Journal of Islamic Marketing

"Mapping the brain in finance: the neurological basis of Muslim investor behavior"

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Received 12 December 2023
Revised 4 August 2024
10 November 2024
15 December 2024
3 May 2025
6 May 2025
Accepted 7 May 2025

Abstract

Purpose – This study aims to delve into the pivotal role of neurotransmitters in the financial decision-making of a Muslim investor and their interaction with information sources, shedding light on the cognitive dimensions driving Muslim investment behaviors. In addition, this study explores the moderating role of emotional intelligence (EI) in this context.

Design/methodology/approach – This study collected data from 719 retail and institutional investors in financial and stock markets through a close-ended questionnaire. Data analysis was conducted using partial least squares structural equation modeling.

Findings – This research uncovers a significant association between neurotransmitters, information sources and investment decisions. Interestingly, this study found that EI does not significantly moderate the relationship between neurotransmitters and Muslim investment choices.

Originality/value – This research validates the pivotal role of neurotransmitters in financial decision-making, highlighting the cognitive biases that drive Muslim investment behaviors. It contributes to understanding cognitive mechanisms in the context of neuroscientific financial exploration, offering new perspectives in this field.

Keywords Information source, Neurofinance, Investment decisions, Emotional intelligence, Neurotransmitters

Paper type Research paper

1. Introduction

Decision-making is a multifaceted process influenced by various factors, including the number of available choices, allocated decision time, perceptual uncertainties, personal experiences and subjective valuations of outcomes (Toma, 2023). Financial decision-making, in particular, often involves high levels of complexity due to the interplay of cognitive, emotional and environmental factors. While effective in certain contexts, traditional economic models

To this study, the first author acknowledges the support and guidance of all her previous supervisors during her PhD journey, specifically Dr Syed Nouman Ahmed Shah. Without their contribution and guidance, she would not be able to produce this research.

Data availability statement: Data is available upon request.

Journal of Islamic Marketing

1759-0833
DOI 10.1108/JIMA-12-2023-0394

frequently fail to account for these nuanced behaviors, especially under conditions of uncertainty and risk.

To address these limitations, scholars have turned to neuroeconomics − a field that synthesizes insights from economics, neuroscience and psychology to better understand the biological and cognitive substrates of decision-making (Nixon, 2023a). Neuroeconomics offers an enriched lens that complements behavioral finance by examining the neural circuitry involved in financial choices. It moves beyond mere description of biases to uncover how brain functions such as valuation, anticipation and emotional arousal shape economic behavior (Nixon, 2023b).

As an extension of economic theory, behavioral finance provides a complementary perspective by examining how cognitive biases, emotions and heuristics shape investment decisions. However, behavioral finance often stops short of explaining the underlying neurological processes, a gap addressed by neurofinance. Neurofinance, a subfield of neuroeconomics, investigates the neural underpinnings of financial choices. Research has identified specific brain regions, such as the prefrontal cortex, amygdala and ventral striatum, as critical to processing risks and rewards in financial contexts (Sahi, 2012; Tseng, 2006). These neurological mechanisms offer vital insights into the decision-making processes of individual investors.

The role of dopamine pathways and reward systems in decision-making has been particularly well-documented. Dopamine neurons are linked to brain regions such as the mesencephalon, ventral pallidum and anterior cingulate gyrus, all of which are involved in assessing gains and losses (Bermejo *et al.*, 2011). This complex interaction between cognitive and emotional processes has profound implications for investment behavior. Recent studies also highlight the role of neurotransmitters in shaping risk-taking behaviors and decision-making patterns (Srivastava *et al.*, 2020).

Cognitive biases, such as overconfidence, loss aversion and anchoring, add further complexity to investment decisions. These biases represent systematic deviations from rational judgment, often leading to suboptimal financial outcomes (DeMartino *et al.*, 2013; Kandasamya *et al.*, 2014). The influence of cognitive biases on individual and institutional investors alike has been widely studied, with findings suggesting that these biases can distort the perception of risks and rewards. By integrating cognitive, emotional and neurological insights, this study aims to extend the understanding of how biases interact with neural processes in shaping financial behavior.

Despite these advancements, limited research has been conducted on the decision-making processes of Muslim investors, a group with distinct behavioral patterns influenced by ethical and religious considerations. For Muslim investors, compliance with *Shariah* principles often intersects with conventional financial strategies, adding a unique dimension to their decision-making processes. While prior research has identified the importance of ethical considerations in financial behavior, the role of neurotransmitters in these contexts remains underexplored (Srivastava *et al.*, 2020).

This study seeks to fill that gap by investigating the influence of key neurotransmitters on the financial decision-making processes of Muslim investors. By integrating perspectives from Pavlovian conditioning, information theory and emotional intelligence, the proposed framework captures both the behavioral and neurological layers of ethical investment behavior. In doing so, this research contributes to a growing body of literature that seeks to contextualize neurofinance insights within diverse cultural and ethical paradigms − ultimately enabling more inclusive, psychologically informed financial models for investors and institutions operating under Islamic principles.

2. Literature review

2.1 Theoretical exposition

This study integrates three established theories to elucidate the mediating model linking neurotransmitters with investment decisions: Pavlov's theory of classical conditioning (Pavlov, 1927), information theory (Shannon, 1948) and emotional intelligence theory (Goleman, 1995). These frameworks collectively provide insights into the psychological and neural mechanisms influencing financial decision-making.

Pavlov's classical conditioning illustrates how stimuli evoke conditioned responses, drawing parallels with herd behavior in financial markets. For example, individuals often imitate others' actions when faced with uncertain outcomes rather than relying on rational analysis (Kahneman, 1973; Tversky and Kahneman, 1979). However, this concept oversimplifies the complex decision-making dynamics observed in modern financial contexts.

Recent studies expand on this by connecting associative learning with neural mechanisms. Reward circuits in the brain, including the ventral striatum and the prefrontal cortex, are activated when observing others' successes, reinforcing imitative behavior (Kraemer and Weber, 2020). This neural activity supports herd behavior by linking social observations to perceived rewards, particularly in volatile financial markets. Associative learning mechanisms also contribute to decision-making under uncertainty, where individuals prioritize observed gains or losses over calculated risks. By incorporating these neural insights, this study refines classical conditioning to better reflect contemporary financial behaviors.

Information theory provides a framework for understanding how external stimuli, such as market fluctuations, are processed into actionable investment decisions. The brain is often described as a central processing unit, but this metaphor oversimplifies its intricate neural pathways. Rather than a single processing unit, the brain uses distributed networks involving the prefrontal cortex, amygdala and anterior cingulate cortex to balance rational and emotional responses in uncertain environments (Kobayashi and Kable, 2024).

