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Time's Influence: A Systematic Review of Biases in Intertemporal Decision-Making

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Abstract

Cognitive biases significantly influence decision-making by distorting how individuals perceive and evaluate outcomes over time. This systematic review synthesizes research from various domains, including behavioral economics, psychology, and health, to explore six time-related biases affecting intertemporal judgments and trade-offs. We analyze the underlying mechanisms of each bias, map their interrelationships, and uncover their impacts on both individual choices and societal decisions. Drawing upon empirical evidence, we propose tailored strategies to mitigate the adverse effects of these biases. Our findings contribute to the literature not only by enhancing the understanding of time-related cognitive biases but also by providing practical insights for improving decision-making and policy design aimed at promoting long-term well-being. The review concludes by highlighting critical gaps in the literature and outlining a future research agenda to further investigate and address biases in intertemporal decision-making.

Contents

1. INTRODUCTION

Time preference is a key concept in understanding how individuals make decisions involving trade-offs between costs and benefits that emerge at different points in time. It reflects the relative value people place on receiving benefits sooner rather than later and can affect every intertemporal decision, ranging from personal savings and investment choices to health behaviors (Thaler 1981). For instance, people who overvalue future financial security over immediate gratification are more likely to choose to deposit money into a savings account instead of spending it immediately. Conversely, those with a high time preference may opt for a smaller immediate reward rather than wait for a larger outcome. These preferences are fundamental in shaping a wide range of personal, economic, and societal behaviors and must be understood and balanced for enhanced well-being.

Time preferences and intertemporal choices are often examined through economic theories such as exponential discounting (Samuelson 1937). This model provides a foundational framework for intertemporal trade-offs, assuming that decision-makers possess time-consistent preferences and act as rational utility maximizers all the time. This means that if an individual prefers a delayed reward over an immediate one today, they will maintain this preference consistently over time, will continue to prioritize long-term benefits, and will aim to maximize their overall utility. However, empirical evidence reveals that individuals often deviate from rational utility maximization, with preferences changing over time (Fishburn & Rubinstein 1982). It has been shown that people tend to place a higher value on immediate rewards compared to delayed ones, even when the latter offer greater overall utility (Thaler 1981). Various intertemporal choice anomalies illustrate how decision-makers violate time consistency and rationality assumptions of the exponential discounting model by changing their preferences over time depending on the type, magnitude, and sequences of outcomes they evaluate (Loewenstein & Prelec 1991, Rambaud et al. 2023, Shelley 1993, Thaler 1981).

Intertemporal choice anomalies can be better understood through the lens of cognitive biases that systematically distort decision-making processes. Cognitive biases play crucial roles in decision-making, particularly when individuals need to make trade-offs and provide judgmental inputs. Research indicates that people heavily rely on mental shortcuts and heuristics during their evaluations and often make biased judgments (Tversky & Kahneman 1974). Within the area of intertemporal choices, cognitive biases influence how people perceive time, assess the value of alternatives, and compare the desirability of outcomes (Frederick et al. 2002). Given that most decisions involve predicting and evaluating outcomes across different time points, misperceptions driven by biases can systematically affect intertemporal trade-offs, leading to low utilities, undesirable outcomes, or even financial losses. For instance, individuals tend to underestimate the magnitude of the changes in their preferences over time, a phenomenon named projection bias (Loewenstein et al. 2003). Projection bias leads decision-makers to form future preferences based on their current circumstances, and it usually causes short-sighted decisions. Similarly, present bias refers to the tendency for individuals to prefer immediate rewards over future outcomes, even when the future rewards are significantly larger. It leads them to make choices that favor short-term gratification at the expense of long-term benefits, often resulting in decisions that are not aligned with their best interests. Recognizing the underlying reasons and potential impacts of time-related biases is crucial for gaining a nuanced understanding of why people make seemingly irrational decisions. The prevalence of these biases in various aspects of life underscores the need for developing systematic strategies to minimize their negative influences. Moreover, sometimes multiple biases can influence judgments simultaneously and lead to compounding distortions or reinforced errors. Since the interaction of biases may amplify complexity and escalate the negative influences, it is crucial to be aware of these relationships. Despite extensive research on intertemporal choice anomalies and time preferences, a notable gap remains in the literature regarding a comprehensive exploration of the influences of time-related biases on decision-making. Specifically, there is a limited investigation into how these biases interact with one another in the intertemporal context and a lack of targeted mitigation strategies to reduce their influences on judgments.

This review focuses on time-related biases by examining their effects on judgments and offers mitigation strategies to reduce their negative impacts. Our methodology involves a two-step process, starting with the identification of six biases that influence intertemporal trade-offs or distort time perception in decision-making. We then subject each of these biases to a systematic literature review and gather empirical evidence from a variety of fields, including economics, finance, health, and psychology. By doing so, we advance our understanding of how each bias plays a role in different decision contexts and which approaches can help decrease their adverse effects on judgments. Furthermore, we analyze the co-occurrence of biases and show how their combined presence may distort evaluations. By structuring a map that illustrates the relationships between biases, we offer new insights into their interconnections. Finally, based on the analyzed studies and recent trends in the literature, we present a research agenda.

Our research contributes to the existing body of knowledge in several ways by synthesizing the effects of multiple time-related biases on decision-making from a holistic perspective. Exploration of the relationships between these biases provides insights into uncovering complex behaviors and eventually designing more sophisticated approaches to improving judgments and decisions across various domains. The findings of this review can guide practitioners and policymakers aiming to enhance decision-making processes and researchers seeking to develop better mitigation strategies or decision-making methods. Our research extends its impact beyond the current findings by systematically reporting literature gaps and presenting a detailed research agenda for each bias. This proactive approach opens up new avenues for exploration. Our comprehensive review aims

not only to enrich the current understanding of time-related biases but also to serve as a catalyst for continued research and exploration in this evolving field.

The structure of this article is as follows. Section 2 provides a background and discusses a few key developments in the time preference and intertemporal decision-making literature. Section 3 introduces the approach employed in this review, elucidating the research design and article selection procedures. The findings of our analysis, offering insights into the empirical evidence on time-related biases and mitigation strategies, are presented from Section 4 to Section 14, with each bias discussed in a separate section. The relationships between the biases are discussed in Section 16. Section 17 is dedicated to a comprehensive discussion of gaps in the literature and outlines potential avenues for future research, underscoring areas that warrant further exploration and investigation. Finally, in Section 18, we summarize our findings and draw conclusions.

2. TIME PREFERENCE AND INTERTEMPORAL CHOICES

Time preference is significant in many decisions, including personal finance, health, education, policy-making, and environmental planning. Due to the importance and prevalence of this phenomenon, numerous theories have been introduced to model intertemporal choices and understand time preferences. One prominent theory for modeling these choices is exponential discounting, which assumes that individuals discount values at a constant rate over time (Samuelson 1937). This model helps explain how people value immediate rewards over future ones, providing a mathematical framework for predicting and understanding intertemporal decisions. The exponential discounting model makes two main assumptions: (*a*) People have a constant discount rate, which is used for all types of outcomes, and (*b*) their preferences are consistent over time. These assumptions imply that decision-makers are rational utility maximizers who always make time-consistent choices. However, the empirical validity of these assumptions has been criticized, and various alternative methods have been introduced to account for behavioral aspects that conflict with these assumptions. For instance, the hyperbolic discounting model shows that discount rates decrease over time rather than being constant, and individuals strongly prefer immediate rewards over long-term benefits (Ainslie 1975).

On the other hand, prospect theory reveals that gains and losses are perceived and evaluated differently in intertemporal decisions (Kahneman & Tversky 1979). Individuals often prefer smaller immediate rewards over larger future outcomes due to the stronger emotional impact of potential losses and the tendency to heavily discount future benefits. **Table 1** chronologically presents a few key theories developed to better represent the human decision-making process, particularly in the context of evaluating intertemporal outcomes and incorporating behavioral factors. While some of these theories are related to modeling intertemporal choices (descriptive approaches), a few are about motivating decision-makers to make more informed decisions that are aligned with their long-term well-being (prescriptive approaches). For instance, the nudge theory is about structuring choice environments and influencing people's behavior in a way that encourages them to make decisions that are in their best interest without restricting their freedom of choice (Thaler & Sunstein 2008). Most of these theories conflict with the rational agent assumption of exponential discounting and incorporate behavioral patterns aiming to better model real-life preferences.

3. RESEARCH METHODOLOGY

This systematic review applies a two-level methodology to identify and examine time-related biases. In the first step, we followed an approach to determine which biases can possibly emerge while making intertemporal trade-offs. We began by identifying keywords related to time preference, such as present, past, future, temporal, intertemporal, time, preference, and discounting.

