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Article

Relationship between (under)confidence and prospect theory in risky decisions: Challenges for financial literacy policies

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Abstract: The principal objective of this article is to gain insight into the biases that shape decision-making in contexts of risk and uncertainty, with a particular focus on the prospect theory and its relationship with individual confidence. A sample of 376 responses to a questionnaire that is a replication of the one originally devised by Kahneman and Tversky was subjected to analysis. Firstly, the aim is to compare the results obtained with the original study. Furthermore, the Cognitive Reflection Test (CRT) will be employed to ascertain whether behavioural biases are associated with cognitive abilities. Finally, in light of the significance and contemporary relevance of the concept of overconfidence, we propose a series of questions designed to assess it, with a view to comparing the various segments of respondents and gaining insight into the profile that reflects it. The sample of respondents is divided according to gender, age group, student status, professional status as a trader, status as an occasional investor, and status as a behavioural finance expert. It can be concluded that the majority of individuals display a profile of underconfidence, and that the hypotheses formulated by Kahneman and Tversky are generally corroborated. The low frequency of overconfident individuals suggests that the results are consistent with prospect theory in all segments, despite the opposite characteristics, given the choice of the less risk-averse alternative. These findings are useful for regulators to understand how biases affect financial decision making, and for the development of financial literacy policies in the education sector.

Keywords: behavioral finance; expected utility theory; prospect theory; cognitive reflection test; overconfidence; financial development policies

1. Introduction

Traditional Finance models (Markowitz, 1952; Sharpe, 1963, 1964) are based on the principle that the human being has developed cognitive and behavioral capabilities which make him an entirely rational being. Therefore, all his decisions are made in the context of a perfect market in which there is equal information for everyone, and all decisions are designed considering the maximization of individual utility. In recent decades, this conception has been influenced by the areas of psychology and sociology, originating the field of "behavioral finance". This connection enables the recognition of human beings' limited rationality and helps understanding decision-making based on emotions.

Indeed, recognizing that an individual is not a fully rational being is a valid principle, but an extremely complex one to explain. However, the compilation of

studies allows us to list a set of cognitive biases (Adler, 2020; Atanasiu, 2021; Claus and Nguyen, 2023; Enke, et al., 2023) and behavioral deviations (Dervishaj, 2021; Hirshleifer, 2001; Huber and Kirchler, 2023; Usvitskiy, 2022), among which overconfidence is identified (Butt and Shah, 2024). Given the lack of a measurement model, the evaluation of this phenomenon has been carried out using different methods, making the comparison between studies arduous. As a result, this area of research continues to attract financial research interest and requires further studies.

In order to understand individuals' decision-making, several procedures and tests have emerged, among the most notorious, prospect theory (Kahneman and Tversky, 1979) and the Cognitive Reflection Test (Frederick, 2005). The first theory calls into question all the principles of utility theory and, therefore, is considered a revolutionary, timeless and universal theory that is still used to understand an individual's decision-making. Furthermore, this theory presents a set of effects that, in light of what happens with cognitive biases and behavioral deviations, justify the subject's paradoxical behavior. The Cognitive Reflection Test makes it possible to directly recognize some deviations, given that the fact a person chooses one option over another can be explained by the set of beliefs he has assimilated.

In this context, the main objective of this article is to understand the biases that influence decision-making in environments of risk and uncertainty, in light of prospect theory, and the relationship with individuals' confidence. Thereby, the questionnaire used by Kahneman and Tversky (1979) will be replicated, adding questions that will allow the use of Frederick's (2005) Cognitive Reflection Test. Finally, overconfidence, given its importance in the everyday world, will be included in the study through specific questions in the questionnaire.

The results of the empirical study confirm the universality and timelessness of the original study by Kahneman and Tversky (1979), as the effects of prospect theory have been verified. It was also found that male respondents, aged between 35 and 64, non-students, traders and familiar with the concept of behavioral finance represented the overconfident profile. However, the majority of respondents have a subconfident profile, concluding that the results adhere to the prospect theory, in that the choices fell on the alternative with the lowest risk aversion.

The structure of the article is as follows: After this introduction, Section 2 presents a literature review, followed by Section 3 where the empirical study will be explored and its results discussed. Section 4 summarizes the conclusions of this study.

