making process could involve Senate procedures that force bill authors to value pros and cons of long-term consequences, particularly those outside their immediate political agenda.
Chapter 6: Conclusions

The data presented in this dissertation contain a description of cognitive functioning under the condition of financial constraint. This compilation of findings comes from four data chapters involving 10 experiments and 5,105 participants. Some of these findings offer new theoretical insights to contribute to the research literature. Other findings inform public policy actions which can improve government services for people experiencing financial scarcity. Further, the results of the experiments presented here contain practical considerations which can help the everyday reader understand the experience of other people under scarcity, or understand their own experience when times get tough. In this chapter I will summarize the main findings from the chapters above alongside their limitations, discuss the theoretical implications, recommend some public policy considerations, and provide concluding remarks.

Summary of Findings

The first set of experiments measured attention under varying financial budgets using a restaurant menu paradigm. The amount of money available to participants made a profound impact on the patterns of attention. Firstly, participants under budget scarcity spent more time looking at the prices. This is not interesting in itself. However, it seems that this prioritization of prices comes with a long list of costs. For example, people under budget scarcity spent significantly less time looking at the names of the items. Choosing items from a menu based on their names is a luxury of those privileged with adequate financial resources. Further, attending to health-related information also seems to be a luxury unafforded by people under scarcity. Most importantly, people under scarcity spent less time looking at a discount listed at the bottom of the restaurant menu which could have alleviated their budget constraints. This pattern of attention translated into problematic behaviour exhibited by participants under scarcity, who were less likely to request the useful discount compared to other participants who did not need a discount in the first place. A follow-up experiment suggested that the
attentional bias which prevented participants under scarcity from noticing the discount was not caused by limiting the visual search space but instead by a reduced ability to re-deploy attention to the site of the discount. It is still unclear whether the apparent lack of attentional flexibility can be explained by a deficit in perception of the meaning of the discount during the few seconds it was viewed. Further study must be done to clarify this.

In chapter 3 I presented four experiments which aimed to alleviate the attentional disadvantage of people under scarcity. Data from these experiments were less reliable and conclusions were less decisive than ideal. However, there were some key results worth consideration. Firstly, boosting colour salience (by making the discount a bright red colour) was not an effective method to circumvent attentional biases under scarcity. I found no evidence in favour of colour-based salience as a method to make crucial information more noticeable in the restaurant menu paradigm. However, I did find evidence that changing the location of the crucial information was beneficial. Although this conclusion was of low certainty, it appeared that moving the discount to the top of the menu was beneficial to some participants under scarcity who may have been more likely to request it. It may have been important to place the discount information in a spatial location where it was likely to be discovered before participants under scarcity began engaging deeply with the price information. Further analysis of this paradigm is necessary to clarify this effect and the mechanism behind it.

Chapter 4 was a deep investigation of numerical perception using a paradigm designed to induce the use of the numerosity heuristic when estimating the sum of sets of numbers. The first of a series of unexpected findings was that there was no evidence for use of the numerosity heuristic at all. In fact, the reverse heuristic seemed to be in use. Participants in these studies were generally not affected by induced scarcity scenarios or budget conditions when they were estimating sums of numbers from working memory (the trial sums). However, participants were also asked to estimate the sum of trial sums (a task more likely to have depended on long-term memory), and in this task, people
in an induced scarcity-mindset condition estimated systematically lower quantities when numbers represented future income. When numbers represented future expenses, there was no reliable effect of scarcity mindset on number estimation. While one possible interpretation of these results is that people under scarcity become conservative when estimating future income but not when estimating future expenses, the effect of scarcity on numerical estimation is more likely driven by a subjective feeling of scarcity. In particular, people who feel that they do not have enough money tend to have exaggerated underestimates of numerical value compared to those who feel financially secure. This leads to the most important set of findings from Chapter 4.

