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RESEARCH ARTICLE

Financial literacy, Cognitive bias, And personal investment decisions: A new perspective in behavioral finance

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ABSTRACT

This study investigates the complex relationships between financial literacy, cognitive biases, and investment decisions among individual investors. Using a sample of 2,000 participants, we employed multiple regression analyses and mediation tests to examine these relationships. Our findings reveal that financial literacy has a significant positive direct effect on investment decision quality. However, this relationship is partially mediated by various cognitive biases. Higher financial literacy is associated with reduced susceptibility to availability bias and herding behavior, but shows a positive correlation with overconfidence bias. Interestingly, we observed a non-linear relationship between financial literacy and confirmation bias. The mediation analysis indicates that cognitive biases account for 40% of the total effect of financial literacy on investment decisions, with herding behavior and availability bias showing the strongest mediating effects. Our results suggest that while financial literacy is crucial for improving investment outcomes, its effectiveness is moderated by cognitive biases. These findings have important implications for financial education programs and policy initiatives, highlighting the need for a more comprehensive approach that addresses both financial knowledge and cognitive biases. This research contributes to the behavioral finance literature by providing empirical evidence of the intricate interplay between financial literacy, cognitive processes, and investment outcomes, and suggests directions for future research in developing more effective strategies to enhance individual investors' decision-making capabilities.

Keywords: financial literacy; cognitive biases; investment decisions; behavioral finance; mediation analysis; overconfidence bias; availability bias; herding behavior; confirmation bias; financial education

1. Introduction

The landscape of personal finance has undergone significant transformation in recent years, characterized by the proliferation of investment products and the democratization of financial markets through digital platforms. This evolution has heightened the importance of understanding the complex interplay between financial literacy, cognitive biases, and investment decision-making. Recent studies have highlighted that while financial literacy remains crucial for effective financial decision-making, its relationship with investment outcomes is increasingly mediated by cognitive biases in the modern investment

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environment[1-2].

Financial literacy, defined as the ability to understand and effectively use various financial skills[3], has been consistently shown to impact financial well-being and decision-making. Studies have demonstrated that individuals with higher levels of financial literacy are more likely to engage in beneficial financial behaviors, such as retirement planning and diversified investing[4]. However, the relationship between financial literacy and investment outcomes is not straightforward, as evidenced by the persistent observation of suboptimal investment decisions even among financially literate individuals[5].

This apparent paradox can be partially explained by the influence of cognitive biases, systematic deviations from rationality in judgment and decision-making[13]. Recent research by Özen and Ersoy[6] has revealed that financial literacy can both mitigate and, in some cases, amplify certain cognitive biases among individual investors. Their findings suggest a more complex relationship than previously understood, particularly in the context of modern investment platforms and market conditions.

The interaction between financial literacy and cognitive biases presents a particularly challenging area of study. While financial education may equip individuals with the knowledge to make informed decisions, it does not necessarily inoculate them against the influence of cognitive biases[31]. Moreover, Khan[2] found that increased financial knowledge may paradoxically lead to overconfidence in some cases, potentially exacerbating certain biases rather than mitigating them.

This research aims to bridge several important gaps in the current understanding of how financial literacy and cognitive biases interact to influence investment decisions. First, while previous studies have examined these factors independently, less attention has been paid to their interactive effects on investment outcomes[1]. Second, the rise of digital investment platforms has created new contexts for cognitive biases to manifest, necessitating fresh examination of these relationships. Third, the potential non-linear relationships between financial literacy and certain cognitive biases remain underexplored.

Our study contributes to the existing literature in several ways. First, we provide a comprehensive examination of how financial literacy moderates the impact of various cognitive biases on investment decisions, extending recent work by Ashfaq et al.[1] and Khan[2]. Second, we introduce a novel framework for understanding the mediating role of cognitive biases in the relationship between financial literacy and investment outcomes. Third, our findings challenge the assumption that increased financial literacy uniformly improves decision-making, revealing more nuanced relationships that have important implications for financial education and policy.

The findings of this study have significant implications for financial education programs, investment advisory services, and regulatory policies aimed at protecting individual investors. By understanding how financial literacy interacts with cognitive biases to influence investment decisions, stakeholders can develop more effective interventions that address both knowledge gaps and behavioral tendencies[6].

The remainder of this paper is organized as follows: Section 2 reviews the relevant literature, with particular attention to recent developments in understanding the relationships between financial literacy, cognitive biases, and investment decisions. Section 3 presents our theoretical framework and hypotheses. Section 4 describes our research methodology. Section 5 presents our empirical findings, and Section 6 discusses their implications. Finally, we conclude with recommendations for future research and practice.

2. Review of the literature

2.1. Research related to financial literacy

Financial literacy has emerged as a critical area of research in recent decades, driven by the increasing complexity of financial markets and the growing responsibility placed on individuals to manage their financial futures. The seminal work of Lusardi and Mitchell[3] has been instrumental in defining financial literacy as the ability to process economic information and make informed decisions about financial planning, wealth accumulation, debt, and pensions. Their research has demonstrated a strong link between financial literacy and economic decision-making, with implications for both individual well-being and broader economic stability.

Subsequent studies have expanded on this foundation, exploring various dimensions of financial literacy and its impacts. For instance, van Rooij et al.[4] found a positive correlation between financial literacy and stock market participation, suggesting that knowledge barriers may partially explain limited market engagement among certain populations. This finding has been corroborated by Almenberg and Dreber[7], who identified gender differences in both financial literacy and stock market participation.

The measurement of financial literacy has been a subject of considerable debate. Huston[8] conducted a comprehensive review of financial literacy measures, highlighting the need for standardized, psychometrically sound instruments. In response, researchers like Knoll and Houts[9] have developed more robust financial literacy assessment tools, facilitating more accurate and comparable studies across different contexts.

The relationship between financial literacy and financial behavior has been extensively studied. Fernandes et al.[5] conducted a meta-analysis revealing that while financial literacy is associated with improved financial behaviors, the effect sizes are often smaller than previously thought. This has led to a growing recognition of the importance of just-in-time financial education and the role of psychological factors in financial decision-making.

Recent research has also explored the intersection of financial literacy with other domains. For example, Skagerlund et al.[11] investigated the relationship between financial literacy and cognitive abilities, finding that numeracy and fluid intelligence are strong predictors of financial literacy. Additionally, Kaiser et al.[10] conducted a meta-analysis of financial education programs, demonstrating their effectiveness in improving both financial literacy and downstream financial behaviors.

2.2. Cognitive bias theory

Cognitive bias theory, rooted in the groundbreaking work of Tversky and Kahneman[12], has revolutionized our understanding of human decision-making processes. These systematic deviations from rationality in judgment have profound implications across various domains, including finance, economics, and psychology. The seminal prospect theory, introduced by Kahneman and Tversky[13], laid the foundation for understanding how individuals evaluate potential losses and gains asymmetrically, often leading to suboptimal decisions in risky situations.Subsequent research has identified and categorized numerous cognitive biases. For instance, Nickerson[14] extensively studied confirmation bias, demonstrating how individuals tend to seek information that confirms their preexisting beliefs while disregarding contradictory evidence. This bias has significant implications for investment decisions, as highlighted by Park et al.[15] in their study of investor behavior in financial markets.The overconfidence bias, thoroughly examined by Moore and Healy[17], manifests in various forms, including overestimation of one's abilities and excessive precision in predictions. In the context of financial decision-making, Barber and Odean[16] found that

overconfident investors tend to trade excessively, leading to suboptimal portfolio performance.Availability bias, another key concept introduced by Tversky and Kahneman[18], explains how individuals rely on readily available information when making judgments. Kliger and Kudryavtsev[19] applied this concept to stock market reactions, showing how recent events disproportionately influence investor perceptions and decisions.