Table 1   A few key developments in the time preference literature

Reference	Theory or concept	Key contribution
Samuelson (1937)	Exponential discounting	The first generalized model for intertemporal choices that assumes individuals have a constant discount rate and their preferences are consistent over time
Koopmans (1960)	Time consistency	A set of plausible axioms that show under well-specified circumstances that decision-makers have positive time preferences and behave as theorized in the exponential utility model
Ainslie (1975)	Hyperbolic discounting	Proposed as an alternative to exponential discounting by empirically showing that discount rates do not stay stable but decrease over time and individuals strongly prefer immediate rewards over delayed ones
Kahneman & Tversky (1979)	Prospect theory	Introduced psychological insights into how individuals evaluate gains and losses over time and the role of uncertainties in the trade-offs
Laibson (1997)	Quasi-hyperbolic discounting	A hybrid model that accounts for present bias and addresses the limitations of both exponential and hyperbolic discounting; it applies a dual parameter approach for addressing short- and long-term discounting parameters simultaneously
O'Donoghue & Rabin (2001)	Dynamic inconsistency and sophistication	Explores the behavior of individuals who are either naïve or sophisticated in their model of procrastination
Trope & Liberman (2003)	Temporal construal theory	Suggests that the psychological distance of events affects how people think about them; this difference in mental representation influences decision-making and preferences over time
Thaler & Sunstein (2008)	Nudge theory	Emphasizes the design of choice architectures that help individuals make better long-term decisions by accounting for behavioral biases like present bias

Based on these keywords, we conducted a comprehensive review of the bias codex, which presents a comprehensive list of cognitive biases (Manoogian & Benson 2017), as well as of seminal review papers on time preference and decision biases (Cooper & Meterko 2019, Ehrlinger et al. 2016, Kahneman et al. 1991, Loewenstein & Prelec 1992, Montibeller & von Winterfeldt 2015, Neal et al. 2022, Rambaud et al. 2023) and established bias taxonomies (Arnott 1998, Peón et al. 2017). By doing so, we obtained descriptions and features of many biases and screened them using these keywords. If the definition of a bias included one or more of the keywords, and if there was an intertemporal dynamic, we considered it for systematic review. This initial step yielded six time-related biases: present bias, projection bias, recency bias, duration neglect, impact bias, and planning fallacy.

In the second step, each of these biases was subjected to a systematic literature review by following the methodology provided by Tranfield et al. (2003). Two main bibliographic databases, Web of Science and Scopus, were considered because of their high-impact publications and extensive interdisciplinary studies (Rambaud et al. 2023). The identified keywords were grouped into two categories. The first category ensures that the article is about the bias we are looking for, and the second one limits the search to articles exclusively about intertemporal decision-making or time preference. The keywords were chosen for the broadest possible scope without losing the focus on intertemporal aspects. For example, the search string for impact bias was ("impact bias*" OR "affective forecast*") AND ("time" OR "temporal" OR "intertemporal" OR "discount*"). The

Table 2   Details of the article selection process

		Bias					
		Present	**Projection**	**Recency**	**Duration neglect**	**Impact**	**Planning fallacy**
Initial search (identification)	Initial search date	Nov. 2023	Feb. 2024	Feb. 2024	Feb. 2024	Sept. 2023	Sept. 2023
	Locations	T/A/K	T/A/K	T/A/K	T/A/K	T/A/K	T/A/K
Initial results	Web of Science	375	49	25	69	91	72
	Scopus	356	45	24	38	81	43
	Total	731	94	49	107	172	115
Screening phase	Removed duplicates	−332	−34	−22	−34	−60	−37
	Screened papers	399	60	27	73	112	78
	Obviously irrelevant	−87	−12	−11	−21	−39	−23
	Eligibility test (full-text reading)	312	48	16	52	73	55
Eligibility test and inclusion	Not human subject	−0	−0	−0	−3	−0	−0
	Not empirical	−159	−11	−4	−11	−12	−10
	Not related to the bias	−75	−13	−2	−2	−18	−14
	Not time-focused	−0	−6	−3	−11	−6	−6
	Included	**78**	**18**	**7**	**25**	**37**	**25**

Abbreviation: T/A/K, title/abstract/keywords.

aforementioned databases were searched using strings specific to each bias, which were structured using the same strategy. The search was limited to articles written in English and published in peer-reviewed journals. We did not consider review papers, conference proceedings, and theses. Also, we did not restrict the search to any journal or time range. The initial searches were conducted between November 2023 and February 2024 at different times for each bias. The details of the article selection process and the number of papers are provided in **Table 2**.

The papers' abstracts, titles, and keywords were screened to identify obviously irrelevant studies before applying the eligibility test. Articles that were found irrelevant were removed in this step and moved to full-text reading. The full texts of the articles were subject to eligibility criteria. Based on those criteria, we included (*a*) studies discussing the bias associated with intertemporal decision-making, (*b*) empirical studies (i.e., studies that are based on observed and measured phenomena and derive data from actual experiences), and (*c*) studies conducted with human participants (excluding studies conducted with animals or computer models). We excluded (*a*) non-peer-reviewed articles (such as editorials, commentaries, or letters) and literature review papers, (*b*) theoretical and conceptual papers that do not present any empirical findings, and (*c*) studies that focus primarily on animal models or nonhuman subjects.

The number of articles included varies for each bias, with the present bias having the highest number and the recency bias having the lowest number. This variation in numbers can be attributed to a few reasons. First, a large number of studies have been produced because present bias has been investigated in parallel with the time preference literature for many years in various fields. On the other hand, more recently identified biases like duration neglect or projection bias have yielded relatively fewer outputs. Second, while some biases are straightforward and easy to control in experiments, others are more difficult to measure or it is harder to distinguish their effects from other factors. This affects the number of experiments on each bias and, consequently, the number of articles included in this review.

After applying the eligibility test, the selected articles were analyzed to extract all related information. While doing so, we followed a data extraction protocol. This protocol consists of four main elements: (*a*) influences (of the bias) on judgments and decisions, (*b*) additional biases and behavioral factors reported in the paper (if so), (*c*) mitigation strategies (if mentioned), and (*d*) literature gaps and future research directions. There is always complexity and ambiguity when the human thinking process is concerned. Therefore, in some cases, empirical results were attributed to or explained by more than one bias. Since these relationships between biases may provide insights into understanding the underlying mechanisms, the additional biases and interrelationships were also extracted. By doing so, we aim to extend our analysis beyond the primary findings and show how these biases may emerge and influence judgments together. In order to provide practitioners with systematic ways to decrease the adverse effects of the considered biases, we gathered all the mitigation strategies discussed in the papers.

4. PRESENT BIAS

The hyperbolic discounting model shows that people do not discount the future at a constant rate as assumed in exponential discounting theory, and they overvalue the immediate outcomes because of the present bias (Frederick et al. 2002, Thaler 1981). The origins of present bias are the subject of varied interpretations. Notably, research indicates that individuals' perceptions and treatment of time play a critical role in shaping judgments (Balakrishnan et al. 2020, Jang & Urminsky 2023, Krčál et al. 2021). Studies have discovered that individuals have subjective perceptions of future time horizons, and they show reduced sensitivity to durations. This reduced sensitivity is posited as one of the reasons for adopting hyperbolic discounting (Zauberman et al. 2009). Further supporting this notion, research shows that individuals tend to create subjective financial periods in their minds and treat time-related outcomes based on these artificial time slots (Jang & Urminsky 2023). People are more impatient when choosing alternatives from different financial periods than when choosing from the same subjective financial period. The way people think and visualize the future is vital in intertemporal decision-making. For example, in a study demonstrating customers' sensitivity to present bias and time horizons, the concreteness of mental representations was the main driving factor (Malkoc & Zauberman 2006). It has been found that temporal framing—the way a consumption decision is presented in terms of time, such as whether it involves delaying (deferring) or accelerating (expediting) consumption—affects the concreteness of mental representations, which in turn influences the degree of present bias. Similarly, people with abstract mindsets show less present bias than those with concrete mindsets (Malkoc et al. 2010). The present bias was reported in financial decisions, including debt (Ikeda & Kang 2015), overspending (Nguyen 2016), loans (Berlinger et al. 2022), and credit card use and borrowing (Meier & Sprenger 2010). These experiments have shown that present-biased individuals can be more engaged with overborrowing and debt-holding (Ikeda & Kang 2015), overspending and impulsive buying (Nguyen 2016), and credit card use (Meier & Sprenger 2010).

Recent investigations into the diversity of intertemporal preferences have scrutinized variables such as age (Ikink et al. 2023, Kulati et al. 2023), gender (Horn et al. 2022), cultural differences (Kim et al. 2012), and socioeconomic status (Kulati et al. 2023). A recent study involving three distinct age cohorts revealed that children and adolescents exhibit greater impatience than young adults (Ikink et al. 2023). People are more sensitive to reward magnitudes but not to delays, which can be interpreted as an indication of increasing patience with advancing age. Parallel findings were observed in an extensive survey conducted across several European nations, suggesting that older individuals tend to assign greater value to future rewards, displaying a willingness to postpone immediate gratification (Meissner et al. 2023). Furthermore, gender emerged as an essential

determinant of intertemporal choices, with men having a higher present bias than women. This gender-related pattern was similarly noted among students in Hungary, where female participants showed a lesser present bias than their male counterparts (Horn et al. 2022). Another research on Poland's elderly population identified a correlation between reduced present bias or enhanced patience and factors such as high numerical abilities, higher income levels, and urban residence (Kulati et al. 2023). Notably, in this study, neither age nor gender was significantly linked to time preference variations, potentially due to the specific emphasis on older demographics. As an essential indicator of many interpersonal differences, the role of culture was revealed in time preferences by comparing the preferences of Western (American) and Eastern (Korean) subjects (Kim et al. 2012). Americans prefer immediate rewards more and show higher discount rates compared to Koreans, drawing attention to the differences between individualistic and collectivistic cultures.