2. Traditional/rational finance vs. behavioral finance

Traditional or rational finance is based on the assumption that all agents present in the market are rational and maximize expected utility (Ritter, 2003). Furthermore, individuals are still able, after receiving additional information, to immediately update their decisions in accordance with the expected utility theory (Barros and Filipe, 2015). In this context, traditional finance focuses on the correct way in which individuals should position themselves and is therefore related to a normative analysis (Kahneman and Riepe, 1998).

Additionally, rational finance is supported by the Efficient Market Hypothesis (EMH) of Fama and Malkiel (1970). This theory is the basis for the so-called market rationality, according to which asset prices are correctly established.

Despite the large-scale acceptance of the premise of individuals' rationality, the emergence of arguments pointing to their inefficiency and inappropriate view of reality was increasingly recurrent. The study on "rational choice" by Simon (1957), in the areas of cognitive psychology constituted a vigorous incentive for the Theory of Bounded Rationality, which goes against expected utility. The author defended the non-existence of unlimited rationality, suggesting the existence of a combination of emotions and other psychological factors in the decision-making process, concluding that individuals tend to choose the most reasonable option at each moment (Fucidji and Melo, 2016).

Behavioral finance constitutes a stream of study in finance that makes the assumption of complete rationality more flexible, taking advantage of knowledge about the way individuals behave (Lobão, 2012). Based on the study of the Theory of Bounded Rationality, the object of study of behavioral finance is related to understanding the reason for the departure from decision-making based on traditional finance and the causes and consequences of individuals making decisions in a non-rational way (Lobão, 2012).

Unlike rational finance, behavioral finance has a prescriptive analysis content, in that it aims to show a line of thought capable of helping individuals understand their decision-making, recognizing their weaknesses from a cognitive and emotional point of view (Kahneman and Riepe, 1998).

According to Thaler (1999), it would be irrational not to update finance models and make them closer to reality, adapting them based on evidence of investor behavior.

2.1. Prospect theory

Kahneman and Tversky (1979) argued that all decisions must be examined autonomously, and not in a macro way as defended by expected utility theory. Prospect theory is considered a theory of cognitive psychology that illustrates how individuals make irrational decisions when they are coerced into choosing an option, in a short space of time, that presents uncertain results. Thus, this theory drives research into individual behavior when making decisions in environments of risk and uncertainty (Gispert-Pérez et al., 2022; Ruggeri et al., 2020).

Furthermore, while in utility theory individuals are expected to choose based on each of the possible alternatives and their respective probabilities, in prospect theory, instead of probabilities there is a weighting function and the final results are related to a value function established in terms of gains and losses, rather than utilities and final wealth. Thus, when making decisions, individuals prioritize changes in their wealth over the final state of gains and losses from their decisions (Pan, 2019; Vasconcelos et al., 2014), and the weights of decisions do not coincide with the probabilities declared.

In the following subsections the main aspects associated with this theory will be highlighted.

2.1.1. Weighting function and value function

The weighting function inherent to prospect theory contradicts utility theory. That function relates the weights of decisions to the declared probabilities and its slope in the stipulated interval of [0,1] represents a measure of the sensitivity of preferences to changes in probability (Kahneman and Tversky, 1979).

In this theory, the value of each choice is multiplied by the decision weight, resulting from the choice between alternatives. In turn, these weights measure the impact of the suitability of alternatives, but are not probabilities (Gomes and Marques, 2018). Furthermore, individuals generally tend to associate a low probability with non-occurrence and a high probability with certainty of occurrence (Kahneman and Tversky, 1979). In this type of value judgments, individuals are under evaluating very likely events to occur and over evaluating the other events (Levy, 2022; Lobão, 2012).

The value function replaces the utilities presented in utility theory, expressing individuals' preferences taking into account an evaluation through gains and losses (Kahneman and Tversky, 1979). This reinforces that the value of decision making is calculated based on changes in wealth and well-being and not on changes in end states.

This function recognizes that the past context of an experience defines a reference point for the response to a given attribute. After a favorable outcome, the individual tends to be more confident and less risk averse than usual; conversely, when an unfavorable result arises, the individual tends to be more conservative.