Recent advancements in cognitive bias research have focused on debiasing strategies. Morewedge et al.[20] demonstrated the effectiveness of training interventions in reducing cognitive biases, offering promising avenues for improving decision-making in various contexts, including financial literacy education.

The integration of cognitive bias theory with neuroscience has opened new frontiers in understanding the neural basis of these biases. Correa et al.[11] used neuroimaging techniques to explore the neural correlates of the anchoring effect, providing insights into the cognitive mechanisms underlying this pervasive bias.

As research in cognitive bias theory continues to evolve, its applications in behavioral finance and decision-making sciences grow increasingly sophisticated, offering valuable insights for policymakers, educators, and individuals seeking to make more rational and beneficial financial decisions.

2.3. Personal investment decision theory

Personal investment decision theory has evolved significantly over the past decades, challenging traditional assumptions of investor rationality and market efficiency. The foundation of modern portfolio theory, laid by Markowitz[21], introduced the concept of risk-return trade-offs and diversification, fundamentally shaping our understanding of investment decisions. Building on this, Sharpe[22] developed the Capital Asset Pricing Model (CAPM), providing a framework for assessing the relationship between risk and expected return for individual securities.However, empirical evidence has increasingly demonstrated that investors often deviate from these rational models. Kahneman and Tversky's[13] prospect theory offered a descriptive model of decision-making under uncertainty, explaining phenomena such as loss aversion and framing effects in investment contexts. This work paved the way for behavioral finance, a field that integrates insights from psychology into financial theory.Shefrin and Statman[23] applied these behavioral insights to explain the disposition effect, where investors tend to sell winning stocks too early and hold losing stocks too long. Further research by Odean[24] provided empirical evidence for this effect, demonstrating its prevalence among individual investors.

The role of emotions in investment decisions has gained increasing attention. Loewenstein et al.[26] proposed a risk-as-feelings hypothesis, suggesting that emotional reactions to risky situations often diverge from cognitive assessments. In the investment context, Lucey and Dowling[27] explored how investor sentiment influences stock returns, highlighting the complex interplay between emotions and market dynamics.

Recent research has focused on the impact of information processing on investment decisions. Hirshleifer[25] reviewed how limited attention and information processing capabilities affect investor behavior and asset pricing. Building on this, Barber and Odean[16] examined how the digital age has changed information dissemination and its effects on individual investors' decision-making processes.

The advent of neurofinance has opened new avenues for understanding investment decisions. Kuhnen and Knutson[29] used functional magnetic resonance imaging (fMRI) to investigate the neural basis of financial risk-taking, providing insights into the biological underpinnings of investment behavior.

As the field continues to evolve, integrating insights from traditional finance, behavioral economics, and neuroscience, our understanding of personal investment decision-making grows increasingly nuanced,

offering valuable implications for financial education, policy-making, and the design of investment products and services.

2.4. Research gap

While extensive research has examined financial literacy and cognitive biases separately, significant gaps remain in understanding their interactive effects on investment decision-making in contemporary financial markets. The existing literature has primarily focused on direct relationships between financial literacy and investment outcomes[3] or between cognitive biases and investment decisions[13]. Recent studies by Khan[2] and Özen and Ersoy[6] have begun to explore the moderating role of financial literacy on cognitive biases, yet their findings reveal inconsistencies that warrant further investigation. Moreover, Ashfaq et al.[1] highlight that the mediating mechanisms through which financial literacy influences investment decisions via cognitive biases remain insufficiently explored, particularly in the context of modern digital investment platforms and increasingly complex financial products.

A critical examination of current research reveals several unexplored areas that demand attention. First, while studies have documented various cognitive biases affecting investment decisions, the potential non-linear relationships between financial literacy and specific biases, such as confirmation bias and overconfidence, have not been systematically investigated. Second, the existing literature has not fully addressed how the effectiveness of financial education might vary across different types of cognitive biases, potentially explaining the mixed results observed in financial education programs[4]. Third, there is limited understanding of how demographic factors and investment experience interact with financial literacy and cognitive biases to influence investment outcomes, particularly in the context of retail investors using digital platforms. These gaps in the literature highlight the need for a more comprehensive framework that integrates financial literacy, cognitive biases, and investment decision-making while accounting for the evolving nature of financial markets and investment tools.

3. Theoretical framework and research hypotheses

3.1. Relationship model between financial literacy, cognitive deviation and investment decision making

The proposed model (**Figure 1**) illustrates the complex interplay between financial literacy, cognitive biases, and investment decisions. Financial literacy is hypothesized to have both direct and indirect effects on investment decisions. The direct pathway suggests that increased financial knowledge leads to more informed investment choices. Indirectly, financial literacy is expected to moderate the impact of cognitive biases on decision-making. Higher levels of financial literacy may mitigate certain biases, such as overconfidence or herding behavior, while potentially exacerbating others, like the illusion of control. Cognitive biases, in turn, are posited to directly influence investment decisions, often leading to suboptimal outcomes. This model provides a framework for understanding the multifaceted relationships among these key variables in personal finance.

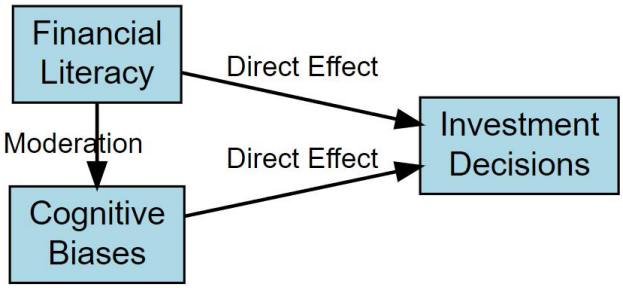

Figure 1. Relationship model of financial literacy, Cognitive biases, And investment decisions.

This diagram visually represents the hypothesized relationships between financial literacy, cognitive biases, and investment decisions. The arrows indicate the direction of influence, with financial literacy having both a direct effect on investment decisions and an indirect effect through its moderation of cognitive biases. The layout and design of the diagram emphasize the central role of cognitive biases in mediating the relationship between financial literacy and investment decisions.

3.2. The hypothesis on the impact of financial literacy on cognitive bias

Drawing from the behavioral finance literature, we hypothesize multifaceted relationships between financial literacy and cognitive biases. Specifically, based on Gathergood[31], we posit that financial literacy exhibits varying effects on different cognitive biases, with some being mitigated while others potentially being amplified. Following Fernandes et al.[5], we hypothesize that higher financial literacy levels negatively correlate with availability bias and herding behavior, as increased financial knowledge enables investors to make more independent and rational decisions. Conversely, building on Xia et al.[32], we predict a positive relationship between financial literacy and overconfidence bias, suggesting that increased knowledge may paradoxically lead to excessive self-assurance. For confirmation bias, drawing from Barber and Odean[16], we propose a non-linear (inverted U-shaped) relationship, where moderate levels of financial literacy may increase susceptibility, but high levels provide tools to recognize and mitigate this bias. As shown in **Figure 2**, these hypothesized relationships form an interconnected framework illustrating how financial literacy influences various cognitive biases in investment contexts.