Besides these individual and cultural drivers, time preferences are also affected by big-scale events like natural disasters, pandemics, or political regime changes (Akesaka 2019, Friehe & Pannenberg 2020, Meunier & Ohadi 2021). For instance, a study compared the time preferences of participants from Japan before and after the tsunami caused by the Great East Japan Earthquake (Akesaka 2019). Although it did not affect the intertemporal discount rates, the tsunami increased the present bias. A longitudinal experiment tested the influence of the COVID-19 pandemic on time and risk preferences (Meunier & Ohadi 2021). Findings show that the pandemic reduced present bias and led to more patience, especially in older people who faced severe health risks. The effect of political regimes on intertemporal judgments was studied using the separation and reunification of Germany after World War II (Friehe & Pannenberg 2020). There was a difference between the time preferences of citizens under the socialist and the capitalist regimes. While former German Democratic Republic (GDR) residents were less present-biased than Federal Republic of Germany residents, these two groups did not differ in patience levels. It has also been found that people who spent too much time (especially in their early childhood years) under the GDR regime had a more substantial present bias, which shows the formability of preferences at early ages of life.

Present bias has been investigated in relation to various emotional states, such as stress and sadness (Haushofer et al. 2013, 2021; Lerner et al. 2013). Experiments with monetary and health outcomes revealed that stress does not significantly influence discount rates or present bias (Haushofer et al. 2013). It is important to note that these experiments were conducted only with male participants, and gender differences were not accounted for. Conflicting results were reported when participants' cortisol levels were increased and their intertemporal preferences over outcomes like money and effort were analyzed (Haushofer et al. 2021). The results show that stress may increase the likelihood of choosing immediate outcomes, regardless of whether they are positive or negative. The role of sadness was tested by comparing the judgments of sad participants with those of neutral or disgusted people (Lerner et al. 2013). The sad people were more willing to accept sooner but smaller rewards rather than greater but delayed outcomes.

Outcome types such as unpleasant tasks (Augenblick & Rabin 2019), gains and losses (Hardisty et al. 2013, Shiba & Shimizu 2020), and reward types (for example, material versus experiential outcomes) (Cheung et al. 2022, Goodman et al. 2019) differ in their relations to present bias. Research on time inconsistency in gains and losses reported that the temporal location of delayed outcomes is the driving factor in direction and degree of inconsistency (Shiba & Shimizu 2020). Moreover, people's time inconsistencies for gains and losses were strongly related to each other, regardless of impatience levels. These findings highlight that people may have similar or even typical time inconsistencies for losses and gains. Contrary to the magnitude effect idea, in a series of experiments, participants discounted small losses less than large ones and large gains more than small gains (Hardisty et al. 2013). Moreover, it has been found that regardless of their magnitude, people tend to resolve both gains and losses immediately. Time inconsistency was investigated

across reward categories like food and money, using students from low-income schools in China (Cheung et al. 2022). The students had a present bias for both rewards. Furthermore, individual measures of present bias and impatience were correlated across different reward types, meaning that if someone knows the monetary preferences of a person, it may be possible to guess their food preferences. From a similar point of view, an experiment comparing the impatience levels of customers toward material versus experiential purchases revealed that people are less impatient for material purchases than for experiential ones, even when product types, delays, and choices vary (Goodman et al. 2019).

Present bias has been investigated for many health-related decisions, including smoking (Grignon 2009), exercising (Eberth et al. 2022), eating habits (Courtemanche et al. 2015, Mørkbak et al. 2017, Soofi et al. 2020), and preventive measures like disease screening (Jennings Mayo-Wilson et al. 2023, Lee et al. 2020, Tang et al. 2023). An experiment in France revealed that although they are not likely to start smoking, present-biased people tend to quit smoking later in life after more failed attempts (Grignon 2009). Similar results apply to exercising behaviors (Eberth et al. 2022, Hunter et al. 2018). Present bias is influential in maintaining physical activity, but its role in the initiation stage is insignificant. However, a survey from Japan shows that present-biased individuals are more likely to develop unhealthy behaviors, and impatience is related to poor health status in general (Kang & Ikeda 2016). Present bias is an essential driving factor in diseases that are closely related to lifestyle and eating habits, such as obesity and diabetes. In a study conducted with a group of people with diabetes from Denmark who were at different stages of the disease, the present bias was significant for both causing early onset and affecting the after-diagnosis preferences (Mørkbak et al. 2017). Similarly, a significant relationship between body mass index (BMI) and time preferences has been reported in a national longitudinal survey conducted in the United States (Courtemanche et al. 2015). The more impatient the participants were, the higher their BMI. The correlation between the probability of being obese and impatience provides further support for the influence of present bias on health (Soofi et al. 2020). The Family Health Habits Survey reveals that the impatience level of parents can significantly affect not only their own but also their children's obesity risk (Stoklosa et al. 2018). These findings show the malleability of preferences depending on other people and environmental factors. The willingness to undergo preventive health measures can also be related to present bias. For example, a high correlation between screening intention and time discounting was reported in a cross-sectional analysis of cancer screening behaviors in Korea (Lee et al. 2020). Individuals who discounted the future heavily were less likely to undergo lung cancer screening. Similar results were also reported by a recent study that focused on diabetic retinopathy screening behavior (Tang et al. 2023).

The influence of present bias is also evident in environmental decision-making (Figueroa et al. 2019, Fuerst & Singh 2018, Schleich et al. 2019, Yue et al. 2023, Wu et al. 2023). Since many environmental decisions require an initial investment and a long wait for the reward to be realized, present-biased people are less likely to switch to environmentally friendly options. For instance, in a study investigating energy-efficient investment preferences in India, present bias was a reason for underinvestment (Fuerst & Singh 2018). Participants were less likely to buy energy-efficient devices like air conditioners and refrigerators because they highly focused on the upfront costs and underestimated the possible future benefits of the investment. In a recent study about rooftop photovoltaic technology adoption in China, present-biased households were less likely to adopt the technology because of the long payback period (Wu et al. 2023). Similarly, a study with a large representative sample from eight European countries shows that time discounting, risk aversion, and loss aversion are negatively correlated with energy-efficient technology adoption (Schleich et al. 2019). Research shows that households occupied by present-biased families consume more electricity on average than time-consistent households (Werthschulte & Löschel 2021). These

families devalue future energy consumption, since they face outcomes at the end of the month and tend to be less careful at the present. The role of present bias is also evident in agricultural decisions, including conservation behaviors (Boonmanunt et al. 2020), warrantage systems participation (Le Cotty et al. 2019), environmental program adoptions (Clot & Stanton 2014), and contract farming applications (Hou et al. 2023). Consistent with the previous experiments, the present-biased farmers are less likely to adopt new technologies (Mao et al. 2021).

5. PRESENT BIAS MITIGATION STRATEGIES

Since the present bias is about being tempted by the desirability of immediate outcomes and giving less importance to long-term consequences, using commitment devices is the most reported mitigation strategy (Albrecht et al. 2011, Benscheidt & Carpenter 2020, Hunter et al. 2018, Imas et al. 2022, Le Cotty et al. 2019, Stoklosa et al. 2018). If people use precommitment devices, they are more likely to stick to their long-term plans in various contexts like quitting smoking (Grignon 2009), enhancing physical activity (Eberth et al. 2022), saving energy (Werthschulte & Löschel 2021), and saving money (Atlas et al. 2017). Although many experiments support commitment devices' applicability and promising performance in various fields, some mitigation strategies outperform. For instance, providing waiting periods between information-receiving and decision-making stages can be more effective than commitment devices (Imas et al. 2022). It has been argued that individuals should overcome the temptations while committing to an action. However, while provided with a waiting period to think about and mentally simulate future outcomes, they do not need to deal with temptations. Therefore, waiting periods may provide a better mitigation than commitment devices in some situations. Alternatively, combining commitment devices with a waiting period can be an effective strategy for mitigating present bias.

Framing intertemporal choices as losses reduces the present bias and increases the preference for delayed rewards (Radu et al. 2011). Since people generally prefer gains over losses, when the immediate outcome is framed as a loss, its attractiveness decreases, and the attention shifts toward the future. This idea was tested in the health domain for preventive measures for HIV (Jennings Mayo-Wilson et al. 2023). Participants' loss aversion was triggered when the consequences were framed as health losses, and they were less tempted by immediate outcomes. A similar idea is framing the future outcomes as large gains or small losses to encourage future-oriented choices (Hardisty et al. 2013). It has been suggested that instead of saying, for example, "saving 10 units a month," framing the problem as "earning 120,000 units in 30 years" may decrease the present bias. Furthermore, framing the problem as a future date, not a delay, also decreases the present bias (Malkoc et al. 2010). If the resolution date of the outcome is provided instead of saying X days later, the decision-maker can have more abstract and contextualized thinking and become less subject to present bias. Making future outcomes more salient or attractive and increasing attention toward the future are among the reported mitigation strategies (Carvalho et al. 2016, Guan et al. 2022, Malkoc et al. 2010). If a delayed outcome is described in detail and its advantages presented clearly, decision-makers can be less influenced by the immediate options. From a similar point of view, increasing the cost of tempting options can also achieve this result (Courtemanche et al. 2015, Soofi et al. 2020). For instance, making the immediate rewards unreachable (e.g., expensive or scarce) for unhealthy eating behaviors may help to decrease present bias and promote healthy eating habits.