2.1.2. Effects arising from the application of the prospect theory

The research by Kahneman and Tversky (1979) presents a set of exemplary situations and the way in which utility theory is not taken into account, for each of them. The conclusions reached were based on a questionnaire of hypothetical situations applied to university students and teachers. Those authors identified three effects resulting from the application of prospect theory.

Certainty Effect

Generally, individuals overvalue outcomes that are considered certain over outcomes that are merely probable. However, when faced with two uncertain events, when the risk is imminent, individuals forget their aversion, changing their behavior (Kahneman and Tversky, 1979). Considering the occurrence of a certain or probable event in situations of potential gains, individuals tend to choose the right event, inferring that they are more averse to risk in situations of safe gains. According to Weber e Chapman (2005), in situations where there is a reduced difference in the probabilities of gain, investors may incur a greater risk, even if they are averse to it, corroborating the Allais (1953) paradox.

Reflex Effect

Individuals are generally more averse to risk when faced with the possibility of gains (Kahneman and Tversky, 1979, 2013). On the contrary, faced with the possibility of loss of the same magnitude, they tend to take more risk in their choices (Pereira et al., 2017). This behavior justifies that losing money causes greater dissatisfaction than the satisfaction of earning the same amount (Johnson and Tierney, 2019). In this way, the reflex effect maintains that individuals make opposite decisions when faced with gains or losses (Ruggeri et al., 2020; Wan, 2018).

Isolation Effect

When making a decision, the individual tends to involuntarily ignore some common components of the alternatives, focusing their choice on the differentiating aspects of the options presented (Kahneman and Tversky, 1979; Levy, 1992). Still, the fact that there are several ways to isolate different factors leads to inconsistent preferences when the same choice is presented differently (Rogers et al., 2007). This effect considers that choices are framed in terms of probabilities of loss or gain. For example, faced with a situation of probable loss, the individual considers it more reasonable to maintain the status quo. In turn, when an opportunity is presented with a probability of gain equal to 100%, certainty and reflex effects emerge in decision making, changing its current state. The individual may not have access to full information about the outcome of their decision, although they demonstrate willingness and commitment to increasing their wealth (Adriaenssen and Johannessen, 2016). Based on the above, the individual prefers to direct his attention to situations where there is certainty of gain or to situations in which the possibility of avoiding losses is expected (Barbosa et al., 2019).

2.1.3. Probabilistic insurance

The utility function presents as a strong evidence of its concavity (meaning individuals' risk aversion) the preponderance of purchasing insurance against large and small losses. The authors of prospect theory recommend that insurance of this type uses statistical and probabilistic models in order to calculate the probability of an event occurring, with the payment of a premium being inherent. Unlike normal insurance, in this case only half the premium is paid, and if there is any damage there is a 50% chance of paying the other half of the premium so that the insurer covers all expenses. On the other hand, there is a 50% chance that the insurance payment will be refunded, although the individual must assume responsibility for all losses (Kahneman and Tversky, 1979).

In fact, this type of insurance presents a reduced probability of the individual not being reimbursed, despite there being an aversion to this type of instruments (Wakker et al., 1998) which is predicted by the weighting function of prospect theory.

2.1.4. Overconfidence

Overconfidence is a characteristic that clearly relates to a cognitive bias, meaning that an individual overvalues their judgment and decision-making capabilities (Frederick and Kahneman, 2005).

The concept is not easy to define or measure, as there is no model for evaluating the phenomenon of under/over confidence and because it is believed that it can occur simultaneously with other biases (Ferreira, 2017).

In this article, two types of classifications are considered, initially adopted by Adams and Adams (1960), for the level of confidence identified in individuals: Over confident (i.e., overconfident) and underconfident.

This bias is in line with the so-called "illusion of control", from which the individual believes that they have control over all situations, even those that are merely random (Schütze et al., 2024). Overconfident individuals, by overvaluing their abilities, become indifferent to new information that contradicts their opinion. This phenomenon is also related to the concept of self-attribution, which consists of a

cognitive bias in which individuals associate success with intrinsic characteristics, while attributing failures to extrinsic factors (Metilda and Mishra, 2015).