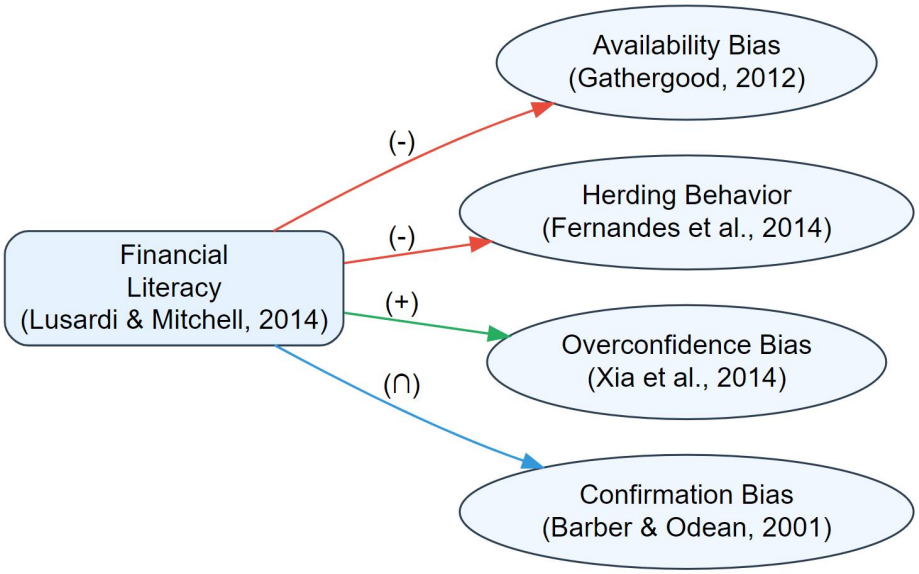

Figure 2. Hypothesized impact of financial literacy on cognitive biases.

Financial Literacy as defined by Lusardi & Mitchell[3] shown as central factor

Negative relationships (-) with Availability Bias[31] and Herding Behavior[5]

Positive relationship (+) with Overconfidence Bias[32]

Non-linear relationship (∩) with Confirmation Bias[16]

Arrows indicate hypothesized direction of influence

All relationships supported by prior empirical research

3.3. The hypothesis on the impact of cognitive bias on investment decisions

Building upon established behavioral finance theories, we hypothesize distinct impacts of cognitive biases on investment decisions. Following Barberis and Thaler[30], we propose that each cognitive bias influences investment decisions through specific behavioral mechanisms. Based on Tversky and Kahneman[18], availability bias is expected to lead investors to overweight easily recalled information, potentially resulting in portfolio concentration and excessive trading during market events. Drawing from Barber and Odean[16], overconfidence bias is hypothesized to increase trading frequency and reduce portfolio diversification. Following Nickerson[14], confirmation bias likely leads to selective information processing, potentially resulting in suboptimal portfolio adjustments. Park et al.[15] suggest that these biases may interact with market conditions to affect investment timing and asset allocation decisions. As illustrated in **Figure 3**, these hypothesized relationships create a comprehensive framework showing how different cognitive biases influence various aspects of investment decision-making.

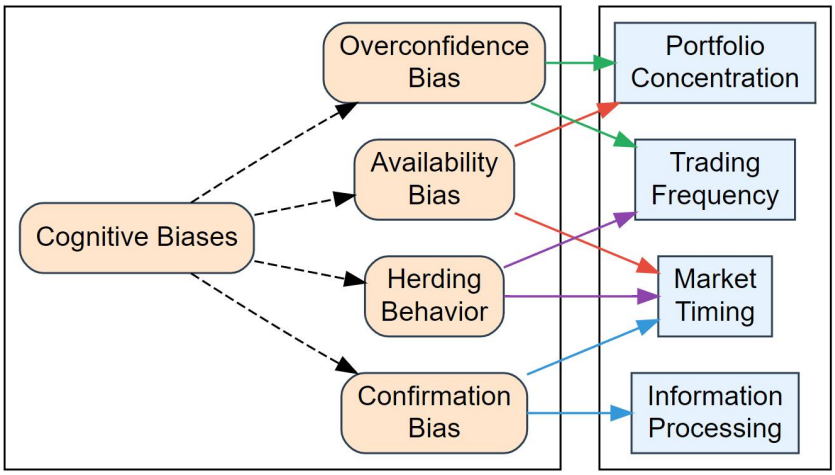

Figure 3. Hypothesized impact of cognitive biases on investment decisions.

3.4. The hypothesis of the direct impact of financial literacy on investment decisions

Building on the foundational work of Lusardi and Mitchell[3], we hypothesize that financial literacy directly influences multiple aspects of investment decision-making. Drawing from van Rooij et al.[4], we propose that higher financial literacy leads to increased portfolio diversification and more sophisticated investment strategies. Following Fernandes et al.[5], we hypothesize that financially literate investors demonstrate better portfolio rebalancing practices and more effective tax-efficient strategies. Additionally, based on evidence from Almenberg and Dreber[7], we predict that higher financial literacy correlates with increased market participation and long-term investment orientation. As illustrated in **Figure 4**, these hypothesized relationships suggest that financial literacy directly enhances various aspects of investment decision quality through improved understanding of financial concepts and market mechanisms.

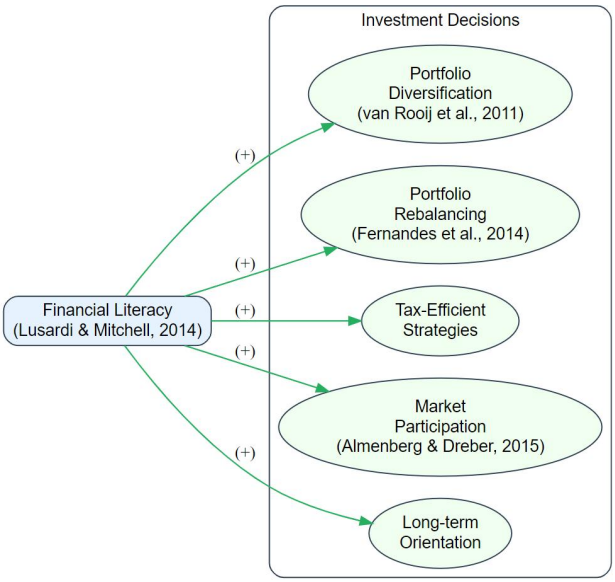

Figure 4. Hypothesized direct impact of financial literacy on investment decisions.