Episodic future thinking refers to the human ability to imagine and mentally simulate future events, and it plays a significant role in reducing temporal discounting and improving decision-making (Schacter et al. 2017). By making future outcomes more tangible and engaging, this cognitive process can help individuals overcome present bias and make farsighted decisions

(Atance & O'Neill 2001, Bulley & Schacter 2020, Peters & Büchel 2010). For instance, mentally simulating future scenarios allows decision-makers to focus on potential long-term benefits over immediate temptations, leading to more informed choices (Benoit et al. 2011).

Offering incentives and nudging to promote future-oriented decision-making are among the most reported mitigation strategies. These methods are discussed for various decisions like disease screening (Lee & Kim 2017, Tang et al. 2023), physical activity (Hunter et al. 2018), switching to energy-efficient products (Figueroa et al. 2019), and healthier eating behaviors (Guan et al. 2022, Kang & Ikeda 2016, Soofi et al. 2020). People can be more motivated when they are reminded by an external source (nudge) or when they are promised a reward for doing a healthy activity. Furthermore, tailoring the incentives to consider individual differences may increase the effectiveness of these strategies (Tang et al. 2023).

Joint decision-making stands as an alternative debiasing strategy (Kono & Tanaka 2019, Nguyen 2016). It has been shown that when people make joint decisions with their spouses, they are less present-biased compared to when they make individual decisions (Kono & Tanaka 2019). Discussing options with someone can make people less tempted by immediate consumption and more aware of the long-term consequences.

6. PROJECTION BIAS

Sometimes, individuals cannot sufficiently estimate the future and assume that their current preferences will remain the same; this is known as projection bias (Loewenstein et al. 2003). Weather and air quality stand as two prominent factors that influence the perceptions of the decision-makers related to the future and lead to time-inconsistent preferences. It has been shown that the consumption decisions related not only to regular daily items such as winter clothes (Conlin et al. 2007) or outdoor movie tickets (Buchheim & Kolaska 2017) but also to durable goods like solar panels (Lamp 2023), cars (Busse et al. 2015), or lands (Pan et al. 2022) are significantly affected by projection bias. Since decision-makers could not accurately isolate the effects of the decision moments from future expectations, they ordered more winter clothes when the weather was cold (Conlin et al. 2007); purchased more outdoor movie tickets, and maybe more seriously decided to adopt solar panels (Lamp 2023), when it was sunny (Buchheim & Kolaska 2017); and paid higher prices for lands located in districts with a heating system (Pan et al. 2022) and bought winter cars (Busse et al. 2015) if the decision was made in a cold day. Similarly, air quality significantly influences individuals when they think about their future well-being. Participants were willing to pay more for better air quality if the experiment was conducted on a day with low air quality (He & Hu 2010), and they overvalued air quality relevance for overall well-being if they were exposed to short-term air pollution (Chen et al. 2019). Besides the environment in which the choices are made, the features of the outcomes and the context of the decisions also cause inconsistencies. When asked to choose between intertemporal unpleasant tasks related to their job, individuals exhibited projection bias and mispredicted their future tastes (Augenblick & Rabin 2019). The distaste of the present tasks affected the value these people attributed to the future.

There are numerous personal drivers that trigger projection bias in intertemporal trade-offs (Kármen 2023). Changes in tastes, education level, and financial control are some of the factors that may cause a gap between estimated and received utilities. There are also visceral factors, such as hunger, thirst, and sexual desires, that distort individual preferences. People mispredict their future desires when they are in a different visceral state from the anticipated consumption state (Fisher & Rangel 2014). In a set of experiments, participants reported varying willingness to pay values for the same objects depending on their hunger level at the time of the experiment (Briz et al. 2015). Since visceral factors directly affect the perceived value of the evaluated outcomes, they trigger intertemporal biases, including projection bias.

Projection bias may distort not only our future preferences but also our perceptions and assumptions about the preferences of other people. Experiments show that when people are asked how much their future preferences resemble the current ones, they tend to be optimistic about their consistency but assume other people's preferences will change more significantly (Renoult et al. 2016). One of the factors contributing to this difference is social distance. When people think about the preferences of a close friend or a family member, they assume less change than when thinking of a generic peer (Bauckham et al. 2019). These findings point to possible mistakes that may emerge when people must decide on behalf of a person or a group. It has been reported that when elderly people were asked to decide about their partners' end-of-life treatment preferences, they were subject to projection and similarity biases (Moorman et al. 2009). They were heavily dominated by their own treatment preferences, and the estimations they reported about their partners were far from reality.

7. PROJECTION BIAS MITIGATION STRATEGIES

The most common strategy against projection bias is the cooling-off period, which means providing people with a period of time to think about their preferences before finalizing their decisions (Camerer et al. 2003). This notion is similar to the waiting period that has been discussed to mitigate present bias (Imas et al. 2022). The strategy is based on the fact that future preferences can be better evaluated by separating them from current emotions. The cooling-off period is applied not only to financial decisions but also to emotional ones (Buchheim & Kolaska 2017, Busse et al. 2015, Loewenstein et al. 2003). For instance, 9% of the couples who applied for divorce suits in Korea changed their minds after being provided with a period of time to think about their decision (Wie & Kim 2015). Although the cooling-off idea has been widely proposed, it needs to be validated by being tested in different decision contexts. There are also other mitigation strategies, such as providing decision-makers with more information related to the problems (Buchheim & Kolaska 2017, Moorman et al. 2009, Pan et al. 2022) or warning them to be aware of the bias (Hetou et al. 2021, Lemay et al. 2015). It is noteworthy that these ideas do not go beyond general suggestions, despite the fact that they are frequently reported for other biases, such as present bias, recency bias, and duration neglect. There are also more unique approaches for projection bias, such as simulating other people's preferences (Renoult et al. 2016), focusing on basic variables instead of thinking of abstract aspects of future preferences (Fisher & Rangel 2014), or using the social distance phenomena as a debiasing strategy (Bauckham et al. 2019). All these strategies require further investigation and empirical evidence.

8. RECENCY BIAS

According to the American Psychological Association Dictionary of Psychology (**https://dictionary.apa.org/recency-effect**), the recency effect is "a memory phenomenon in which the most recently presented facts, impressions, or items are learned or remembered better than the material presented earlier." Since they are remembered more clearly than historical events, individuals may disproportionately weigh the most recent events, leading to judgments compromised by recency bias. An illustrative study involving both researchers and students required participants to synthesize findings from studies on a unified topic (Ernst et al. 2018). The results provide robust evidence of recency bias, showing that participants' conclusions were heavily influenced by the information presented last, irrespective of its relevance or the robustness of the evidence. In other words, regardless of the quality or significance of the presented evidence, participants shaped their judgments based on the most recent information they were exposed to. This tendency suggests

that the temporal sequence of the presented information can significantly skew judgments and decision-making processes.

Major events are essential in changing the perceptions of individuals and making them subject to recency bias (Hao et al. 2016, Rabbani et al. 2021, Welch et al. 1998). For instance, after a major stock market shock, investors' financial risk tolerance was significantly decreased (Rabbani et al. 2021). In another study conducted with US Federal Crop Insurance Program members, recent indemnity and weather conditions heavily influenced farmers' crop insurance decisions (Che et al. 2020). Higher past indemnities and harsh weather conditions encouraged farmers to insure their crops.

9. RECENCY BIAS MITIGATION STRATEGIES

Despite the adverse effects caused by recency bias, our search yielded only one study that explicitly focused on testing the performance of a mitigation strategy. In an experiment conducted with professional regulators and students, accountability was tested regarding its effects on the quality of judgments and recency bias (Schillemans 2022). In this experiment, participants had to evaluate a case and make judgments in the presence and absence of accountability. In other words, some participants had to explain and justify their choices while others did not. The analysis revealed that accountability improves information recall performance and helps to mitigate recency bias. These findings underscore the promising performance of keeping people accountable for their choices to avoid the potential distortions of recency bias.

Although accountability is the only empirically tested mitigation strategy among the analyzed articles, there are several suggestions to reduce the recency bias. Educating decision-makers to be aware of the bias is among them (Rabbani et al. 2021, Welch et al. 1998). The common idea is that if people are trained and warned about the possible effects of recency bias, they can reconsider their judgments and make better decisions. In a study about integrating different findings in a research process, a time-reversal heuristic was proposed to decrease the effect of recency bias (Ernst et al. 2018). It has been suggested that if people imagine and evaluate events in reverse temporal order, recency bias can be mitigated. However, similar to other debiasing ideas, this strategy requires further empirical support.