In terms of academic research, several studies relate the concept of overconfidence to demographic and socioeconomic factors (Barber and Odean, 2001; Bushra et al., 2024; Kumar et al, 2024). For example, while Lundeberg et al. (1991) found no difference between genders, Barber and Odean (2001) argue that men are more confident than women. In turn, with regard to age and education, Kansal and Singh (2018) found that there are no differences in relation to confidence. Teles (2022) also maintains that age is not related to confidence, although he concludes that individuals with less education, qualifications in other areas not related to investments and non-investors are overconfident. Finally, Bushra et al. (2024) evidence that female investors are less susceptible to overconfidence bias than male investors.

2.1.5. Cognitive Reflection Test (CRT)

The Cognitive Reflection Test (CRT) was used by Frederick (2005) when discussing the relevance that cognitive reflection assumes in decision making. The author argues that cognitive reflection is related to the individual's ability to change his initial decision, choosing, afterwards, the most advantageous option. In a superficial way, this is an indispensable characteristic for the individual, as this ability helps to avoid instinctive situations based on his experience.

With the aim of corroborating the importance of cognitive reflection, the author created a test, commonly called "bat and ball problem". The author explains that the three items of the CRT are "simple" in terms of the resolution being easily understood when explained. However, choosing the correct option requires the individual to suppress the erroneous option that he initially thinks to choose impulsively (Frederick, 2005). That said, respondents are divided: The group with a higher cognitive reflection, meaning they answer three questions correctly, and the group with a lower cognitive reflection, answering no questions correctly. The author disregards individuals with 1 or 2 correct answers, focusing the analysis on the extremes, to make it easier to present the results. Signaling the groups, in the first they make analytical decisions, as they are able to filter their cognitive biases, and in the second they act impulsively, being considered intuitive decision makers (Frederick, 2005). Furthermore, the author concluded that all respondents initially thought of the most intuitive answers. Thus, the CRT is considered a predictive model of the choices made by individuals, allowing the identification of a set of cognitive biases.

2.1.6. Empirical evidence from prospect theory

Table 1 presents the results obtained by Kahneman and Tversky (1979), as well as by other authors who more recently replicated the same questionnaire. These results will be compared with those obtained in the empirical study developed in the following section of this article.

Table 1. Frequency distribution (effects).

Studies			**Kahneman and Tversky (1979)**	**Rogers et al. (2007)**	**Yoshinaga and Ramalho (2014)**	**Oliveira and Krauter (2015)**	**Marques and Gomes (2018)**	**Silva (2019)**	**Souza (2023)**
Effects	**Question**	**Alternative**	**Result**	**Result**	**Result**	**Result**	**Result**	**Result**	**Result**
Certainty Effect	Q1	A	18%	31%	25%	47%	**24%**	28%	31%
		B	82%	69%	75%	53%	**76%**	72%	69%
	Q2	A	83%	**94%**	51%	58%	60%	64%	36%
		B	17%	**6%**	49%	42%	40%	36%	63%
	Q3	A	20%	30%	13%	69%	23%	**22%**	12%
		B	80%	70%	87%	31%	77%	**78%**	88%
	Q4	A	65%	**61%**	45%	50%	42%	53%	26%
		B	35%	**39%**	55%	50%	58%	47%	74%
	Q5	A	22%	25%	11%	30%	28%	**22%**	12%
		B	78%	75%	89%	70%	72%	**78%**	88%
	Q6	A	67%	54%	39%	**60%**	41%	57%	26%
		B	33%	46%	61%	**40%**	59%	43%	74%
	Q7	A	14%	19%	**14%**	**14%**	12%	19%	**14%**
		B	86%	81%	**86%**	**86%**	88%	81%	**86%**
	Q8	A	73%	66%	60%	57%	66%	**70%**	59%
		B	27%	34%	40%	43%	34%	**30%**	41%
Reflex Effect	Q3	A	20%	30%	13%	69%	23%	**22%**	12%
		B	80%	70%	87%	31%	77%	**78%**	88%
	Q9	A	92%	81%	**85%**	22%	68%	49%	78%
		B	8%	19%	**15%**	78%	32%	51%	22%
	Q4	A	65%	**61%**	45%	50%	42%	53%	26%
		B	35%	**39%**	55%	50%	58%	47%	74%
	Q10	A	42%	57%	53%	73%	**41%**	46%	64%
		B	58%	43%	47%	27%	**59%**	54%	36%
	Q7	A	14%	19%	**14%**	**14%**	12%	19%	**14%**
		B	86%	81%	**86%**	**86%**	88%	81%	**86%**
	Q11	A	92%	**88%**	72%	74%	56%	45%	85%
		B	8%	**12%**	28%	26%	44%	55%	15%
	Q8	A	73%	66%	60%	57%	66%	**70%**	59%
		B	27%	34%	40%	43%	34%	**30%**	41%
	Q12	A	30%	54%	44%	58%	35%	**33%**	60%
		B	70%	46%	56%	42%	65%	**67%**	40%
Probabilistic Insurance	Q13	A	20%	41%	-	32%	**24%**	32%	-
		B	80%	59%	-	68%	**76%**	68%	-