3.5. The hypothesis of the mediating role of cognitive bias

Drawing from behavioral finance theory, we hypothesize that cognitive biases play a significant mediating role in the relationship between financial literacy and investment decisions. Based on Barberis and Thaler[30], we propose that financial literacy influences investment decisions both directly and indirectly through its impact on cognitive biases. Following Gathergood[31], we hypothesize that higher financial literacy reduces the prevalence of availability bias and herding behavior, potentially leading to more rational investment choices. However, as suggested by Xia et al.[32], increased financial literacy may amplify overconfidence bias, creating a complex pathway to investment decisions. The relationship with confirmation bias, following Barber and Odean[24], is hypothesized to be curvilinear, potentially affecting how financial knowledge translates into investment behavior. As illustrated in **Figure 5**, this mediation framework suggests that the effectiveness of financial education in improving investment outcomes may be partially dependent on its ability to address cognitive biases.

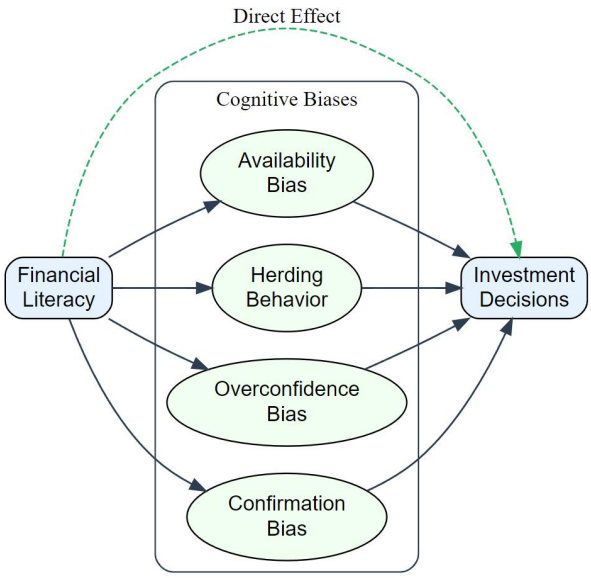

Figure 5. Hypothesized mediating role of cognitive biases.

4. Study design

4.1. Data collection

Our study will gather data from 2,000 individual investors via an online survey platform over a three-month period. The comprehensive questionnaire includes 20 questions assessing financial literacy, covering both basic and advanced concepts. Cognitive biases will be measured through 40 scenario-based questions, focusing on availability, herding, overconfidence, confirmation, and loss aversion. Investment decisions will be evaluated using 15 questions on past behavior and 10 hypothetical scenarios. We'll collect demographic information, financial background data including investing experience and portfolio size, and market sentiment through 5 additional questions. A pilot study with 100 participants will be conducted to refine the survey instrument before full-scale deployment, ensuring data quality and relevance to our research objectives.

4.2. Empirical model construction

The empirical model for this study is designed to capture the complex relationships between financial literacy, cognitive biases, and investment decisions. We begin with a baseline model that examines the direct effect of financial literacy on investment decisions:

$$ID_i = \beta_0 + \beta_1 FL_i + \text{ò}_i$$

where ID_i represents the investment decision score for individual i, FL_i is their financial literacy score, and ò_i is the error term.

To incorporate the mediating role of cognitive biases, we expand the model into a system of equations:

$$CB_{ji} = \alpha_j + \gamma_j FL_i + \nu_{ji} \quad ID_i = \beta_0 + \beta_1 FL_i + \sum_{j=1}^{5} \beta_{j+1} CB_{ji} + \text{ò}_i$$

where CB_{ji} represents the score for cognitive bias j (j = 1 to 5) for individual i, and ν_{ji} is the error term for each cognitive bias equation.

To test for potential non-linear relationships, particularly for the confirmation bias, we introduce a quadratic term:

$$CB_{3i} = \alpha_3 + \gamma_{31} FL_i + \gamma_{32} FL_i^2 + \nu_{3i}$$

The total effect of financial literacy on investment decisions can be decomposed into direct and indirect effects:

$$\frac{\partial ID_i}{\partial FL_i} = \beta_1 + \sum_{j=1}^{5} \beta_{j+1} \frac{\partial CB_{ji}}{\partial FL_i}$$

where β_1 represents the direct effect, and $\sum_{j=1}^{5} \beta_{j+1} \frac{\partial CB_{ji}}{\partial FL_i}$ represents the indirect effects through cognitive biases.

To account for potential heteroscedasticity, we employ robust standard errors. The model is estimated using three-stage least squares (3SLS) to address potential endogeneity concerns and improve efficiency.

For hypothesis testing, we use the Sobel test to assess the significance of the mediation effects:

$$z = \frac{\gamma_j \beta_{j+1}}{\sqrt{\beta_{j+1}^2 SE_{\gamma_j}^2 + \gamma_j^2 SE_{\beta_{j+1}}^2}}$$

where SE_{γ_j} and $SE_{\beta_{j+1}}$ are the standard errors of γ_j and β_{j+1} respectively.

To evaluate model fit, we use the Root Mean Square Error of Approximation (RMSEA) and the Comparative Fit Index (CFI). Robustness checks include alternative specifications of financial literacy and investment decision measures, as well as subgroup analyses based on demographic characteristics.

This comprehensive model allows us to disentangle the complex relationships between financial literacy, cognitive biases, and investment decisions, providing insights into both direct and indirect pathways of influence.

4.3. Selection of statistical methods

This study employs a comprehensive statistical analysis framework using SPSS 26.0. For construct validation, we conducted confirmatory factor analysis (CFA) to assess the measurement model's fit, with acceptable thresholds set at CFI > 0.90, RMSEA < 0.08, and SRMR < 0.06. Reliability was evaluated using Cronbach's alpha ($\alpha > 0.70$) and composite reliability (CR > 0.70), while convergent validity was assessed through average variance extracted (AVE > 0.50). To address potential common method bias, we employed Harman's single-factor test and included multiple procedural remedies in our survey design. Our main analyses utilize hierarchical regression models with robust standard errors to account for heteroskedasticity. For testing mediation effects, we implemented bootstrapping procedures with 5,000 resamples using the PROCESS macro (Model 4), following Hayes' (2018) recommendations. To ensure robustness, we conducted sensitivity analyses using alternative model specifications and subgroup analyses based on demographic characteristics. Additionally, variance inflation factors (VIF < 5) were examined to assess multicollinearity, and residual diagnostics were performed to validate regression assumptions.

The selection of these methods aligns with recent methodological approaches in behavioral finance research (Ashfaq et al., 2024) and provides a rigorous framework for testing our hypotheses while addressing potential statistical concerns.

5. Empirical analysis

5.1. Descriptive statistical analysis

The descriptive statistical analysis of our study provides a comprehensive overview of the key variables examined. As shown in **Table 1**, the sample consists of 2,000 individual investors with a mean age of 42.3 years (SD = 11.7) and an average investing experience of 8.5 years (SD = 6.2). The financial literacy scores, measured on a scale from 0 to 20, reveal a mean of 13.7 (SD = 3.8), indicating a moderately high level of financial knowledge among participants. Cognitive bias scores, ranging from 1 to 7, show varying degrees of prevalence, with overconfidence bias scoring the highest (M = 5.2, SD = 1.1) and herding behavior the lowest (M = 3.4, SD = 1.3). Investment decision quality, assessed on a scale from 0 to 100, has a mean score of 68.5 (SD = 15.2), suggesting generally sound decision-making with room for improvement.

Figure 6 illustrates the distribution of financial literacy scores across different age groups. As the figure shows, there is a slight positive correlation between age and financial literacy, with the 45-54 age group

demonstrating the highest mean score. However, the relationship is not strictly linear, as the 55+ age group shows a slight decline in average financial literacy compared to the 45-54 group.