Neuroeconomic research highlights the importance of efficient information processing in mitigating biases. For example, while information overload can impair decision-making by overstimulating emotional circuits (Kraemer and Weber, 2020), efficient neural pathways enable investors to evaluate risks and rewards more objectively. These findings emphasize the dynamic interplay between emotional and rational processing, particularly in high-stakes investment scenarios (Serra, 2021). This study builds on these advancements to explore how neural information processing interacts with neurotransmitter activity to shape investment outcomes.

Emotional intelligence theory emphasizes the importance of recognizing and managing emotions in decision-making. Losses evoke stronger emotional responses than equivalent gains, often leading to irrational behaviors such as selling winning investments prematurely or holding onto losing ones (Barber and Odean, 1999; Shefrin and Statman, 1985). Investors with higher emotional intelligence are better equipped to regulate these emotional responses, enabling more rational decision-making even during market volatility (Lerner *et al.*, 2015).

Recent research highlights the role of emotional regulation in mitigating cognitive biases like overconfidence and loss aversion (Mohanty *et al.*, 2024; Agrawal *et al.*, 2024). This regulation is particularly evident in institutional investors, who exhibit greater emotional intelligence and strategic decision-making capabilities compared to retail investors (Bykova *et al.*, 2024). The divergence stems from institutional investors' access to resources and their ability to maintain emotional control, reducing susceptibility to market fluctuations. Conversely, retail investors often face limited resources and emotional regulation capacities, amplifying the impact of biases on their decisions.

The integration of these theories highlights the critical role of neurotransmitters, such as dopamine and serotonin, in mediating emotional and cognitive responses to financial risks. Dopamine, for instance, is associated with reward anticipation, while serotonin influences mood regulation, directly affecting investment behaviors (Sacré *et al.*, 2016). The interaction between neurotransmitter activity and neural pathways provides a nuanced understanding of how investors process information, regulate emotions and make decisions.

In alignment with the proposed model (Figure 1), each theoretical lens anchors a specific component of the decision-making framework. Pavlov's theory of classical conditioning underpins the variable of information sources, highlighting how investors develop associative responses to repeated market cues or observed behaviors. Information theory supports the role of neurotransmitters as internal processors of external financial stimuli, emphasizing how the brain encodes, evaluates and responds to investment information through neural pathways. Finally, emotional intelligence theory provides the foundation for the moderating role of emotional intelligence, explaining how self-awareness and emotional regulation shape the path from neural activation to final investment decisions. This integrative mapping strengthens the theoretical coherence of

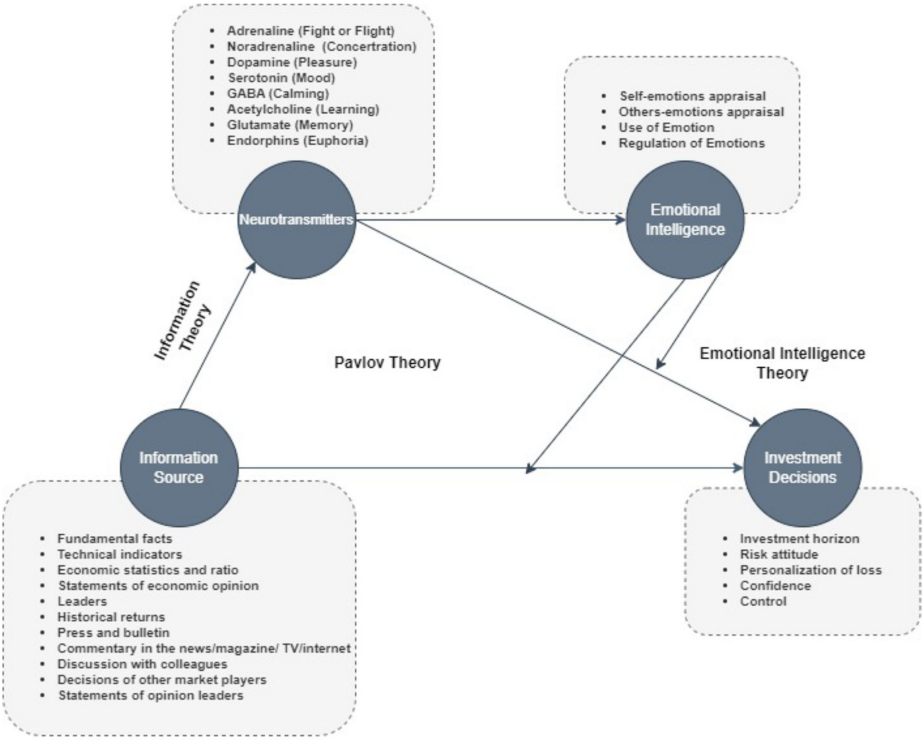

Figure 1. Theoretical framework

Note: This figure illustrates the relationships among information sources, neurotransmitters, emotional intelligence and investment decisions, grounded in Pavlov's theory, emotional intelligence theory and information theory. It highlights how information sources influence neurotransmitters, which mediate emotional intelligence and shape investment decisions through cognitive and emotional processes

Source: Authors' own work

the model and clarifies how distinct psychological and neural mechanisms interact to influence financial behavior in ethically bounded contexts.

2.2 Empirical literature

2.2.1 Areas of brain involved in investment decision-making. The decision-making process in finance is influenced by a complex interplay of benefits, risks and losses (Pirtošek *et al.*, 2009). This process hinges on neural evaluations conducted in regions like the limbic system and prefrontal cortex, where neurotransmitters such as dopamine facilitate reward-motivated decisions. For example, dopamine pathways in the ventral striatum help evaluate risks and rewards, crucial in competitive financial contexts (Pirtošek *et al.*, 2009; Genevsky and Yoon, 2022).

Recent studies indicate that neurobiological mechanisms, such as the hierarchical interaction between the limbic system and prefrontal cortex, significantly impact on decision-making. These mechanisms determine how risks are perceived and evaluated under uncertainty (Assadi *et al.*, 2009). Zhang *et al.* (2019) further explored the influence of these processes in the context of herding behavior, highlighting the role of neural competitiveness among investors.

Particularly for Muslim investors, ethical considerations in decision-making are inherently tied to *Shariah*-compliant principles. These principles could shape how neurotransmitters interact with cognitive processes, such as risk assessment, reward evaluation and information interpretation. Thus, based on this literature, this study hypothesizes:

H1. Neurotransmitters significantly influence the interpretation and transmission of simulated investment-related information in decision-making processes.