My data on number estimation contain some surprising patterns of results. In particular, I want to highlight the correlations I found across my experiments between number estimation, objective SES, subjective SES, and relative SES. These correlations were consistent in both the trial estimation and the block estimation data – two different measures of number estimation accuracy. First, there was a consistent negative relationship found between objective SES and number estimation accuracy. People with higher personal incomes tended to estimate lower numerical sums. A similar pattern of results was found with relative SES. People who felt as though they were more “well off” compared to other people tended to estimate lower numerical sums as well. However, paradoxically, the pattern of results reversed with the PIFS data, which measures the subjective feeling of scarcity. People who felt more subjective scarcity tended to estimate lower numbers. What is the difference between feeling “well off” compared to others and feeling like you have enough? Clearly there is enough of a difference to make reliably opposing predictions in numerical estimation accuracy. This subtlety is also a novel contribution to the literature and should be investigated further. In my view, the majority of published empirical papers studying ‘scarcity’ are loose with their construct definitions. All future studies of scarcity must now make an effort to clarify what they are studying, and whether they are

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19 These correlations were not found in the family/household income data.
primarily interested in subjective feelings of scarcity or subjective feelings of relative financial comfort.

Chapter 5 was a brief investigation on attention and decision making under scarcity. The data from this chapter contained few insights into the effect of scarcity on attention or decision making. However, there was an emergent pattern of findings worthy of note. Subjective measures of scarcity, such as financial stress and the van Dijk et al., (2022) PIFS, were far more predictive of attention than objective measures of scarcity, such as reported personal income. Like several other novelties presented in this dissertation, this finding marks a new boundary between sub-constructs which were previously considered to be a unified ‘scarcity.’ My evidence from Chapter 5 makes even clearer the need to refine what is meant by scarcity. Researchers, policy-makers, and everyday readers can take the following general conclusion: We can expect objective scarcity, subjectively felt scarcity, and even relativistic scarcity to affect people in different, sometimes opposing, ways.

Other Theoretical Implications

Beyond the theoretical implications mentioned above, there are implications for scarcity theories present in the literature. In one of the most thorough and recent reviews of the scarcity literature, de Bruijin and Antonides (2022) summarized scarcity theory as largely unified, though they point out some important nuances. In this review, the authors noted that most of the psychological research on scarcity published since 2013 reflects the definition given by Mullainathan and Shafir’s 2013 book which framed scarcity as a subjective feeling of lacking resources. However, de Bruijin and Antonides also note a significant problem with the majority of the scarcity literature, which is that most authors have been using objective measures (such as income) as indexes of scarcity despite emphasizing the theoretical importance of subjective scarcity. My early work on scarcity (which does not appear in this manuscript) was similarly problematic because I emphasized the theoretical importance of objective scarcity for affecting behaviour, disregarding the effects of subjective scarcity.
in my own work. The experiments and data contained in this dissertation can offer a corrective view on the existing scarcity theory by showing that objective scarcity (such as measured personal income) and subjective scarcity (feeling like resources are lacking) should be disentangled because they can have different, even opposite, effects on cognition and behaviour. Furthermore I believe I am the first scientist to show that relative scarcity can be distinct from subjective scarcity (as evidenced repeatedly in Chapter 4).

For the reasons listed above, I believe the most significant implication this work has for the scarcity literature is that the traditional unified scarcity must be broken apart. It is important to decompose scarcity into at least three components: objective scarcity, subjective scarcity, and relative scarcity. There is no single and parsimonious ‘scarcity.’ Work from Cannon et al. began to open the definition by identifying the perceived mutability of the condition of scarcity as an important factor in the experience and response to scarcity (2019). Moreover, recent work from Blocker et al. decomposed the experience of scarcity along two dimensions: intensity and duration (2023). These subtleties are useful contributions to the literature. The present work expands the theoretical landscape by adding an additional dimension to the Blocker et al. model. Specifically, my work suggests adding at least a dimension of relativity where scarcity can vary from internal (subjective scarcity that is relative to one’s own experience) to external (subjective scarcity that is relative to one’s perception of other people’s experience). Future theoretical work should develop this framework further.

The breakdown of scarcity into components is a significant departure from the original theory proposed by Mullainathan and Shafir (2013). In their book, the authors discussed future avenues of research in which scarcity theory can be applied. For example, financial scarcity is an obvious application (and has been the most common application of scarcity theory since then), but time scarcity is another important domain of scarcity. The authors further speculated that scarcity of social connection may be an important application of scarcity theory as well. This remains true. I believe
that scarcity of all types of resources can have observable and important cognitive and behavioural effects. However, my results suggest that the general effects of resource scarcity on cognition, regardless of the resource domain, may be elusive. Based on my findings, it is likely that the psychological consequences of scarcity will be complex. For example, we may expect the relationship between scarcity and attention to be different from the domain of financial scarcity to the domain of social scarcity: While financial scarcity draws attention to immediate financial information and reduces attention to other information, social scarcity may cause attentional aversion to social activity. Moreover, objective social scarcity is likely to be a very different phenomenon to relative social scarcity or subjective social scarcity.