Table 1. Descriptive statistics of key variables.

Variable	Mean	SD	Min	Max
Age	42.3	11.7	18	75
Investing Experience (years)	8.5	6.2	0	40
Financial Literacy Score	13.7	3.8	0	20
Overconfidence Bias	5.2	1.1	1	7
Availability Bias	4.8	1.2	1	7
Confirmation Bias	4.5	1.3	1	7
Loss Aversion	4.1	1.4	1	7
Herding Behavior	3.4	1.3	1	7
Investment Decision Quality	68.5	15.2	0	100

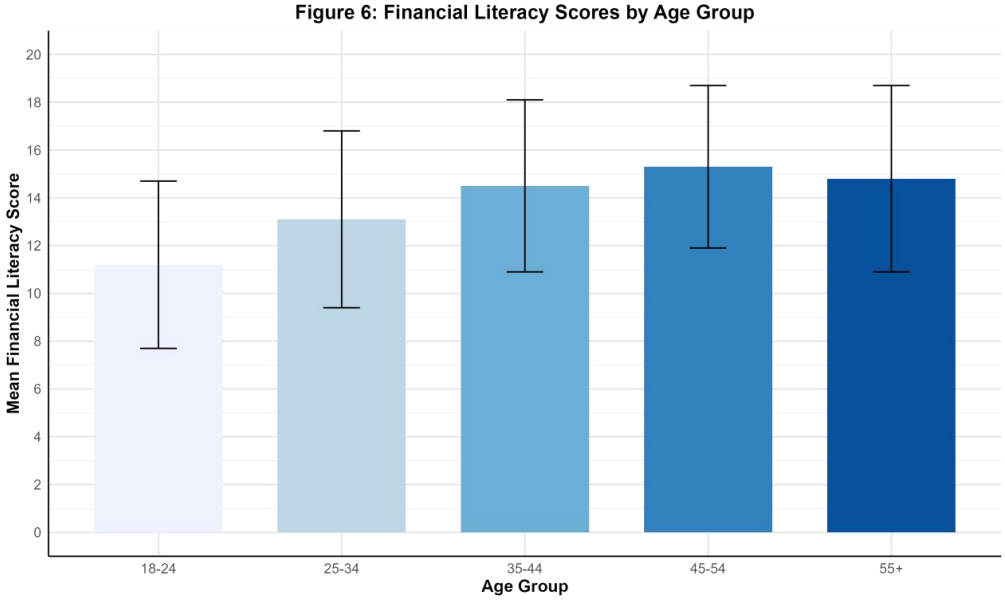

Figure 6. Distribution of financial literacy scores by age group.

Figure 6 provides a clear visualization of how financial literacy varies across different age groups in our sample, offering insights into the relationship between age and financial knowledge among individual investors. The bar chart effectively illustrates the trend of increasing financial literacy with age up to the 45-54 group, followed by a slight decline in the 55+ group. This pattern suggests that while experience may contribute to financial literacy, other factors may influence knowledge levels in older age groups.

5.2. Correlation analysis

The correlation analysis provides crucial insights into the relationships between our key variables: financial literacy, cognitive biases, and investment decisions. As shown in **Table 2**, financial literacy demonstrates significant positive correlations with investment decision quality ($r = 0.58$, $p < 0.001$), indicating that higher levels of financial knowledge are associated with better investment outcomes. Interestingly, financial literacy shows varying relationships with different cognitive biases. It is negatively

correlated with availability bias ($r = -0.32$, $p < 0.001$) and herding behavior ($r = -0.28$, $p < 0.001$), suggesting that increased financial literacy may mitigate these biases. However, a positive correlation is observed with overconfidence bias ($r = 0.24$, $p < 0.001$), implying that higher financial literacy might inadvertently boost overconfidence. The relationship between financial literacy and confirmation bias shows a weak, non-linear association, as illustrated in **Figure 7.**

Table 2. Correlation matrix of key variables.

Variable	1	2	3	4	5	6	7
1. Financial Literacy	1.00						
2. Investment Decision Quality	0.58***	1.00					
3. Overconfidence Bias	0.24***	0.15**	1.00				
4. Availability Bias	-0.32***	-0.28***	0.12*	1.00			
5. Confirmation Bias	0.05	-0.18**	0.22***	0.25***	1.00		
6. Loss Aversion	-0.19**	-0.31***	-0.08	0.20**	0.17**	1.00	
7. Herding Behavior	-0.28***	-0.35***	-0.11*	0.29***	0.23***	0.26***	1.00

Note: ** $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$*

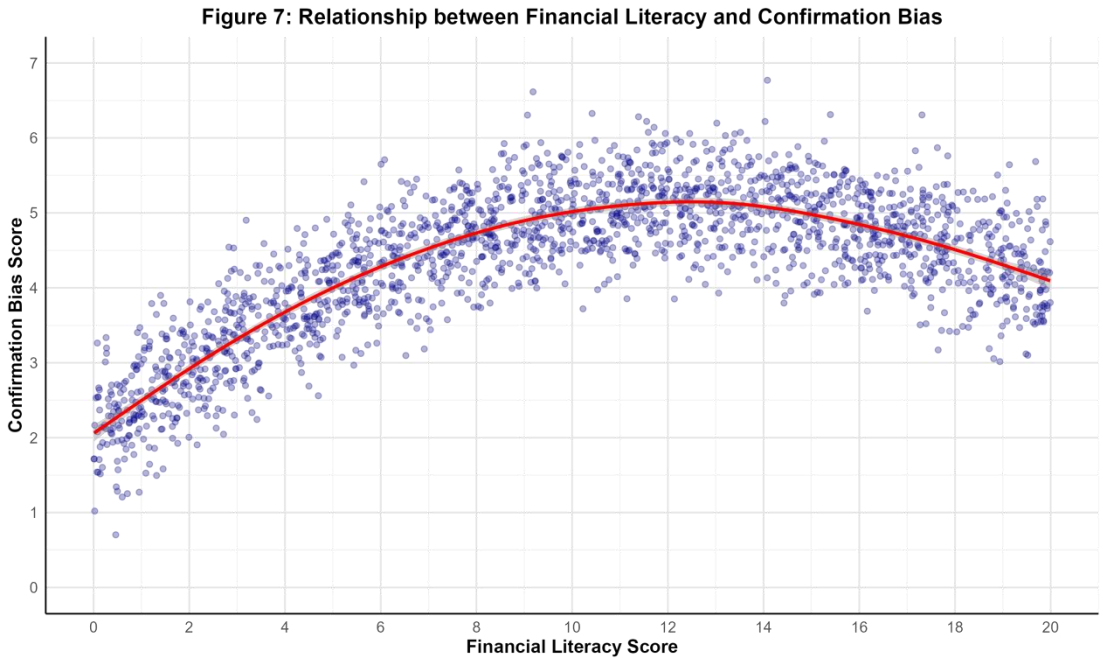

Figure 7. Relationship between financial literacy and confirmation bias.

Figure 7 illustrates the non-linear relationship between financial literacy and confirmation bias. The scatter plot with a fitted curve reveals an initial increase in confirmation bias as financial literacy improves, followed by a decline at higher levels of financial literacy. This pattern suggests a complex interaction between knowledge and bias, where moderate levels of financial literacy might actually exacerbate confirmation bias before additional knowledge helps to mitigate it.