H2. Neurotransmitters have a significant positive relationship with the investment decisions of Muslim investors, particularly in contexts involving ethical and *Shariah*-compliant considerations.

H3. Neurotransmitters mediate the relationship between the type of information sources (e.g. fundamental vs nonfundamental) and investment decisions of Muslim investors, influencing risk perception and reward evaluation.

2.2.2 Emotional intelligence and investment decision. Emotional intelligence (EI), the ability to recognize and manage emotions, plays a crucial role in investment decisions (Kunnanatt, 2014). Investors with high EI are better equipped to regulate emotions, enabling rational choices even under volatile market conditions (Odean, 2000; Thaler, 2000). For instance, EI helps mitigate biases like loss aversion, ensuring investors avoid impulsive actions such as prematurely selling assets during market downturns.

Neurobiological mechanisms further underpin EI's influence on decision-making. Neurotransmitters like serotonin and dopamine modulate emotional responses, enhancing or impairing decision-making depending on their balance (Kosonogov *et al.*, 2019). For Muslim investors, who may face unique emotional triggers related to ethical and religious considerations, EI could play a dual role: managing biases and aligning decisions with *Shariah* principles. Based on this body of research, this study proposes the following hypothesis:

H4. Emotional intelligence significantly influences the investment decisions of Muslim investors by enhancing their ability to manage emotional responses to financial risks and rewards.

H5. Emotional intelligence moderates the relationship between information sources and investment decisions of Muslim investors, strengthening or weakening the influence based on the investor's emotional regulation capabilities.

H6. Neurotransmitters have a significant relationship with the emotional intelligence of Muslim investors, impacting their ability to process and regulate emotions during investment decision-making.

H7. The relationship between neurotransmitters and the investment decisions of Muslim investors is moderated by emotional intelligence, mitigating the effects of neural mechanisms on decision outcomes.

2.2.3 Information source and investment decision. Investors rely on both fundamental and nonfundamental information to evaluate opportunities, manage risk and achieve portfolio diversification (Menkhoff, 1998; Torsten Arnswald, 2001). The quality and source of this information significantly impact decisions, particularly in volatile markets (Abreu and Mendes, 2010). For Muslim investors, *Shariah*-compliant information sources are crucial in shaping their decision-making, ensuring alignment with ethical and religious values. Word-of-mouth communication and relational trust are increasingly significant for Muslim investors in collective decision-making contexts (Ivković and Weisbenner, 2007). Therefore, the selection of information sources and the extent of their impact on investment decisions are intricately linked, making it crucial for investors to thoroughly evaluate and analyze available information sources to make well-informed investment decisions. Thus, this study hypothesizes:

H8. The type and quality of information sources significantly influence the investment decisions of Muslim investors, with a preference for ethical and *Shariah*-compliant information leading to more informed and value-aligned decisions.

3. Methodology

3.1 Analytical method

To determine the measurement and structure of the empirical model, this study uses structural equation modeling (SEM) with the partial least squares (PLS) approach. PLS-SEM is a widely recognized and robust method for analyzing complex relationships, particularly in management science (Hair *et al.*, 2017). It was chosen for its ability to handle models with multiple latent constructs, assess both direct and indirect effects, and accommodate nonnormally distributed data. The model in this study involves several latent constructs − neurotransmitters, emotional intelligence, information sources and investment decisions − necessitating a method capable of evaluating such interrelationships. Regarding model specification, all constructs were operationalized using reflective measurement models, including higher-order constructs. For example, emotional intelligence was modeled as a second-order reflective–reflective construct in line with best practices in partial least squares structural equation modeling (PLS-SEM). The decision was based on theoretical support and empirical consistency among indicators, as recommended by Hair *et al.* (2019).

The analysis was conducted in three stages:

(1) data preparation;

(2) measurement model assessment; and

(3) structural model assessment.

Missing values (<2% of the data set) were replaced using mean imputation. The measurement model was evaluated for internal consistency reliability (Cronbach's alpha and composite reliability ≥ 0.7), convergent validity (average variance extracted [AVE] ≥ 0.5) and discriminant validity using the Fornell−Larcker criterion. The structural model was assessed for path coefficients, *T*-statistics and *p*-values using bootstrapping with 5,000 resamples. Predictive accuracy was evaluated using R^2 values, with values above 0.70 indicating substantial explanatory power. The analysis was conducted using Smart-PLS 3.0 software.

3.2 Measures

Table 1 outlines the key variables measured in this study, including neurotransmitters, investment decisions, emotional intelligence and information sources. Neurotransmitters, with eight subdimensions comprising 58 items, were assessed based on their behavioral effects such as pleasure, concentration, calming, fight or flight, mood regulation, learning, memory and euphoria. The items for neurotransmitters were developed using prior literature

Table 1. Measurement of key variables

Constructs	Subdimensions	Items	Source
Neurotransmitters	Adrenaline or epinephrine Noradrenaline or norepinephrine Dopamine Serotonin GABA (gamma-aminobutyric acid) Acetylcholine Glutamate Endorphins	58	(Khan and Mubarik, 2020)
Investment decision	Investment horizon Risk attitude Personalization of loss Confidence Control	21	(Wood and Zaichkowsky, 2004)
Emotional intelligence	Self-emotions appraisal Regulation of emotions Use of emotion Others-emotions appraisal	16	(Law *et al.*, 2004)
Information source	Fundamental facts Technical indicators Economic statistics and ratio Statements of economic opinion Leaders Historical returns Press and bulletin Commentary in the news/magazine/ TV/internet Discussion with colleagues Decisions of other market players Statements of opinion leaders	10	(Warther, 1995; Lutje and Menkhoff, 2007; Menkhoff and Schmidt, 2005, (Abreu and Mendes, 2010, 2012)

Note(s): This table presents the constructs, their subdimensions, the number of items used and the sources for each construct in the study. The constructs include neurotransmitters, investment decision, emotional intelligence and information source, each with specific subdimensions that capture various aspects of investor behavior and decision-making processes
Source(s): Authors' own work

(Sahi, 2012; Tseng, 2006; Bermejo *et al.*, 2011; Walter *et al.*, 2005) and validated in earlier research (Khan and Mubarik, 2020).