10. DURATION NEGLECT

Duration neglect refers to the cognitive bias whereby individuals fail to accurately remember the length of an event, instead basing their judgments primarily on the most intense moments and the ending of the experience (Fredrickson & Kahneman 1993). Building on the foundational work of Fredrickson & Kahneman (1993), subsequent research has explored the nuances of duration neglect and the peak-end rule across various domains. Studies have investigated how the temporal locations and the order of the events influence the overall satisfaction levels of individuals (Godovykh & Hahm 2020, Weingarten et al. 2021). For instance, in political contexts, voters' evaluations of economic performance and election decisions were disproportionately influenced by the most recent economic status, often neglecting the broader temporal scope of an administration's policies (Galiani et al. 2019, Healy & Lenz 2014). Furthermore, another study conducted with voters in villages has revealed that the peak-end rule may affect not only the judgments about economic situations but also the final decisions about whom to vote for (Galiani et al. 2019). The study shows that voters receiving large (peak) or recent (end) money transfers are more likely to vote for the incumbent party. Similar results apply to tourism activities. In an experiment, retrospective evaluations of participants regarding trips were swayed by the most extreme and most recent experiences (Chark et al. 2022, Hansenne & Christophe 2019, Kemp

et al. 2008). Furthermore, these effects were also valid even when participants did not visit the places but watched advertisement videos about them.

The implications of duration neglect and the peak-end rule extend into health care, influencing decisions like colonoscopy or pap smear screening (Hetou et al. 2021, Redelmeier et al. 2003, Yen et al. 2023). For instance, significant differences was reported in remembered pain and future screening behaviors in a clinical experiment with patients who underwent different colonoscopy procedures with various lengths and pain intensity levels (Redelmeier et al. 2003). Patients who experienced a longer colonoscopy procedure that ended with a less painful step recalled the operation as being less unpleasant and painful compared to those who underwent a shorter procedure with a more painful ending. The experiment found a 10% increase in screening return rates when duration neglect was activated by adding a non-painful end stage to the procedure. The same approach was adopted in a randomized controlled trial with two groups of patients who had cystoscopy (Hetou et al. 2021). Patients who had the modified screening reported much lower pain and anxiety scores after the procedure. Supporting results were also reported in a study conducted at a cervical cancer screening center with a group of females aged between 30 and 70 (Yen et al. 2023). Of the two groups, the one that had the modified pap smear screening with an added short, non-painful step recalled the procedure as less painful, and these participants were more willing to get rescreened in the future. Since duration neglect and the peak-end rule may influence remembered experiences, they can be used to promote health interventions, as in these examples. Educational decision-making contexts also reveal the impact of duration neglect. For example, in an experiment conducted on learning tasks with primary school children, the peak-end rule was a driving factor for future studying preferences (Hoogerheide & Paas 2012). If a learning experience ended with a pleasurable activity, students were more willing to study that topic in the future regardless of its difficulty level or duration (Finn & Miele 2016).

11. DURATION NEGLECT MITIGATION STRATEGIES

Despite many problems caused by duration neglect, we could only identify a few mitigation strategies in the analyzed papers. Changing the sequences of events is an effective strategy against duration neglect (Rode et al. 2007). Since the order of the events plays a crucial role in terms of peaks and ends, changing their order may improve decision-makers' evaluations. From a similar perspective, the timing of evaluations may affect remembered memories, and some studies present mitigation strategies consistent with this idea. Deconstructing the time intervals (Langer et al. 2005, Miron-Shatz 2009), changing the evaluation time (Woloschuk et al. 2011), and measuring multiple time points (Strijbosch et al. 2019) are among the reported ideas. In one study, increasing the familiarity of the decision-makers with the evaluated events was tested as a debiasing strategy (Morewedge et al. 2009). It has been found that if people become more familiar with the stimulus, they are less likely to neglect its durations.

Besides these empirically tested approaches, there are also more general ideas, such as keeping a detailed record of past experiences (Kemp et al. 2008), providing transparent information and feedback regarding durations (Galiani et al. 2019, Sels et al. 2019), adopting objective evaluation measures (Strijbosch et al. 2019, Weingarten et al. 2021), and increasing the attention and education levels (Galiani et al. 2019, Hoelzl et al. 2011). These ideas require further testing in various decision contexts to see whether they can effectively mitigate duration neglect or not.

12. IMPACT BIAS

When individuals experience an emotion, they can overestimate its intensity and duration, a bias called impact bias (Wilson & Gilbert 2005). They tend to believe the emotional state will last

longer and be more intense in the future than it will. This overestimation influences intertemporal judgments and distorts estimations in many contexts. Studies have illuminated the correlation between emotional intelligence (EI) and the accuracy of affective forecasting, positing EI as a significant predictor of individual variances in forecasting abilities (Dunn et al. 2007). Individuals with higher EI exhibit more accurate forecasts and are less prone to impact bias compared to those with lower EI. As with personality traits and individual differences, the impact bias was considered in relation with age and experience (Nielsen et al. 2008, Scheibe et al. 2011, van Dijk et al. 2008). Research indicates that younger adults are more susceptible to forecasting errors and exhibit heightened negative responses to losses compared to their older counterparts (Nielsen et al. 2008). An experiment found evidence of age-related improvement in affective forecasting accuracy only for positive events (Scheibe et al. 2011). A conflicting finding was reported in a study conducted with track athletes about their estimations related to their feelings after a race (van Dijk et al. 2008). This experiment found that experience does not teach people to make more accurate forecasts or become less subject to impact bias, but it can help them cope better with their emotions.

The phenomena of focalism and immune neglect have been identified as pivotal in fostering impact bias and forecasting inaccuracies (Gilbert et al. 1998, Hoerger 2012, Lench et al. 2011, Wilson et al. 2000). Focalism refers to decision-makers' tendency to focus too much on a particular aspect and neglect other relevant factors, which generally causes people to consider events from a narrow perspective and end up with inaccurate forecasts. For example, participants were asked to estimate their future happiness in experiments using positive and negative scenarios about football games, space accidents, and national crises (Wilson et al. 2000). Since they were overthinking about the focal event and thinking too little about other incidents that may require their attention, participants mistakenly estimated their emotions as more intense than they were. Furthermore, estimations about the length of these emotional stages were also biased due to immune neglect, which is the tendency of human beings to underestimate psychological coping strategies that can reduce the impact of adverse events. Research shows that individuals may overestimate the duration and intensity of their positive and negative emotions mainly because they neglect the role of the psychological immune system, which helps adjust emotions and well-being (Gilbert et al. 1998).

The role of impact bias extends into shaping individuals' risk and time preferences (Chanel et al. 2023, Karl et al. 2021). For example, in a recent survey conducted with Danish soldiers deployed to Afghanistan in 2011, affective forecasting errors influenced soldiers' time, risk, and occupation preferences (Chanel et al. 2023). Moreover, positive affective forecasting errors regarding excitement strengthen the motivation of soldiers to stay in the military services. Similar findings were reported in a study focusing on travelers' perceived coronavirus infection risk and emotions during the COVID-19 pandemic (Karl et al. 2021). Regarding risk perception, two experiments focused on how probabilities and outcome specifications affect people's judgments in affective forecasting (Buechel et al. 2014, 2017). It has been reported that forecasters and experiencers may feel different emotional impacts depending on an outcome's magnitude, probability, and duration (Buechel et al. 2017). Forecasters were more sensitive to outcome specifications than experiencers, leading them to rely on these factors in their predictions and to become more subject to biases.

The effect of time and temporal factors on impact bias has also attracted attention (Buehler & McFarland 2001, Eastwick et al. 2008, Finkenauer et al. 2007, Motoki et al. 2023). In a longitudinal study, driving exam participants could forecast linear changes in their affective reactions over time, but they were not good at quadratic changes (Finkenauer et al. 2007). This naïveté was attributed to their underestimating the speed of change in their emotions and not knowing how

time would affect their experiences. In addition, the temporal location of events was an essential factor in prediction accuracy. People were more accurate in their estimations about positive but distant, or negative but closer, events. In an experiment about predicting emotions regarding different temporally located videos, participants were more accurate when indicating the sadness of watching a short and distant video or a long and near one (Buechel et al. 2017). Similarly, when the estimated adverse events were located close to the present time, people overestimated their emotional reactions, but they were more accurate in their long-term predictions (Eastwick et al. 2008). COVID-19 vaccination preferences were studied for near and distant future scenarios by focusing on the time effect in affective forecasting (Motoki et al. 2023). Experiment results revealed that distant future simulations enhance positive affective forecasting and increase vaccination intentions. These findings highlight the importance of temporal distance and forecasting accuracy in attitude changes.

Gilbert et al. (2002) propose a three-step process for understanding intertemporal hedonic experiences. Initially, individuals assess the experience without considering time. Next, they project their current emotions onto future events. Finally, they adjust their preferences based on the timing of the event. However, this adjustment is cognitively demanding, often leading to biased evaluations. It has been hypothesized that people discount the future mainly because their hedonic states regarding the evaluated events become less intense as they move toward the future (Kassam et al. 2008). So, when people mispredict the intensity or length of their emotional states, they tend to discount the future more and make poor decisions. This relationship can be used to explain the immediate gratification phenomenon to some extent.

Adverse events such as terrorist attacks, wars, fires, or limb losses may cause intense emotions, and some researchers have focused on these scenarios for studying impact bias (Doré et al. 2016, Dunn & Ashton-James 2008, Peeters et al. 2012). When evaluating the possible emotions toward a future event, if people remembered an extreme past event, their forecasts tended to mirror that extremity. Therefore, the source of the impact bias might be decision-makers' tendency to use atypical past events in their evaluations. Personal health adversities, such as limb amputation or colostomy surgery, were also utilized to study impact bias (Peeters et al. 2012). When asked to predict and recall their well-being expectations, people with new disabilities overestimated their adaptation capabilities. They were more optimistic about adapting to new situations in the estimation phase than in the experience phase. These findings show how our intense emotions and current situation may affect our future preferences and strategies of coping with adverse events.