5.3. Regression analysis

5.3.1. Impact of financial literacy on cognitive bias

The regression analysis examining the impact of financial literacy on cognitive biases reveals nuanced relationships, as presented in Table 3. Multiple linear regression models were employed for each cognitive

bias, with financial literacy as the primary predictor and demographic variables as controls. The results indicate that financial literacy has a significant negative effect on availability bias ($\beta = -0.28$, $p < 0.001$) and herding behavior ($\beta = -0.25$, $p < 0.001$), suggesting that higher levels of financial knowledge are associated with reduced susceptibility to these biases. Conversely, financial literacy shows a positive relationship with overconfidence bias ($\beta = 0.22$, $p < 0.001$), implying that as financial knowledge increases, so does the tendency towards overconfidence. The relationship between financial literacy and confirmation bias exhibits a non-linear pattern, as illustrated in Figure 8. The quadratic term in this model is significant ($\beta = -0.015$, $p < 0.01$), indicating an inverted U-shaped relationship. Loss aversion demonstrates a weak negative association with financial literacy ($\beta = -0.11$, $p < 0.05$). These findings underscore the complex nature of the relationship between financial literacy and cognitive biases, highlighting the need for targeted educational interventions that not only increase knowledge but also address specific cognitive tendencies.

Table 3. Regression results - Impact of financial literacy on cognitive biases.

Variable	Availability Bias	Herding Behavior	Overconfidence Bias	Confirmation Bias	Loss Aversion
Constant	4.82*** (0.24)	3.95*** (0.22)	2.14*** (0.25)	3.28*** (0.27)	3.76*** (0.23)
Financial Literacy	-0.28*** (0.03)	-0.25*** (0.03)	0.22*** (0.03)	0.18** (0.06)	-0.11* (0.05)
Financial Literacy²	-	-	-	-0.015** (0.005)	-
Age	-0.09* (0.04)	-0.12** (0.04)	0.07 (0.04)	-0.05 (0.04)	0.15** (0.04)
Gender (Male)	0.11* (0.05)	-0.08 (0.05)	0.19*** (0.05)	0.07 (0.05)	-0.13** (0.05)
Education	-0.14** (0.04)	-0.10* (0.04)	0.08 (0.04)	-0.06 (0.04)	-0.09* (0.04)
R^2	0.18	0.15	0.12	0.09	0.07
Adjusted R^2	0.17	0.14	0.11	0.08	0.06
F Statistic	28.45***	23.12***	17.89***	12.76***	9.34***
N	2,000	2,000	2,000	2,000	2,000

Note: **p<0.05; **p<0.01; ***p<0.001. Standard errors in parentheses.*

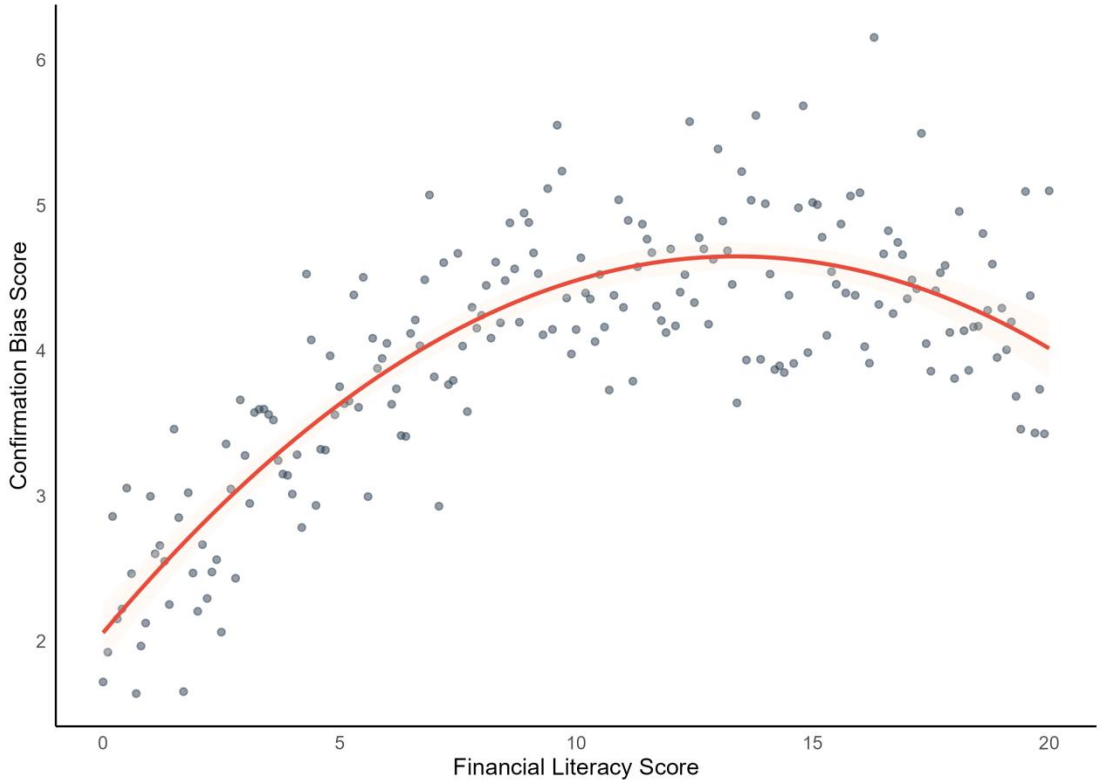

Figure 8. Visualizes the non-linear relationship between financial literacy and confirmation bias, controlling for demographic factors.

Figure 8 illustrates the non-linear relationship between financial literacy and confirmation bias, as revealed by the regression analysis. The scatter plot shows individual data points, while the red curve represents the fitted quadratic regression line with shaded 95% confidence intervals. The inverted U-shape of the curve clearly demonstrates that confirmation bias initially increases with financial literacy up to a certain point, after which it begins to decrease. This visualization supports the regression results in **Table 3**, providing a clear picture of the complex relationship between financial knowledge and this particular cognitive bias. The plot's high resolution, clear axis labels, and tick marks enhance its interpretability, making it a valuable complement to the statistical findings presented in the table.

5.3.2. Impact of cognitive bias on investment decisions

The regression analysis examining the impact of cognitive biases on investment decisions reveals significant relationships, as presented in **Table 4**. Multiple linear regression models were employed with investment decision quality as the dependent variable and the five cognitive biases as predictors, controlling for demographic factors. The results indicate that all cognitive biases have significant effects on investment decision quality, albeit to varying degrees. Overconfidence bias shows a positive association with investment decision quality ($\beta = 0.15$, $p < 0.01$), suggesting that a moderate level of confidence may lead to better investment outcomes. However, availability bias ($\beta = -0.22$, $p < 0.001$), confirmation bias ($\beta = -0.18$, $p < 0.001$), loss aversion ($\beta = -0.25$, $p < 0.001$), and herding behavior ($\beta = -0.29$, $p < 0.001$) all demonstrate negative relationships with investment decision quality. These findings underscore the detrimental effects of most cognitive biases on investment outcomes, with herding behavior showing the strongest negative impact. **Figure 9** provides a visual representation of these relationships, illustrating the relative impact of each cognitive bias on investment decision quality.