The investment decision construct consisted of five subdimensions with 21 items, adapted from (Wood and Zaichkowsky, 2004). Emotional intelligence was measured using four subdimensions with 16 items, based on Law *et al.* (2004). The information source variable, comprising 10 items, was adapted from prior studies (Warther, 1995; Lutje and Menkhoff, 2007; Menkhoff and Schmidt, 2005; Abreu and Mendes, 2010, 2012).

All items were scored on a five-point Likert scale ranging from “strongly disagree” (1) to “strongly agree” (5). The first section of the questionnaire collected demographic details such as years of investing in the stock market and investment size, while the second section included measurement items for the study variables.

3.3 Data collection

The data for this study were collected from Muslim retail and institutional investors actively trading on the Pakistan Stock Exchange (PSX). A purposive sampling technique was used to identify respondents who fulfilled the first dimension of religiosity − beliefs − based on criteria established by Shah *et al.* (2020). In addition, a snowball sampling technique was used to reach a broader pool of participants, as initial respondents were encouraged to refer other eligible investors within their networks.

According to CDC statistics, as of September 2023, 340,772 account holders were actively trading in 1,059 securities, valued at PKR 5.26tn. Among these account holders, 73,601 are retail investors, while the remaining are institutional investors, forming the study’s target population. The target sample size of 1,000 respondents is consistent with Comrey and Lee’s (1992) guidelines, who classified a sample of 1,000 as “excellent” for multivariate statistical techniques such as SEM. Out of the 1,000 investors approached, 791 completed the survey, resulting in a robust response rate of 71.9%. The final sample consisted of retail and institutional investors capturing diverse perspectives on investment decision-making. Data collection spanned approximately six months, ensuring sufficient time to gather responses from diverse investor groups. The questionnaire was distributed online via Google Forms to ensure accessibility and broad geographic coverage. Measures were taken to maintain respondent anonymity and reduce potential biases, including voluntary participation and clear instructions about confidentiality.

Table 2 provides the profile of the respondents. The data shows that 91% of the respondents are male, while 9% are female. In addition, the profile reveals that 69.68% of the respondents are retail investors, while 30.32% are institutional investors. Portfolio values managed by respondents are as follows: 43.25% manage a portfolio value of less than 1 million, 13.07% manage a portfolio between 1 and 3 million, 10.01% manage between 3 and 6 million, 14.05% manage between 6 and 9 million and 19.61% manage more than 9 million. Furthermore, 39.08% of respondents have more than 20 years of trading experience, while 17.94% have 16–20 years of experience. In this study, each respondent is requested to respond to an identical list of questions, randomly ordered to minimize biases.

4. Findings

This study used a two-step technique: the measurement model and the structural model. The measurement model was assessed based on confirmatory factor analysis (Hair *et al.*, 2012), while the relationships between the latent constructs were evaluated through the structural model. This dual approach enhances both the reliability of the findings and their relevance to complex constructs in financial decision-making. If the evaluation of the measurement model demonstrates reliability and validity, the structural model can then be examined.

Table 2. Respondent profile

Gender	*n* (719) (%)
Male	91
Female	9
Nature of investor	
Retail investor	69.68
Institutional investor	30.32
Value of portfolio	
Less than 1,000,000 (1million)	43.25
1,000,000 (1 million) to 3,000,000 (3 million)	13.07
3,000,000 (3 million) to 6,000,000 (6 million)	10.01
6,000,000 (3 million) to 9,000,000 (9 million)	14.05
More than 9,000,000 (9 million)	19.61
No. of experience of trading	
Less than 1 year	5.56
2 – five years	10.29
6–10 years	16.55
11–15 years	10.57
16–20 years	17.94
More than 20 years	39.08

Note(s): This table provides a demographic breakdown of the study's respondents, including gender distribution, type of investor (retail vs institutional), portfolio value categories and years of trading experience. It gives an overview of the characteristics of the sample used in the study
Source(s): Authors' own work

4.1 Measurement model

The reliabilities for each construct's composite of measures (i.e. internal consistency reliability) and the convergent and discriminant validities of measures are both examined in the measurement model assessment. Internal consistency was assessed through composite reliability and Cronbach's alpha; as shown in Table 2, all constructs exhibit Cronbach's alpha and composite reliability values of 0.7 or above, indicating the reliability (Chin, 2010; Hair *et al.*, 2019).

Factor loadings were obtained to assess convergent validity at the item level. Some items were dropped gradually because the factor loadings were below the threshold. Based on this, one item of acetylcholine, dopamine, endorphins, emotional appraisal, self-emotions appraisal and information source; two items of investment horizon and noradrenaline; three items of control; and four items of glutamate were dropped from the analysis. The remaining items were retained with loading values were ≥ 0.7 (Hair *et al.*, 2013). To assess the convergent validity at the construct level, the AVE was calculated, and all the constructs met the minimum accepted threshold of AVE $\geq$ 0.5 (Hair *et al.*, 2013). Finally, discriminant validity was assessed using the Fornell−Larcker criterion (Fornell and Larcker, 1981). The results are exhibited in Table 3, which shows that the squared root of each AVE is higher than interconstruct correlations.

The measurement model assessment evaluates internal consistency reliability, convergent validity and discriminant validity. Internal consistency was assessed through composite reliability and Cronbach's alpha; as shown in Table 2, all constructs exhibit Cronbach's alpha and composite reliability values of 0.7 or above, confirming reliability (Chin, 2010; Hair *et al.*, 2019).

Table 3. Reliability

Variables	Cronbach's alpha	Composite reliability	AVE	Factor loadings (min−max)
Information source	0.919	0.933	0.607	0.74–0.81
Neurotransmitters				
Acetylcholine	0.863	0.902	0.648	0.71–0.85
Adrenaline	0.926	0.938	0.602	0.72–0.81
Dopamine	0.814	0.870	0.573	0.72–0.78
Endorphins	0.756	0.844	0.576	0.70–0.80
GABA	0.867	0.904	0.652	0.79–0.82
Glutamate	0.904	0.923	0.600	0.70–0.80
Noradrenaline	0.868	0.886	0.519	0.71–0.73
Serotonin	0.833	0.881	0.599	0.73–0.83
Emotional intelligence				
Emotion appraisal	0.715	0.840	0.637	0.75–0.83
Regulation of emotion	0.786	0.862	0.609	0.76–0.80
Self-emotions appraisal	0.750	0.857	0.666	0.81–0.82
Use of emotions	0.806	0.873	0.626	0.76–0.83
Investment decision				
Confidence	0.892	0.916	0.608	0.75–0.80
Control	0.649	0.806	0.582	0.70–0.83
Investment horizon	0.788	0.904	0.825	0.90–0.91
Personalization of loss	0.742	0.886	0.795	0.88–0.90
Risk attitude	0.728	0.880	0.786	0.88–0.89