13. IMPACT BIAS MITIGATION STRATEGIES

A widely recognized strategy for mitigating impact bias and estimating future emotions is using surrogate information from people who have undergone similar experiences (Eastwick et al. 2008, Finkenauer et al. 2007, Scheibe et al. 2011). This can improve forecasting accuracy and support people to better regulate their emotions. Another promising strategy is using mental representations, encouraging decision-makers to concretely simulate events and their possible outcomes (Buechel et al. 2014, Finkenauer et al. 2007, Gilbert et al. 1998, Kassam et al. 2008). This will help them to see the events from a broader perspective, focus less on focal events, and eventually provide more accurate estimations. As an alternative strategy, exposing people to simulations or scenarios that mimic real-life cases has also been used (Chanel et al. 2023). The motivation behind this strategy is that instead of relying on mental images, using real-life simulation can provide better forecast inputs.

One of the primary causes of impact bias is the tendency of decision-makers to overly focus on focal events. To counter this, considering multiple future events occurring simultaneously can help

reduce the bias (Buehler & McFarland 2001, Lench et al. 2011, Morewedge et al. 2005, Wilson et al. 2000). Instead of thinking about how a person will feel regarding one specific event, training them to activate multiple events from a broader range can motivate them to see the bigger picture. This approach may prevent decision-makers from treating an emotional event as a unique experience. Knowledge of the surrounding context and outcome characteristics may also be helpful at this point. Another driver of impact bias is how decision-makers assess events over time and adjust their judgments. This can be mitigated by evaluating temporal forecasts across multiple time periods (Eastwick et al. 2008). It is believed that when asked about their emotions multiple times, people become more aware of them. This chance to reflect on the forecasts may decrease the likelihood of overestimating future emotions. Research shows that emotionally intelligent individuals can provide more accurate estimations and are less affected by impact bias. Therefore, enhancing EI skills (Dunn et al. 2007) and improving emotion regulation awareness (van Dijk et al. 2012, 2017) could be used to mitigate impact bias. As in many other cognitive biases presented in this study, there are some general mitigation ideas, such as ensuring transparency and accountability (Lau et al. 2016), increasing public awareness and education (Chanel et al. 2023, Lau et al. 2016, Scheibe et al. 2011), providing feedback to forecasters (Buechel et al. 2014, Chanel et al. 2023, Gilbert et al. 2002), and creating ethical standards, guides, and tools (Buechel et al. 2014, Lau et al. 2016). These ideas require further investigation and empirical testing to validate their effectiveness.

14. PLANNING FALLACY

People often underestimate the time, energy, money, and risks related to future outcomes and make optimistic plans, a behavioral factor known as the planning fallacy (Kahneman & Tversky 1979). This overoptimism may distort intertemporal evaluations and cause poor judgments. The perceived temporal distance is a crucial factor for the accuracy of future estimations (Nussbaum et al. 2006, Peetz et al. 2010, Wang & Chiou 2022). For instance, the perceived temporal distance may shorten for an individual who faces a future task that requires high effort (Wang & Chiou 2022). This delusion makes people less optimistic about task completion predictions and reduces the planning fallacy. The temporal distance may also affect predictions in different ways, depending on where individuals focus their attention (Peetz et al. 2010). For instance, emphasizing the potential obstacles rather than the required steps can shift people's focus to more realistic aspects of the planning and mitigate bias. Research reveals that depending on the level of construal information used, temporal distance also affects individuals' confidence while making intertemporal predictions (Nussbaum et al. 2006). High-level construals, which involve more abstract and generalized thinking, are more commonly used when predicting distant future events and cause more confidence in estimations. In contrast, low-level construals, which focus on concrete details, can create difficulty and reduce confidence in predictions.

Similar to temporal distance, the way people perceive time also plays a role in the planning fallacy (Boltz & Yum 2010). There is a difference in estimated durations when people perceive themselves as moving through time and when they think of time as moving toward them. They may adopt different thinking styles and ways of evaluation while estimating the future, and these differences may lead to biased judgments. For instance, an experiment revealed essential findings regarding the differences between thinking styles ("why" versus "how") and task duration estimation accuracy (Siddiqui et al. 2014). While considering simple tasks, if participants focus on "why," they might overestimate the required time. On the other hand, for complex problems, "how" causes a similar issue. This way of thinking also relates to using different levels of construal while making estimations.

15. PLANNING FALLACY MITIGATION STRATEGIES

Unpacking a task into smaller components is one of the most reported debiasing strategies against planning fallacy (Aczel et al. 2015, Kanten 2011, Peetz et al. 2010, Wang & Chiou 2022). Instead of estimating the duration of a complex project, focusing on each component can help do more accurate estimations. Furthermore, writing a thought list related to each step of a bigger problem is also recommended (Wang & Chiou 2022). By doing so, decision-makers can realize possible obstacles and make less optimistic judgments. Backward planning is another promising debiasing strategy for the planning fallacy (Wiese et al. 2016). When people start with the end goal and move backward to identify the required steps, they provide more realistic time durations and fall less to the planning fallacy bias.

Since decision-makers generally build their future preferences on past experiences, memory is an essential factor in intertemporal trade-offs (Schacter et al. 2012, Tulving 2002). By adjusting how they recall past experiences, individuals can improve the accuracy of their predictions for similar future tasks (Roy & Christenfeld 2007). Experiments reveal that participants who take reference information into account can make more accurate estimates of task completion duration (Shmueli et al. 2016). Therefore, motivating people to connect their past experiences to current tasks can serve as a promising debiasing strategy (Buehler et al. 1994, McDermott et al. 2016). As an alternative to the idea of relying on past experiences, providing feedback could also mitigate the planning fallacy (Roy et al. 2008, Thoma & Tytus 2018). If the memory of an individual is corrected by supplying feedback related to the durations of previous tasks, those individuals may be able to provide more accurate judgments (Roy et al. 2008).

Adopting an external perspective while making predictions can also serve as a mitigation strategy (Buehler et al. 1994, Shmueli et al. 2016, Thoma & Tytus 2018). It has been revealed that taking the third-person perspective improves judgments and makes decision-makers less subject to planning fallacy. When asked to imagine themselves as someone else, people can be more focused on details, less optimistic about timing, and more realistic in scheduling. Thinking about the preferences of their future selves may also help people mitigate the planning fallacy (Atance & O'Neill 2001). Episodic future thinking encourages individuals to simulate future events and incorporate detailed context together with potential obstacles (Schacter et al. 2017). This enables decision-makers to be less optimistic about their future plans and consider the practical requirements and potential challenges they may face (Baumeister et al. 2016).

It has been found that motivating people to form more concrete and detailed plans may decrease the planning fallacy (Boltz & Yum 2010, Kanten 2011, Koole & van't Spijker 2000). As individuals focus on real details and avoid abstract plans, they come up with more accurate estimations. Receiving feedback from others, asking for advice, and being accountable are among the strategies that can be used against the planning fallacy (Kanten 2011, Katt et al. 2021, Peetz et al. 2010, Roy et al. 2008, Siddiqui et al. 2014). Experiments show that decision-makers make more accurate predictions if they ask advice from an expert or peer or if they feel they need to explain their judgments to someone else.

16. RELATIONSHIPS BETWEEN BIASES

Understanding the relationships between biases is essential for uncovering how they interact and influence intertemporal judgments. To offer a comprehensive overview of these relationships, we begin by examining each time-related bias individually and discussing the reported additional biases and how their coexistence was explained in the analyzed experiments. Then, by using all these findings, we structure a visual bias map. By doing so, we aim to summarize the relationships between biases and provide insights into their working mechanisms.

Loss aversion is among the behavioral factors most frequently reported with present bias (Bernedo Del Carpio et al. 2022, Jennings Mayo-Wilson et al. 2023, Meissner et al. 2023, Meunier & Ohadi 2021, Schleich et al. 2019, Tang et al. 2023). Because loss aversion makes the pleasure of a gain less intense than the pain of a potential loss, a decision-maker is likely to show a stronger preference for immediate gains to avoid the potential loss of not receiving that reward. Such individuals would rather accept a smaller gain now than wait to receive a potentially larger gain in the future. In scenarios where a decision involves a potential loss (e.g., an initial payment), loss aversion may increase the likelihood that the decision-maker will delay or even avoid any action that could lead to the loss (Schleich et al. 2019). This generally results in a preference for immediate gains and present-biased choices. Risk aversion and framing effect can lead to similar behaviors (Grignon 2009, Hunter et al. 2018, Le Cotty et al. 2019, Malkoc & Zauberman 2006, Radu et al. 2011). Risk-averse people tend to prefer certain outcomes, even if it means settling for smaller rewards. As such, they often prefer guaranteed immediate outcomes rather than waiting for future payouts, which explains the emerging risk aversion–present bias relationship. When projection bias appears with present bias, it suggests that decision-makers are not only focusing on short-term outcomes but also incorrectly assuming their current preferences will persist into the future (Albrecht et al. 2011, Augenblick & Rabin 2019). This combination results in decisions that are distorted by both immediate desires and false beliefs about the future.