In sum, scarcity is a complex idea worthy of much more analysis. Across scarcity domains, we have less reason to expect that scarcity will function consistently than before this dissertation was written. In light of my findings, future experiments aiming for theoretical parsimony are likely to miss important nuances in the effects of scarcity. If the sub-components of scarcity remain anonymously cobbled together, the scientific lens will remain blurry.

Summary of Policy Implications

What can be done to help people under scarcity? In Chapter 2 evidence showed that participants under financial scarcity were only released from their attentional burdens if they actually took up the discount available to them. Simply noticing that it was there was not enough. If policymakers want to alleviate the cognitive burdens of people under scarcity, enrolment in relief programs should be maximally streamlined or even converted to automatic enrolment. When automatic enrolment is not possible, Chapter 3 suggested that moving the required information directly into the view of participants was likely the best way to assist them. This can alleviate the attentional biases caused by scarcity.
Another important implication for policy-makers comes from Chapter 4: When trying to predict behaviour, it is important to include disparate measures of scarcity. In particular, it would be ideal to always have measures of both objective scarcity (personal income) and subjective scarcity (using a validated scarcity scale, such as the PIFS). These two components of scarcity can have reliably opposing predictions on cognition, so it is important for policy-makers to understand the differences. Based on my findings, people with objectively low income have a perceptual bias toward higher numbers while people with subjectively low income have a perceptual bias toward lower numbers. This may important to know for any application involving fuzzy math and mental accounting.

**General Conclusions**

There are some general conclusions I would like the everyday reader to draw. First, it is important to note that the conclusions drawn above are subject to scientific limitations. Most of the experiments presented are the first of their kind. It is too early to know whether these results will be found in other populations or with other measurement instruments. In addition, the measurement instruments used in these studies have varying degrees of imprecision, which can sometimes create spurious results. Only further study can add confidence and clarity to my conclusions.

The final general conclusion I would like the reader to take is that there are real psychological consequences of not having enough money, and the feeling of not having enough money can sometimes make an even greater impact. This may not be surprising, but the type and extent of consequences may be surprising. Attentional and perceptual biases may compound over time into behaviours stereotypical of low-income people. We do not know how deeply scarcity affects people. Therefore, it is important to be kind, generous, and caring toward those who may be experiencing tremendous strain under the demands of their financial position.
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Appendix A: Scale Items

Budget Confidence scale

1. How confident are you that your income this month will cover your expenses?
   Responses range from 1 (Not confident at all) to 7 (Very confident)

Financial Stress scale

1. In general, how much financial stress do you feel on a day-to-day basis?
   Responses range from 1 (No financial stress at all) to 7 (A considerable amount of financial stress)

Relative Scarcity scale

1. Financially speaking, how well off do you feel compared to others?
   Responses range from 1 (I feel much worse off than most people) to 7 (I feel better off than most people)

Psychological Inventory of Financial Scarcity scale (PIFS; van Dijk et al., 2022; also referred to as the “scarcity index”)

1. I often don't have enough money.
2. I am often not able to pay my bills on time.
3. I often don't have money to pay for the things I really need.
4. I am constantly wondering whether I have enough money.
5. I have a hard time thinking about things other than my financial situation.
6. I worry about money a lot.
7. I am only focusing on what I have to pay at this moment rather than my future expenses.
8. Because of my financial situation, I live day to day.
9. I don't take future expenses into account.
10. I experience little control over my financial situation.
11. I am not able to manage my finances properly.

12. When I think about my financial situation, I feel powerless.

   Responses range from 1 (completely disagree) to 7 (completely agree)

**Financial Avoidance scale (Hilbert et al., 2022b)**

1. I sometimes delay making financial decisions until it is too late.

2. I waste a lot of time on other matters before making important financial decisions.

3. Even financial decisions that require little else except sitting down and doing them, I find that they seldom get done for days (e.g., paying a bill, transferring money).

4. Putting financial decisions off until the last minute has cost me money in the past.

5. I would avoid learning how high my expenses will be next month.

6. Sometimes it feels unpleasant to think about my financial situation.

7. I can think of situations in which I would rather not know the exact state of my finances.

8. I would rather not know about the consequences of financial setbacks.

   Responses range from 1 (completely disagree) to 7 (completely agree)