Note(s): This table presents the reliability and validity metrics for each construct, demonstrating adequate internal consistency (Cronbach's alpha ≥ 0.7), composite reliability (≥0.8) and average variance extracted (AVE ≥ 0.5) across all constructs
Source(s): Authors' own work

Factor loadings were obtained to assess convergent validity at the item level, with items having loadings below the threshold gradually removed. Specifically, one item each from acetylcholine, dopamine, endorphins, emotional appraisal, self-emotions appraisal and information source; two items from investment horizon and noradrenaline; three items from control; and four items from glutamate were dropped. Remaining items retained loadings ≥ 0.7 (Hair *et al.*, 2013). At the construct level, the AVE met the accepted threshold (AVE ≥ 0.5) (Hair *et al.*, 2013), while discriminant validity was confirmed using the Fornell−Larcker criterion (Fornell and Larcker, 1981). Table 3 illustrates that the squared root of AVE exceeds interconstruct correlations. While the measurement model confirms reliability and validity, potential cultural or contextual biases inherent in the data should be acknowledged. Such biases may influence respondents' interpretations of certain constructs, particularly in a financial context.

4.2 Coefficient of determination (R^2)

The PLS structural model evaluates the combined effect of exogenous and endogenous variables. The R^2 coefficient measures how much variance in endogenous constructs is explained by exogenous constructs. According to Chin (1998), significant path estimates that effectively explain variance are crucial. Hair *et al.* (2013) suggested that R^2 values range between 0 and 1, with higher values indicating predictive accuracy.

Using the Smart-PLS algorithm, this study found an R^2 value of 0.748 (Table 4). This implies that information sources, neurotransmitters and emotional intelligence collectively explain 74.8% of the variance in investment decisions. While this value is adequate for explaining variance, unaccounted factors such as broader economic conditions or unmeasured psychological constructs might also influence investment decisions.

4.3 Structural model

The structural model analysis measured the direct and indirect relationships among the latent constructs through their path coefficients, *t*-statistics and significance values. Table 5 presents the structural model assessment that the five primary paths are significant. The path relationship between information source and neurotransmitters is significant ($\beta = 0.112$, $p = 0.002$), indicating a positive relationship. This finding supports *H1*, suggesting that neurotransmitters effectively transmit simulated financial information.

This study also examined each neurotransmitter's role in transmitting information. Results indicate a significant relationship between information sources and each neurotransmitter, including dopamine ($\beta = 0.081$, $p = 0.002$), serotonin ($\beta = 0.083$, $p = 0.002$), acetylcholine ($\beta = 0.081$, $p = 0.002$), noradrenaline ($\beta = 0.075$, $p = 0.002$), adrenaline ($\beta = 0.075$, $p = 0.002$), gamma-aminobutyric acid (GABA; $\beta = 0.082$, $p = 0.002$), glutamate ($\beta = 0.063$, $p = 0.001$) and endorphins ($\beta = 0.055$, $p = 0.001$), supporting subhypotheses 1a to 1h.

Furthermore, neurotransmitters significantly impact investment decisions ($\beta = 0.082$, $p = 0.000$), supporting *H2*. The assessed individual impact of each neurotransmitter on investment decisions is: for dopamine ($\beta = 0.064$, $p = 0.001$), serotonin ($\beta = 0.080$, $p = 0.000$), acetylcholine ($\beta = 0.060$, $p = 0.004$), noradrenaline ($\beta = 0.057$, $p = 0.005$), adrenaline ($\beta = 0.071$, $p = 0.030$), GABA ($\beta = 0.058$, $p = 0.008$) and glutamate ($\beta = 0.083$, $p = 0.029$). Thus, the results indicate that all the neurotransmitters are significantly involved in the investment decision. However, endorphins ($\beta = -0.004$, $p = 0.863$) had an insignificant effect on investment decisions.

Emotional intelligence also significantly impacts investment decisions ($\beta = 0.143$, $p = 0.000$), supporting *H4*, as strong emotional intelligence can lead to more effective decisions. Neurotransmitters significantly affect emotional intelligence ($\beta = 0.098$, $p = 0.029$), supporting *H6*. Analysis of each neurotransmitter's effect on emotional intelligence indicates significant roles for dopamine ($\beta = 0.174$, $p = 0.001$), serotonin ($\beta = 0.184$, $p = 0.000$), acetylcholine ($\beta = 0.102$, $p = 0.040$), noradrenaline ($\beta = 0.114$, $p = 0.008$), glutamate ($\beta = 0.291$, $p = 0.000$) and endorphins ($\beta = 0.145$, $p = 0.000$). In contrast, adrenaline ($\beta = 0.006$, $p = 0.947$) and GABA ($\beta = -0.049$, $p = 0.249$) have insignificant effects on emotional intelligence. On the other hand, information sources positively affect investment decisions ($\beta = 0.762$, $p = 0.000$), supporting *H8*, as more authentic information leads to more effective decisions.

Table 4. Coefficient of determination

	Original sample (O)	Sample mean (M)	SD	*t*-statistics (|O/STDEV|)	*p*-values
Investment decision	0.748	0.759	0.028	26.459	0.000

Note(s): This table shows the R^2 values for the dependent variable, investment decision, with a value of 0.748. This indicates that 74.8% of the variance in investment decisions can be explained by the model, confirming its predictive adequacy
Source(s): Authors' own work