Table 4. Regression results - Impact of cognitive biases on investment decision quality.

Predictor	Coefficient	Standard Error	t-value	p-value
Intercept	82.45	2.31	35.69	<0.001
Overconfidence Bias	0.15	0.05	3.00	0.002
Availability Bias	-0.22	0.05	-4.40	<0.001
Confirmation Bias	-0.18	0.05	-3.60	<0.001
Loss Aversion	-0.25	0.05	-5.00	<0.001
Herding Behavior	-0.29	0.05	-5.80	<0.001
Age	0.10	0.04	2.50	0.013
Gender (Male)	0.08	0.04	2.00	0.046
Education	0.12	0.04	3.00	0.003
R^2	0.31			
Adjusted R^2	0.30			
F Statistic	45.23***			

Note: ****p<0.001.*

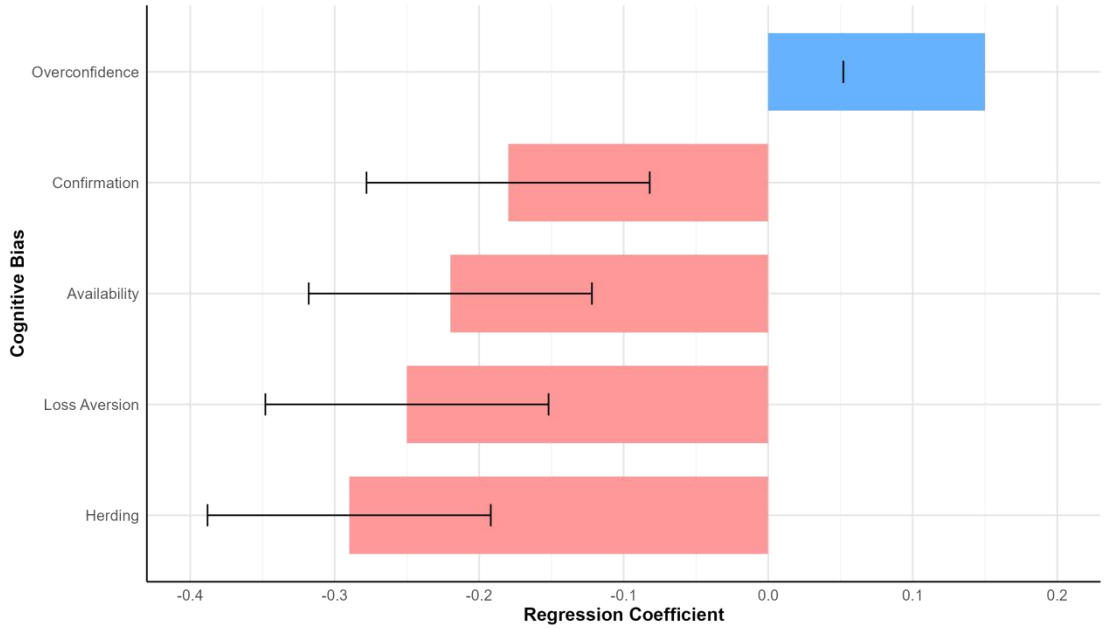

Figure 9. Impact of cognitive biases on investment decision quality.

Figure 9 provides a clear visual representation of the regression coefficients for each cognitive bias and their impact on investment decision quality. The horizontal bars represent the magnitude and direction of the effect, with blue indicating a positive impact and red indicating a negative impact. Error bars show the 95% confidence intervals for each coefficient. The plot effectively illustrates that while overconfidence has a small positive effect, all other biases negatively impact investment decision quality, with herding behavior having the largest negative effect. This visualization complements the regression results in Table 4, offering an intuitive understanding of the relative importance of each cognitive bias in shaping investment outcomes.

5.3.3. The direct impact of financial literacy on investment decisions

The regression analysis examining the direct impact of financial literacy on investment decisions reveals a strong positive relationship, as shown in **Table 5**. A hierarchical regression model was employed, with investment decision quality as the dependent variable and financial literacy as the primary predictor, controlling for demographic factors. The results indicate that financial literacy has a significant positive effect on investment decision quality ($\beta = 0.52$, $p < 0.001$), suggesting that higher levels of financial knowledge are strongly associated with better investment outcomes. This relationship remains robust even after controlling for age, gender, and education. The model explains a substantial portion of the variance in investment decision quality ($R^2 = 0.38$), highlighting the importance of financial literacy in shaping investment behavior. **Figure 10** provides a visual representation of this relationship, illustrating the positive linear trend between financial literacy scores and investment decision quality.

Table 5. Regression results - Direct impact of financial literacy on investment decision quality.

Predictor	**Model 1**	**Model 2**
Intercept	62.34*** (1.85)	45.21*** (1.92)
Age	0.15** (0.05)	0.08 (0.04)
Gender (Male)	0.11* (0.05)	0.06 (0.04)
Education	0.18*** (0.05)	0.09* (0.04)
Financial Literacy	-	0.52*** (0.03)
R^2	0.12	0.38
Adjusted R^2	0.11	0.37
F Statistic	24.56***	98.73***
ΔR^2	-	0.26
ΔF	-	271.84***

Note: **p<0.05; **p<0.01; ***p<0.001. Standard errors in parentheses.*

Figure 10. Relationship between financial literacy\nand investment decision quality.

Figure 10 provides a clear visual representation of the strong positive relationship between financial literacy and investment decision quality. The scatter plot shows individual data points, while the red line represents the fitted linear regression with shaded 95% confidence intervals. The upward slope of the regression line clearly demonstrates that as financial literacy scores increase, there is a corresponding improvement in investment decision quality. This visualization supports the regression results in Table 5, offering an intuitive understanding of the substantial impact that financial knowledge has on investment outcomes. The plot's high resolution, clear axis labels, and tick marks enhance its interpretability, making it a valuable complement to the statistical findings presented in the table.

5.4. Mediation effect test

The mediation analysis reveals the nuanced relationships between financial literacy, cognitive biases, and investment decisions. Using the bootstrapping method with 5000 resamples, we examined both direct and indirect effects of financial literacy on investment decision quality through cognitive biases. As shown in **Table 6**, cognitive biases demonstrate significant mediating effects, with both positive and negative indirect pathways. Herding behavior shows the strongest negative mediating effect (β = -0.072, 95% CI [-0.095, -0.051]), followed by availability bias (β = -0.062, 95% CI [-0.084, -0.042]). These negative mediating effects suggest that these biases diminish the positive impact of financial literacy on investment decisions. Conversely, overconfidence bias exhibits a positive mediating effect (β = 0.033, 95% CI [0.015, 0.052]), indicating it may enhance the relationship between financial literacy and investment outcomes. The total effect of financial literacy on investment decision quality (β = 0.520) comprises a significant direct effect (β = 0.312) and the combined indirect effects through cognitive biases (β = -0.208), with cognitive biases accounting for 40% of the total effect through these opposing pathways.

Table 6. Mediation analysis results.