Table 1. (*Continued*).

Studies			**Kahneman and Tversky (1979)**	**Rogers et al. (2007)**	**Yoshinaga and Ramalho (2014)**	**Oliveira and Krauter (2015)**	**Marques and Gomes (2018)**	**Silva (2019)**	**Souza (2023)**
Effects	**Question**	**Alternative**	**Result**	**Result**	**Result**	**Result**	**Result**	**Result**	**Result**
Isolation Effect	Q4	A	65%	**61%**	45%	50%	42%	53%	26%
		B	35%	**39%**	55%	50%	58%	47%	74%
	Q14	A	22%	29%	-	36%	**23%**	23%	-
		B	78%	71%	-	64%	**77%**	77%	-
	Q15	A	16%	38%	-	42%	36%	**33%**	-
		B	84%	62%	-	58%	64%	**67%**	-
	Q16	A	69%	64%	-	**68%**	62%	53%	-
		B	31%	36%	-	**32%**	38%	47%	-
Value Function	Q17	A	18%	-	-	16%	**17%**	34%	-
		B	82%	-	-	84%	**83%**	66%	-
	Q18	A	70%	-	-	31%	53%	**63%**	-
		B	30%	-	-	69%	48%	**37%**	-
Weighting Function	Q19	A	72%	-	-	**75%**	58%	56%	-
		B	28%	-	-	**25%**	42%	44%	-
	Q20	A	17%	-	-	63%	**37%**	40%	-
		B	83%	-	-	37%	**63%**	60%	-

Notes: Own preparation. "-" means that the issue was not considered in the indicated study. Krauter and Oliveira (2015) presented a segmentation of responses between students and professionals, so the results presented in the table are calculated based on the weighted arithmetic mean of the two groups of respondents.

In general, consistency can be seen in the results, highlighting the universality and timelessness of the study by Kahneman and Tversky (1979). The results highlighted in "bold" in each question are those that come closest to the initial study.

3. Materials, methods and research hypotheses

The empirical work of this article is based on the replication of the survey developed by Kahneman and Tversky (1979) and the CRT developed by Frederick (2005), as well as on the integration of the analysis of overconfidence.

The underlying methodology uses exploratory research, based on a survey shared through a convenience sample. Respondents under the age of 18 were considered as an exclusion criterion, given that they are not yet mature enough to understand the notion of risk nor will they be able to make investment decisions.

The original surveys by Frederick (2005) and Kahneman and Tversky (1979) were translated into Portuguese and referenced in the "euro" currency. To disseminate and collect responses to the questionnaire, the Google Forms program was used and for the subsequent statistical treatment of the results, the IBM SPSS 28.0 software (Statistical Package for Social Sciences) was used.

The statistical tests employed in this study, including the chi-square test was selected based on the nature of the data and the research objectives (Hair et al., 2019).

Specifically, the chi-square test is well-suited for examining relationships between categorical variables that are prevalent in the dataset, such as gender, investor type and familiarity with behavioral finance concepts. The rationale for utilizing this non-parametric test was driven by the necessity to examine data that does not assume a normal distribution, which is a prevalent attribute of categorical data.