Table 5. Structural model

Hypothesis	Path coefficient	Coefficient	*t*-statistics	*p*-values	Decision
H1	Information source → neurotransmitters	0.112	3.288	0.002	Supported
	Information source → dopamine	0.081	3.250	0.002	Supported
	Information source → serotonin	0.083	3.243	0.002	Supported
	Information source → acetylcholine	0.081	3.248	0.002	Supported
	Information source → noradrenaline	0.075	3.324	0.002	Supported
	Information source → adrenaline	0.075	3.324	0.002	Supported
	Information source → GABA	0.082	3.318	0.002	Supported
	Information source → glutamate	0.063	3.484	0.001	Supported
	Information source → endorphins	0.055	3.553	0.001	Supported
H2	Neurotransmitters → investment decision	0.082	4.398	0.000	Supported
	Dopamine → investment decision	0.064	3.541	0.001	Supported
	Serotonin → investment decision	0.080	4.382	0.000	Supported
	Acetylcholine → investment decision	0.060	2.992	0.004	Supported
	Noradrenaline → investment decision	0.057	2.966	0.005	Supported
	Adrenaline → investment decision	0.071	2.230	0.030	Supported
	GABA → investment decision	0.058	2.772	0.008	Supported
	Glutamate → investment decision	0.083	2.250	0.029	Supported
	Endorphins → investment decision	−0.004	0.173	0.863	Not supported
H4	Emotional intelligence → investment decision	0.143	4.561	0.000	Supported
H6	Neurotransmitters → emotional intelligence	0.098	2.253	0.029	Supported
	Dopamine → emotional intelligence	0.174	3.662	0.001	Supported
	Serotonin → emotional intelligence	0.184	5.235	0.000	Supported
	Acetylcholine → emotional intelligence	0.102	2.112	0.040	Supported
	Noradrenaline → emotional intelligence	0.114	2.777	0.008	Supported
	Adrenaline → emotional intelligence	0.006	0.066	0.947	Not supported
	GABA → emotional intelligence	−0.049	1.165	0.249	Not supported
	Glutamate → emotional intelligence	0.291	2.776	0.000	Supported
	Endorphins → emotional intelligence	0.145	5.275	0.000	Supported
H8	Information source → investment decision	0.762	27.354	0.000	Supported

Note(s): This table presents the structural model results, including path coefficients, *t*-statistics, *p*-values and decisions for each hypothesis. Supported hypotheses show significant relationships between constructs, indicating that the model's paths are consistent with the study's theoretical framework
Source(s): Authors' own work

4.4 Mediating and moderating analysis

This study examines neurotransmitters as mediators between information sources and investment decisions of Muslim investors. Following Hair *et al.* (2017), a bootstrapping approach was used for mediation analysis. Table 6 presents, the mediation results, where *H3* tells the mediating role of neurotransmitters between information sources and investment decisions. The findings (β = 0.009, *p*-value = 0.010), confirm significant mediation. Each neurotransmitter's mediating effect was also assessed, showing significant mediation for dopamine (β = 0.031, p = 0.030), serotonin (β = 0.013, p = 0.002), acetylcholine (β = 0.006, p = 0.048), noradrenaline (β = 0.008, p = 0.041), adrenaline (β = 0.008, p = 0.043) and glutamate (β = 0.011, p = 0.029). GABA and endorphins, however, had insignificant effects, with *p*-values of 0.466 and 0.869, respectively.

The research model has proposed one mediating path and two moderating paths. The first moderating path predicted a moderating effect of emotional intelligence on the relationship between neurotransmitters and investment decisions. On the other hand, the second path predicted a moderating effect on emotional intelligence on information sources and

Table 6. Mediating analysis

Hypothesis	Path coefficient	Coefficient	*t*-statistics	*p*-values	Decision
H3	Information source → neurotransmitters → investment decision	0.009	2.666	0.010	Supported
	Information source → dopamine → investment decision	0.031	2.239	0.030	Supported
	Information source → serotonin → investment decision	0.013	3.269	0.002	Supported
	Information source → acetylcholine → investment decision	0.006	1.978	0.048	Supported
	Information source → noradrenaline → investment decision	0.008	2.097	0.041	Supported
	Information source → adrenaline → investment decision	0.008	2.079	0.043	Supported
	Information source → GABA → investment decision	−0.003	0.734	0.466	Not supported
	Information source → glutamate → investment decision	0.011	2.342	0.023	Supported
	Information source → endorphins → investment decision	0.000	0.166	0.869	Not supported

Note(s): This table displays the mediating effects of neurotransmitters on the relationship between information sources and investment decisions, with path coefficients, *t*-statistics, *p*-values and decisions for each specific neurotransmitter. Supported mediations indicate a significant indirect effect
Source(s): Authors' own work

investment decisions. As shown in Table 7, both paths exhibited insignificant effects, with $\beta = -0.023$, $p = 0.409$ for the first path and $\beta = 0.006$, $p = 0.800$ for the second path, leading to the rejection of *H5* and *H7*.

4.5 Multigroup analysis

This study conducted multigroup analysis to determine if path coefficient differences were statistically significant across groups. Following Hair *et al.* (2018), the null hypothesis assumes no significant difference in path coefficients across groups, while the alternative hypothesis assumes a significant difference. As reported in Table 8, four paths (information source and neurotransmitters, emotional intelligence and investment decisions, information sources and investment decisions and information source * emotional intelligence and

Table 7. Moderating analysis

Hypothesis	Path	Coefficient	*t*-statistics	*p*-values	Decision
H7	Neurotransmitter * emotional intelligence → investment decision	−0.023	0.833	0.409	Rejected
H5	Information sources * emotional intelligence → investment decision	0.006	0.255	0.800	Rejected

Note(s): This table presents the moderating analysis for emotional intelligence's role between neurotransmitters, information sources and investment decisions. Path coefficients, *t*-statistics and *p*-values are provided, with results showing that emotional intelligence does not significantly moderate these relationships
Source(s): Authors' own work

Table 8. PLS-MGA

Hypothesis	Path coefficient	PLS-MGA Path coefficients − diff (Retail − institutional)	Bootstrapping p-value new (Retail vs institutional)	Path coefficients Institutional	p-values Retail	Institutional	Retail
H1	Information source → neurotransmitters	−0.134	0.132				
H2	Neurotransmitters → investment decision	−0.131	0.005	0.182	0.051	0.000	0.032
H4	Emotional intelligence → investment decision	0.111	0.155				
H6	Neurotransmitters → emotional intelligence	0.056	0.475	0.060	0.116	0.253	0.047
H8	Information source → investment decision	−0.048	0.520				
H3	Information source → neurotransmitters → investment decision	−0.034	0.039	0.038	0.004	0.032	0.445
H7	Neurotransmitter * emotional intelligence → investment decision	0.158	0.010	−0.167	−0.009	0.002	0.785
H5	Information sources * emotional intelligence → investment decision	−0.202	0.078				

Note(s): This table presents the results of the multigroup analysis, comparing institutional and retail investors. It includes bootstrapping results and significance levels for path differences across hypotheses
Source(s): Authors' own work

investment decisions) had insignificant *p*-values ($p > 0.05$), indicating an insignificant difference between groups.