When people make decisions in groups or on behalf of others, some factors emerge with present bias, like declaration bias (Grignon 2009), overconfidence bias (Hunter et al. 2018), self-reporting bias (Ikeda & Kang 2015), and self/other discrepancy (Albrecht et al. 2011). For example, overconfident people may focus too much on short-term gains and overestimate their capacity to handle the long-term consequences of their actions. The self/other discrepancy can amplify present bias in group discussion. These individuals may think they are more future-oriented than other participants, even while prioritizing immediate gratification over future benefits themselves.

The salience effect refers to individuals' tendency to give disproportionate importance to salient outcomes, and it is the behavioral phenomenon most commonly reported along with projection bias. It is not always easy to distinguish between the salience effect and projection bias (Bordalo et al. 2013, Busse et al. 2015, Loewenstein et al. 2003). Therefore, when the perceptions of individuals about the future resemble their current preferences, there might be at least two possible explanations: (*a*) They might be affected by projection bias and assume that their future tastes will be similar to the current ones, or (*b*) they may be heavily influenced by the salient features of the present circumstances and attribute disproportionate weight to them. When making decisions, individuals may mistakenly place greater emphasis on outcomes related to their recent experiences and project them into the future, giving rise to the recency bias along with the projection bias (Chen et al. 2019). This combination may create a powerful effect whereby current circumstances and recent experiences heavily distort future planning and lead to suboptimal choices. Optimism bias, which is the tendency to overestimate positive outcomes, is also reported with projection bias (Lemay et al. 2015, Meyer et al. 2008). It has been shown that while thinking about the future, optimistic individuals may underestimate adverse outcomes and focus only on positive results. When combined with projection bias, optimism bias may cause a mistaken belief that one's future self will continue to maintain the perceived positive conditions. When they were asked to forecast the future preferences of their peers, individuals showed false uniqueness bias, which is a tendency to think one's situation is unique and the preferences of others will be different (Bauckham et al. 2019, Renoult et al. 2016).

Behavioral factors reported alongside recency bias include anchoring bias (Hao et al. 2016). In a study investigating the role of a 52-week high price (i.e., the highest trading price of a stock over

the past 52 weeks) in predicting future stock returns in Taiwan, recency and anchoring biases were reported together (Hao et al. 2016). While anchoring bias explained why investors used high prices as a reference point and ignored new information about stocks, the recency bias was the answer to why some were influenced by recent information rather than distant analyses and favored the stocks that recently reached the highest price. These two coexisting biases were used to explain traders' patterns in the stock market (Krieger et al. 2021). Projection bias can also emerge together with recency bias in some situations (Chen et al. 2019). For instance, when asked to report how much they would pay for better air quality, Chinese residents thought their future preferences would resemble the current ones. Their judgments were distorted by recent air quality (recency bias) and the mistaken belief about the preferences of their future selves (projection bias).

In alignment with the end effect phenomenon, the recency bias is among the biases reported with duration neglect (Rode et al. 2007, Woloschuk et al. 2011). Since the end rule is dominant in remembering retrospective events, the recency effect could be an influential factor in judgment formation. These two biases can lead individuals to make choices that are heavily influenced by recent or intense experiences rather than the overall circumstances. Although a few other cognitive biases have also been reported with duration neglect, we could not identify any repeated pattern. Nonetheless, there are examples of social desirability bias, salience effect (Miron-Shatz 2009), and illusion of control (Cowley et al. 2015).

Hot–cold empathy gaps and projection bias have been discussed with impact bias (Dunn & Ashton-James 2008, Gilbert et al. 2002, Nielsen et al. 2008). The hot–cold empathy gap is the challenge of accurately predicting how someone would think, feel, or decide if they were in a different emotional or physical state than they are now (Loewenstein et al. 2003). Therefore, people can mistakenly assume their future emotions will resemble the current ones and end up with impact bias in preferences without considering visceral influences, emotional changes over time, and adaptation factors. The tendency of decision-makers to discount the value of the future is also valid for emotions, and some experiments report discounting factors together with impact bias (Karl et al. 2021, Walsh & Ayton 2009). Thus, individuals may underappreciate future emotional values while overestimating how impactful certain events will be, leading to skewed and present-focused judgments. For example, in a study, participants showed discounting and impact biases when asked about their feelings regarding their future travel plans during the COVID-19 pandemic (Karl et al. 2021). When people predict their emotions in response to future events, they sometimes use surrogate information. While doing so, they may also discount other people's information and adopt imagination to adjust their forecasts (Walsh & Ayton 2009). Overcorrection bias, the tendency to adjust the initial thoughts too much based on additional information, may also emerge together with impact bias (Lau et al. 2016). The tendency of people to use past events as references to estimate future emotions may trigger some problems. For example, in one study, recollection bias, or misremembering past emotional reactions to events, was reported with impact bias (Hoerger 2012). Because recollection bias causes people to misremember the length and intensity of their past emotions, it also distorts their predictions about the future. Similarly, hindsight bias, also known as the I-knew-it-all effect, may appear when people use past experiences to estimate future feelings (Pollai et al. 2010, Sanna & Schwarz 2004).

Optimism bias, which refers to the tendency of individuals to be overly positive about their estimations, is highly reported together with planning fallacy (Buehler et al. 2012, Peetz et al. 2010, Qian & Zheng 2012, Rodon & Meyer 2012, Wang & Chiou 2022, Weick & Guinote 2010). If decision-makers are under the influence of optimism bias, they will likely underestimate the time and effort that future tasks will require while making estimations, and they will end up with a planning fallacy. Another bias frequently reported with planning fallacy is memory bias (Koole & van't Spijker 2000, Roy & Christenfeld 2007, Roy et al. 2008, Thomas et al. 2018). Experiments
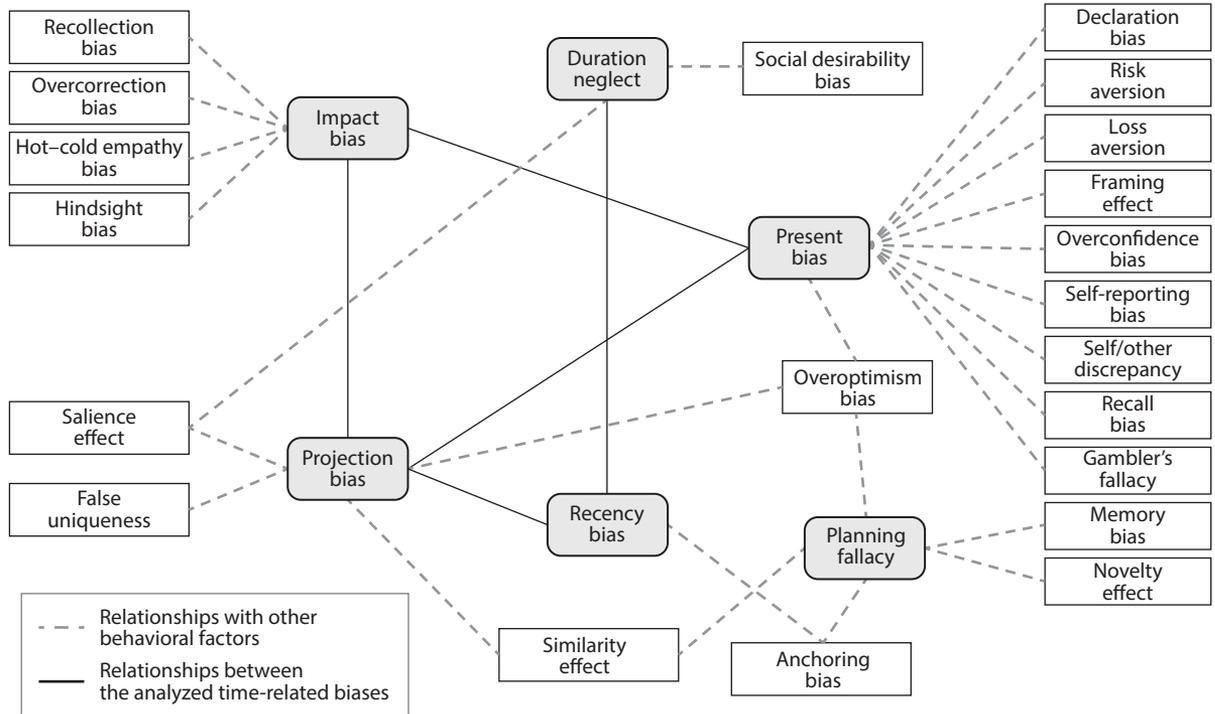
Figure 1

Relationships among biases.

reveal that sometimes people rely heavily on past experiences or memories while planning the future. If they have distorted memories or difficulty recalling the information correctly, they are likely to underestimate the task completion times and become subject to planning fallacy. In the planning fallacy context, past experiences in similar tasks can anchor (anchoring bias) people's evaluations and prevent them from adjusting new information or temporal differences in their estimations (König et al. 2015, Thomas & König 2018, Thomas et al. 2004). Eventually, they end up with skewed judgments and inaccurate forecasts.