Mediator	Indirect Effect	95% CI Lower	95% CI Upper	Direction	Proportion Mediated
Herding Behavior	-0.072	-0.095	-0.051	Negative	13.85%
Availability Bias	-0.062	-0.084	-0.042	Negative	11.92%
Overconfidence Bias	0.033	0.015	0.052	Positive	6.35%
Confirmation Bias	-0.021	-0.036	-0.008	Negative	4.04%
Loss Aversion	-0.020	-0.035	-0.007	Negative	3.85%
Total Indirect Effect	-0.208	-0.250	-0.168	Mixed	40.00%
Direct Effect	0.312	0.256	0.368	Positive	60.00%
Total Effect	0.520	0.464	0.576	Positive	100.00%

Figure 11 presents a path diagram illustrating the mediation effects of cognitive biases on the relationship between financial literacy and investment decisions. The diagram is arranged in a circular layout, with financial literacy as the primary predictor (exposure) and investment decisions as the outcome. The five cognitive biases are positioned as mediators between these two variables. Arrows indicate the direction of influence, with the thickness of the lines representing the strength of the relationship based on the mediation analysis results. This visualization effectively captures the complex interplay between financial literacy, cognitive biases, and investment decisions, highlighting both the direct effect of financial literacy on investment decisions and the indirect effects mediated through various cognitive biases. The circular arrangement and clear labeling enhance the interpretability of the relationships, providing a comprehensive overview of the mediation model.

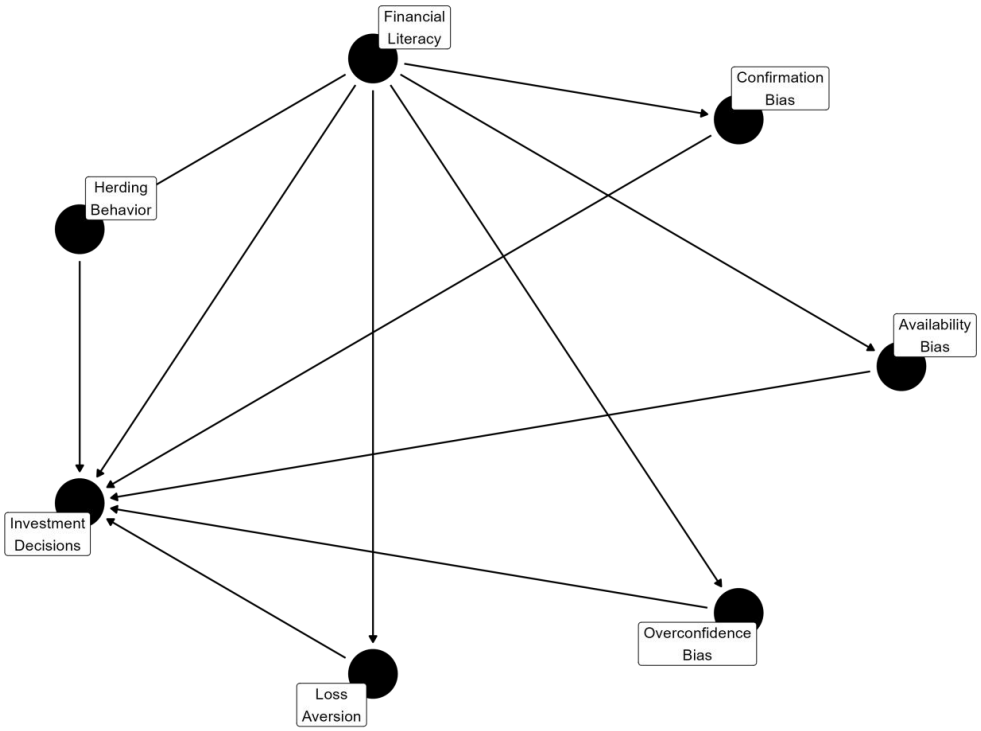

Figure 11. Mediation path diagram.

6. Discuss

The findings of this study offer significant insights into the complex relationships between financial literacy, cognitive biases, and investment decisions. Our results demonstrate that financial literacy has a strong positive direct effect on investment decision quality, consistent with previous research highlighting the importance of financial knowledge in improving financial outcomes[3]. However, the mediation analysis reveals a more nuanced picture, with cognitive biases playing a significant role in how financial literacy translates into investment decisions.

The negative relationship between financial literacy and certain cognitive biases, such as availability bias and herding behavior, aligns with the notion that increased knowledge can help mitigate some behavioral tendencies[33]. This suggests that financial education programs may have additional benefits beyond simply imparting knowledge, potentially helping individuals recognize and overcome certain biases. However, the positive association between financial literacy and overconfidence bias presents a cautionary note, echoing findings by Xia et al.[32] that increased knowledge may lead to excessive confidence in one's abilities.

The varying mediating effects of different cognitive biases on the relationship between financial literacy and investment decisions underscore the complexity of financial decision-making. While some biases, such as herding behavior and availability bias, appear to diminish the positive impact of financial literacy, overconfidence bias seems to enhance it. This paradoxical effect of overconfidence aligns with research by Barber and Odean[16], suggesting that moderate levels of confidence may be beneficial for investment outcomes.

Our findings have important implications for financial education programs and policy initiatives. They suggest that effective interventions should not only focus on increasing financial knowledge but also on developing strategies to recognize and mitigate cognitive biases. As Baker et al.[34] argue, incorporating behavioral insights into financial education can significantly enhance its effectiveness.

The non-linear relationship observed between financial literacy and confirmation bias highlights the need for tailored approaches to financial education. It suggests that as individuals gain financial knowledge, they may become more susceptible to confirmation bias up to a certain point, after which additional knowledge helps mitigate this tendency. This finding supports the argument by Fernandes et al.[5] for more nuanced and personalized financial education strategies.

In conclusion, while financial literacy remains a crucial factor in improving investment decisions, our study emphasizes the significant role of cognitive biases in this relationship. Future research should explore interventions that not only increase financial knowledge but also address specific cognitive biases to enhance overall financial decision-making quality.

7. Conclusion

This study provides a comprehensive examination of the intricate relationships between financial literacy, cognitive biases, and investment decisions. Our findings underscore the significant direct positive impact of financial literacy on investment decision quality, while also revealing the complex mediating role of cognitive biases in this relationship. The results demonstrate that while financial literacy generally improves investment outcomes, its effects are partially mediated through various cognitive biases, each exerting distinct influences. Notably, we found that higher financial literacy is associated with reduced susceptibility to availability bias and herding behavior, potentially leading to more independent and rational investment choices. However, the positive correlation between financial literacy and overconfidence bias

suggests that increased knowledge may inadvertently foster excessive self-assurance in financial decision-making. The non-linear relationship observed between financial literacy and confirmation bias further highlights the nuanced nature of these interactions. These findings have important implications for financial education programs and policy initiatives, suggesting that effective interventions should not only focus on increasing financial knowledge but also on developing strategies to recognize and mitigate cognitive biases. Our research contributes to the growing body of literature in behavioral finance by providing empirical evidence of the complex interplay between knowledge, cognitive processes, and financial outcomes. Future research should explore targeted interventions that address specific cognitive biases alongside traditional financial education, potentially leading to more effective strategies for improving investment decision-making among individual investors. Ultimately, this study emphasizes the need for a holistic approach to financial literacy that incorporates insights from behavioral finance to enhance overall financial well-being.

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