Conversely, the other four paths (neurotransmitters and investment decisions, neurotransmitters and emotional intelligence, information sources and investment decisions and neurotransmitters * emotional intelligence and investment decisions) exhibited significant *p*-values ($p < 0.05$), indicating a significant difference across investor types (institutional vs retail). The bootstrapping results for *H2* and *H3* show that institutional investors ($\beta = 0.182$, $\beta = 0.038$) have stronger path coefficients than retail investors ($\beta = 0.051$, $\beta = 0.004$). Conversely, for *H6* and *H7*, retail investors ($\beta = 0.116$, $\beta = -0.009$) demonstrate stronger path coefficients than institutional investors ($\beta = 0.060$, $\beta = -0.167$).

5. Discussion

This study aimed to examine the role of neurotransmitters in the investment decisions of Muslim investors in Pakistan by assessing how they transmit simulated information about the financial market. The data analysis was conducted using PLS-SEM, and the results supported the reliability and validity of the measurement model, as shown in Tables 3 and 9. From the structural model evaluation, the R^2 coefficient of 0.748 was found to be adequate.

Hypothesis testing results reveal that *H1* was supported, showing a significant positive relationship between information sources and all neurotransmitters (dopamine, serotonin, acetylcholine, noradrenaline, adrenaline, GABA, glutamate and endorphins). This finding aligns with Srivastava *et al.* (2020), who stated that the reward system's information-carrying neurons predominantly communicate via neurotransmitters. *H2* findings also show that all neurotransmitters, except endorphins, have a significant relationship with investment decisions. The study further identified the significant mediating role of all neurotransmitters, except GABA and endorphins, in the relationship between information sources and investment decisions. This indicates that mood regulation becomes challenging when an investor experiences extreme emotions, such as depression or excitement, due to financial loss or gain, which impacts decision-making by limiting emotional control.

Each neurotransmitter was found to have a specific function that affects decision-making. For instance, adrenaline is involved in the "fight or flight" response, enabling quick decisions in high-stress situations (Tank and Wong, 2015). Noradrenaline influences mood and concentration, affecting heart rate and blood pressure in response to stress. Dopamine, a pleasure or reward neurotransmitter, is released during enjoyable activities (Arias-Carrián *et al.*, 2010). Serotonin, a mood regulator, plays a key role in alleviating depression and anxiety (Albert *et al.*, 2014). GABA has a calming effect, inhibiting neuron overactivity; its deficiency can lead to anxiety and restlessness. Acetylcholine is critical for learning, and its deficiency affects cognitive function, while glutamate supports memory but can cause cellular damage at high levels (Wang and Reddy, 2016). Endorphins, known as natural pain relievers, constrain pain signals, and their deficiency may cause headache disorders.

These findings indicate that each neurotransmitter is responsible for specific functions that contribute to decision-making. An optimal balance of neurotransmitters is essential for investors' mental health. Imbalances triggered by financial risks, rewards and uncertainty can lead to issues like overexcitement, stress, depression, anxiety, irritability, mood swings, panic attacks and headaches, potentially impacting investment decisions.

This study underscores the significant role neurotransmitters play in Muslim investors' decision-making by transmitting or simulating financial information. These findings address a gap identified by Srivastava *et al.* (2020), who emphasized the need for research on neurotransmitters' role in investment decision-making, particularly among Muslim investors. Furthermore, the study confirms that neurotransmitters are significantly associated

Table 9. Fornell−Larcker criterion

Latent constructs	AD	ACE	CONF	CONT	DA	EA	END	GABA	GLU	IH	IS	NOR	PL	RA	ROE	SEA	SE	UOE
Acetylcholine	0.805*																	
Adrenaline	0.180	0.776*																
Confidence	0.123	0.052	0.780*															
Control	−0.138	−0.060	−0.057	0.763*														
Dopamine	0.606	0.224	0.208	−0.100	0.757*													
Emotion appraisal	0.090	−0.057	0.429	−0.026	0.140	0.798*												
Endorphins	0.509	−0.024	0.091	−0.120	0.405	0.096	0.759*											
GABA	0.451	0.658	0.000	−0.070	0.309	−0.008	0.158	0.808*										
Glutamate	0.248	0.526	0.044	−0.100	0.096	0.044	0.282	0.576	0.774*									
Information source	0.077	0.026	0.827	−0.042	0.167	0.421	0.102	−0.040	0.038	0.779*								
Investment horizon	0.155	0.118	0.694	−0.051	0.208	0.267	0.108	0.065	0.085	0.701	0.908*							
Noradrenaline	0.471	0.342	0.152	−0.139	0.608	0.057	0.360	0.193	0.007	0.105	0.216	0.721*						
Personalization of loss	0.050	0.064	0.753	−0.001	0.127	0.345	0.014	−0.004	0.078	0.680	0.584	0.025	0.891*					
Regulation of emotions	0.086	0.005	0.552	−0.048	0.167	0.528	0.116	−0.027	0.079	0.496	0.400	0.129	0.414	0.780*				
Risk attitude	0.102	0.081	0.729	−0.017	0.198	0.310	0.089	0.033	0.076	0.723	0.657	0.118	0.720	0.448	0.887*			
Self-emotion appraisal	0.056	0.032	0.518	−0.069	0.133	0.596	0.081	−0.034	0.096	0.520	0.338	0.057	0.396	0.608	0.396	0.816*		
Serotonin	0.583	0.211	0.217	−0.025	0.737	0.159	0.426	0.412	0.184	0.160	0.217	0.541	0.132	0.145	0.197	0.137	0.774*	
Use of emotion	0.042	−0.071	0.527	−0.045	0.082	0.603	0.083	−0.084	0.057	0.462	0.274	0.007	0.432	0.647	0.369	0.657	0.114	0.795*

Note(s): This table displays the Fornell−Larcker criterion, which is used to assess discriminant validity among the constructs in the study. Each construct's average variance extracted (AVE) is compared with its correlations to other constructs, confirming that constructs are distinct from one another
Source(s): Authors' own work

with emotional intelligence, except for adrenaline and GABA, thus supporting *H6*. Previous studies (Wang *et al.*, 2020) affirm that the neurotransmitter system influences emotional intelligence.

The findings also reveal that information sources significantly impact investment decisions, supporting *H8*. However, the study found that emotional intelligence did not significantly moderate the relationships between neurotransmitters and investment decisions or between information sources and investment decisions, leading to the rejection of *H5* and *H7*. This result contrasts with earlier literature, suggesting that factors like stress, depression, anxiety and personality disorders can diminish emotional intelligence, complicating emotional management (Downey *et al.*, 2008; Lizeretti *et al.*, 2014; Obeid *et al.*, 2021; Tannous and Matar, 2010).