Figure 1 illustrates the relationships between six time-related biases and the biases that were reported alongside them in the analyzed studies. If any two time-related biases were reported together, they are associated with a thick line. The relationships with other biases are illustrated with dashed lines. For example, duration neglect was discussed along with recency bias. Therefore, these two biases are associated with a thick line. Duration neglect was also reported with salience effect and social desirability bias, which are not time-related biases considered in the context of this study, so these relationships are represented with dashed lines. It can be seen that the planning fallacy was not reported with any of the time-related biases and stands apart. It must be emphasized that this map is only an overview of the analyzed studies and does not consider the frequencies of the relationships. It only aims to give a general overview of our findings. Identifying patterns between these biases and providing a more systematic diagram require further investigation and analysis. Also, context dependency should be considered while evaluating the map, since there were many different experiments from health, economics, environment, and psychology. Experimental features and chosen cases may cause some of the reported discrepancies.

17. FUTURE DIRECTIONS AND RESEARCH AGENDA

There are some research gaps that require further investigation to enhance our understanding of the influences of time-related biases on judgments. This section discusses future lines of research for each bias from both a theoretical and an empirical perspective, considering not only the analyzed papers but also recent trends from the literature.

Understanding the mechanisms of the present bias and uncovering underlying psychological and environmental factors remain crucial gaps in the literature (Ikink et al. 2023, Mao et al. 2021, Mograbi 2022, Werthschulte & Löschel 2021). Furthermore, looking at neurological aspects and studying the role of emotional states like sadness or stress can yield important insights (Benscheidt & Carpenter 2020, Hughes et al. 2024). Besides the psychological drivers, reasons that may cause heterogeneity in present bias among individuals—such as country of origin, age, social norms, cultural differences, sociodemographic aspects, political regimes, and financial or educational inequalities—should be explicitly investigated (Eberth et al. 2022, Ikink et al. 2023, Irvine et al. 2022, Jennings Mayo-Wilson et al. 2023, Mao et al. 2021, Schleich et al. 2019). Examining these factors, separately or together, may shed light on why some people make long-term decisions while others consistently fall into the present bias.

People respond differently to types of outcomes, which may lead to biased choices (Lipman 2024). From this point of view, there is a need to conduct experiments with actual incentives instead of hypothetical rewards (Yue et al. 2023), to extend the scope of the experiments beyond financial outcomes (Jang & Urminsky 2023), and to test the role of reward nature (e.g., monetary, utilitarian, hedonic) on the present bias (Krčál et al. 2021). This can help to understand present bias and design better systems by knowing the potential reactions of users to outcomes. Although many experiments have been conducted in different fields, the complexity of the preferred tasks makes their applicability to real-life decision-making settings still limited. The present bias should be investigated in more complex real-life choices to uncover the real mechanism behind the preferences (Augenblick & Rabin 2019, Ikink et al. 2023, Irvine et al. 2019). From a methodological point of view, examining the robustness and reliability of preference elicitation methods and developing more complex and realistic approaches that align with real-life choice behaviors may improve the ways present bias is studied (Akesaka 2019, Mao et al. 2021).

As with all biases discussed in this review, reducing the adverse effects of present bias on judgments is a crucial research gap. In alignment with this, future studies should focus on improving the performance of well-known mitigation strategies like commitment devices and developing more advanced methods against present bias (Eberth et al. 2022, Jennings Mayo-Wilson et al. 2023, Tang et al. 2023).

There are a few significant literature gaps related to projection bias. First, more empirical and methodological research is required to better understand the effects of projection bias. As in the other biases, the underlying mechanisms behind the projection-biased preferences are not yet fully understood (He & Zhang 2021). Since the pure effects of projection bias have not been revealed in many studies (as the projection bias generally appears with other factors such as the salience effect), identifying secondary biases and developing strategies to differentiate between their interdependent relations are among the literature gaps that require consideration (Augenblick & Rabin 2019, Pan et al. 2022). Second, after understanding the bias and its effects on judgments, developing debiasing strategies is another important research direction. A third literature gap concerns implementing the identified strategies into laws and helping people make more informed decisions (Chen et al. 2019). Authorities should consider the possibility of distortions caused by projection bias and provide individuals with better options, which is an area that requires particular attention from a policy-making perspective.

A few future research lines can help better understand and mitigate recency bias in intertemporal decisions. Uncovering psychological variables and cognitive processes behind the bias is crucial (Che et al. 2020). Additionally, studying secondary cognitive biases that appear together with recency bias and developing methods to differentiate between their effects are interesting research areas (Rabbani et al. 2021). Future studies should not only test the performance of existing methods with different cases and participant profiles but also come up with more sophisticated methods to mitigate recency bias (Schillemans 2022).

Future directions for research on duration neglect include exploring psychological and psychophysiological factors, understanding the role of emotions, studying the impact of cognitive load and memory factors, and uncovering cultural differences (Chark et al. 2022, Hetou et al. 2021, Weingarten et al. 2021, Williams et al. 2019, Yen et al. 2023). Similarly, reported empirical findings must be tested in various decision fields to enhance their reliability. Moreover, testing current intervention strategies in different fields and developing new strategies for mitigating the effects of duration neglect stand as crucial literature gaps.

One of the major literature gaps concerning impact bias is an investigation of its underlying motivational and psychological mechanisms (Chanel et al. 2023). In addition, personal characteristics, age differences, and cognitive abilities should be studied using diverse participant samples. There is a need to understand problem features that affect impact bias, such as the role of uncertainty and probabilities in complex decisions and reward magnitudes. Studying the role of temporal distance between forecasting and real events might help with understanding the effect of timing in triggering impact bias. In addition, comparing temporal characteristics like days, weeks, or months, and testing the impact of co-occurring multiple events are among the future research directions. The importance of real-life applications and testing the generalizability of affective forecasting theories require additional research—for example, testing the robustness of the theories in health, different social contexts, and daily life (Karl et al. 2021, Motoki et al. 2023, Villinger et al. 2020); looking at the influence of contextual factors in judgments; and exploring emotional fluctuations over time. Developing mitigation strategies and testing them empirically in various fields are also important tasks.

There is a need to understand the personality traits, underlying psychological mechanisms, and adopted cognitive styles related to planning fallacy and overoptimistic estimations (Wang & Chiou 2022). Future studies should focus on uncovering planning fallacy in different decision contexts and conducting more work in the field. In addition, the applicability and generalizability of the findings should be tested. Investigating the role of episodic future thinking in planning fallacy can reveal interesting findings (Wang & Chiou 2022). Extending the research into different domains like health and politics may lead to very interesting discoveries and help design more efficient systems (Katt et al. 2021). From an intertemporal decision-making perspective, the role of temporal distance in estimations and the nature of the intertemporal trade-offs are important areas to look at for a better understanding. Mitigation strategies like perspective-taking, abstract thinking, or different construal-level adaptations require further empirical validation.

18. CONCLUSION

People often use mental shortcuts to deal with complex information processing and make quick judgments. Although these shortcuts are generally helpful in simplifying complexity and reducing cognitive load, they can also cause biases. Research reveals that biases systematically distort individual evaluations and lead to poor decisions in various areas of life. Intertemporal judgments are also not immune to these distortions, and trade-offs can become subject to many types of deviations from rationality. Multiple biases, such as present bias, planning fallacy, and projection bias,

distort the perceptions that decision-makers have of time and time-dependent outcomes and lead to poor choices. It is crucial to examine the influences of these biases on judgments and develop strategies to reduce their negative effects. In this review, we identified six biases that can influence intertemporal decisions when individuals evaluate time-related outcomes, and we conducted systematic literature reviews to gather empirical evidence for their influences on judgments. In addition, we provided an overview of the interrelationships between time-related biases and other behavioral factors. Finally, we discussed mitigation strategies and research directions that require further attention.

Our analyses reveal that in many personal and societal decision contexts, time-related judgments and intertemporal trade-offs are subject to biases. The frequently reported underlying reasons include psychological and environmental factors, outcome-related features, thinking styles, temporal locations of outcomes, and various behavioral patterns. Our findings emphasize the importance of mitigating time-related biases since they exist in many, if not all, areas of life, such as health, education, finance, environment, research, sports, and law. Although these biases have been studied in many fields, there is a lack of mitigation strategies tailored to different circumstances to decrease their adverse effects. In other words, while the current literature mainly focuses on descriptive research, there remains a significant gap in prescriptive approaches to help decision-makers mitigate the negative influence of time-related biases and make informed choices. Our results emphasize the need to develop more systematic mitigation strategies and test their empirical validity in different fields. Moreover, more sophisticated methods are required to differentiate the influences of multiple biases on judgments. While this review provides insights into identifying, understanding, and mitigating biases in intertemporal trade-offs, there remains a need for further empirical research, and particular attention should be paid to developing targeted differentiation methods and debiasing strategies.

This research contributes to the literature by explicitly examining time-related biases and their impacts on intertemporal decisions. Our systematic literature reviews gather empirical evidence, shedding light on the prevalence of these biases and their implications for decision-makers. We believe that the findings of this research will lead to new investigations and enhance our understanding of time preferences and behavioral aspects. Despite these contributions, some limitations remain. Acknowledging the scope of our review, future research could extend the analysis by delving deeper into the theoretical underpinnings of intertemporal decision-making. Additionally, utilizing a more systematic approach for uncovering the complex relationships between biases may be an interesting topic for future studies. We hope this comprehensive review will serve as a foundational resource for understanding the impact of biases on intertemporal decision-making and will inspire future research to investigate the application of these biases in diverse real-world contexts and to develop more advanced debiasing methods.

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