In conclusion, this study emphasizes the crucial role neurotransmitters play in shaping the mental states of Muslim investors and, consequently, their decision-making processes. Neurotransmitter imbalances, often triggered by financial risks, rewards and the ambiguity of trading or financial information, can result in various negative emotional states and mood disorders, which ultimately impact an investor's decision-making capabilities. The study also highlights the significant mediating effect of neurotransmitters in the relationship between information sources and investment decisions. This implies that how financial information is presented and perceived can influence neurotransmitter levels, thereby impacting investment choices. Xiao *et al.* (2020) highlighted that the type of product or decision context moderates such effects, adding to the understanding of decision-making in complex markets.

The research further explores the differences between institutional and retail Muslim investors, revealing unique dynamics in their decision-making processes. Findings indicate that institutional investors' emotional intelligence significantly moderates the relationship between neurotransmitters and investment decisions. Institutional investors tend to exhibit greater emotional control and a focus on long-term investment strategies, which enhance their emotional intelligence. In contrast, retail investors, who often invest their funds directly, are more susceptible to market volatility and emotional influences on their decisions. The higher emotional intelligence of institutional investors grants them a competitive edge, enabling sound investment decisions even during market fluctuations. This competitive advantage is strengthened by their professional expertise, deep financial market knowledge and long-term investment perspective (Valaskova *et al.*, 2021; Kristóf and Virág, 2022).

5.1 Conclusion, implications and limitations

This study examined the influence of eight neurotransmitters on Muslim investors' decision-making by transmitting simulated information related to financial markets. The findings indicate that all neurotransmitters, except endorphins, significantly contribute to investment decision-making by transmitting information on investment magnitudes. The study also identifies a significant mediating role for all neurotransmitters, except GABA and endorphins, in linking information sources with investment decisions. This insignificant relationship may stem from various factors, including Muslim investors' concerns about currency pressures and market instability (Mensi *et al.*, 2017; Ho *et al.*, 2014) along with ongoing spikes in commodity or fuel prices (Jawadi *et al.*, 2014).

Furthermore, the findings reveal that endorphins are not significantly involved in the investment decisions of Muslim investors and have no mediating effect on the relationship between information sources and investment decisions. This may be attributed to the role of endorphins, which are typically released during physical activity and work by interacting with brain receptors to reduce pain (Cleveland Clinic, 2021). This suggests that endorphins are not directly related to decision-making in financial contexts. Similarly, the study finds that GABA and noradrenaline do not significantly mediate the relationship between information sources and investment decisions. GABA's primary function is to calm the brain; however, low levels of GABA, often associated with stress or depression, suggest that anxious or stressed investors may not experience its calming effect (ReNurex, 2022).

The study also notes an insignificant moderating role of emotional intelligence on investment decisions when accounting for the presence of neurotransmitters. This indicates that disruptions in neurotransmitter levels due to simulated financial information may cause Muslim investors to experience heightened emotions, such as overexcitement, depression, irritability or stress, potentially leading to emotional imbalances. As a result, investors may struggle to manage emotional intelligence, thereby impacting their decision-making ability. Given the highly competitive nature of financial markets, effectively regulating neurotransmitter levels could provide Muslim investors with a competitive edge. Investors capable of managing neurotransmitter levels may be better equipped to process financial information, make rational decisions and manage emotions in volatile markets.

5.1.1 Practical implications. This study offers actionable insights for both investors and financial service providers. For Muslim investors, understanding the influence of neurotransmitters on risk perception, reward evaluation and emotional regulation can lead to more rational and consistent financial choices. By recognizing their susceptibility to neurochemical triggers such as dopamine-driven overconfidence or serotonin-linked risk aversion, investors can adopt more disciplined strategies that align with both ethical values and financial goals.

Financial institutions, particularly those serving faith-based markets, can leverage these findings to design tailored investment products and personalized advisory services that reflect the neurological and psychological tendencies of Muslim investors. Tools and platforms that integrate emotional intelligence training, bias awareness modules or decision-assistance algorithms could empower clients to manage impulsive decisions during market volatility. In addition, incorporating neuroscience-informed communication strategies may help relationship managers build stronger client trust and engagement.

The study also suggests opportunities for fintech innovation, particularly in the development of decision-support systems, robo-advisors or mobile apps that incorporate emotional or neurofeedback elements to guide investors during high-stakes decisions.

5.1.2 Managerial implications. For portfolio managers, institutional investors and financial strategists, the findings underscore the importance of neuro-cognitive diversity in shaping investor behavior. Decision-makers can benefit from understanding that market reactions are not purely rational but are shaped by neurological patterns that differ across individuals and contexts. Organizations that incorporate such insights into investor profiling, segmentation and behavioral risk assessment may enhance advisory outcomes and product-market fit.

Moreover, the findings highlight the potential of integrating artificial intelligence and neural computation models − such as artificial neural networks (ANNs) into investment decision frameworks. These tools can simulate investor behavior under varying emotional or neurochemical states, offering predictive analytics for product development, risk modeling and behavioral compliance initiatives.

5.1.3 Theoretical implications. This study contributes to the theoretical expansion of neurofinance by integrating three foundational perspectives − Pavlovian conditioning, information theory and emotional intelligence − to conceptualize how neurotransmitters mediate investment decisions within an Islamic ethical context. It advances existing behavioral finance frameworks by incorporating biological correlations of cognition and emotion, offering a more holistic model of financial decision-making.

In addition, the research demonstrates the moderating role of emotional intelligence as a bridge between neural activity and decision outcomes, suggesting new directions for model refinement in investor behavior studies. These insights can inform future interdisciplinary research combining cognitive neuroscience, finance and behavioral economics, especially within culturally specific contexts.

5.1.4 Limitations. While this study provides valuable insights, it has limitations. Common method bias is a potential limitation, as data was collected from a single source. Future research should consider multisource data collection across different time points for a more comprehensive view. In addition, future studies may replace the emotional intelligence variable with specific emotions to analyze how neurotransmitters shape emotional responses and influence investment decisions. Triangulating results from real-world settings with spatial data collection could further strengthen findings.

This study was designed to mirror real-world investment scenarios by using methods that capture actual behaviors and decisions. Collecting data from real investors ensures responses reflect authentic experiences and choices. The study's relevance is further enhanced by focusing on volatile market conditions. For example, using neuroimaging techniques to observe Muslim investors during live trading could identify which brain areas are activated and how neurotransmitters affect *Shariah*-compliant investment decisions. This approach would validate the findings in a real-world context while providing deeper insights into the neural mechanisms underlying financial behavior.

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