The questionnaire is divided into four sections: (i) Identification of the respondent and their characteristics; (ii) questions from the study by Kahneman and Tversky (1979); (iii) three CRT questions, the answers to which are divided into intuitive, correct and other; (iv) additional questions to identify the profile of an overconfident individual.

To meet the proposed objectives, the hypotheses are divided into three groups. The first group is related to the prospect theory of Kahneman and Tversky (1979):

H1: Individuals, contrary to what is explicit in utility theory, prefer to opt for a certain event over an uncertain event (certainty effect).

H2: Individuals act oppositely in situations of loss and gain, and in situations of gain they seek less risk and, on the contrary, in situations of loss they are less averse to risk (reflex effect).

H3: Probabilistic insurance represents an unattractive protection tool.

H4: Individuals tend to ignore common data between alternatives and isolate the remaining data that stand out due to their difference (isolation effect).

H5: The original value function does not follow the same principles as the value function in prospect theory (value function).

H6: Individuals tend to associate a low probability with the uncertainty of an occurrence and a high probability with the certainty of the occurrence (weighting function).

H7: There are no differences between subcategories of individuals.

The second group is related with the CRT:

H8: CRT, when aimed at individuals with knowledge in the area of investments, produces differentiated results.

The third group is related with the phenomenon of overconfidence:

H9: Overconfidence is identified in categories of individuals with greater investment experience.

H10: There is a relationship between prospect theory and under or over confidence.

3.1. Data collection procedure and sample shaping

The empirical study yielded 376 valid responses between 14 July and 31 August 2023. The responses were primarily collected through electronic sharing (via email) among higher education students, various entities, and professionals in the financial investment sector, particularly those associated with banks and brokerages. It must be acknowledged that the sample is not entirely representative of the general population, as it includes a broad spectrum of respondents, including students and professionals with varying levels of engagement in financial markets.

The respondents were predominantly male (55.9%), within the 18–34 age bracket (43.6%), identified as students (51%) and described themselves as occasional

investors (55.1%). Furthermore, 52.4% of the participants indicated that they were unfamiliar with the concept of behavioural finance. While this offers a significant contribution to the understanding of a specific demographic group, the aforementioned demographic traits suggest an overrepresentation of younger, male, and more financially literate individuals, particularly those who are more likely to be engaged in financial investments or studying finance-related disciplines.

Given that the sample is skewed towards younger individuals with a higher probability of exposure to financial education or investment knowledge, the results may not fully capture the behaviours, attitudes, or experiences of older adults, individuals from different educational or occupational backgrounds, or those less involved in financial markets.

4. Results and discussion

4.1. Prospect theory

Table 2 presents a comparison between the results obtained by Kahneman and Tversky (1979) and the results of this study in relation to the effects and components of prospect theory.

Table 2. Original study versus present study.

					Original Study		Present Study	
Effects	**Question**	**Alternative**	**Expected Uitility Function**	**Value**	**Result**	**Statistical Significance**	**Result**	**Statistical Significance**
Certainty Effect	Q1	A	0.33 × u (2500) + 0.66 × u (2400)	2409	18%		23%	
		B	u (2400)	2400	82%	*	77%	*
	Q2	A	0.33 × u (2500)	825	83%	*	81%	*
		B	0.34 × u (2400)	816	17%		19%	
	Q3	A	0.80 × u (4000)	3200	20%		28%	
		B	u (3000)	3000	80%	*	72%	*
	Q4	A	0.20 × u (4000)	800	65%	*	66%	*
		B	0.25 × u (3000)	750	35%		34%	
	Q5	A	0.05 × u (3 weeks)	0.15	22%		31%	
		B	u (1 week)	1	78%	*	69%	*
	Q6	A	0.05 × u (3 weeks)	0.15	67%	*	68%	*
		B	0.10 × u (1 week)	0.1	33%		32%	
	Q7	A	0.45 × u (6000)	2700	14%		22%	
		B	0.90 × u (3000)	2700	86%	*	78%	*
	Q8	A	0.001 × u (6000)	6	73%	*	72%	*
		B	0.002 × u (3000)	6	27%		28%	

Table 2. (*Continued*).

					Original Study		Present Study	
Effects	**Question**	**Alternative**	**Expected Uitility Function**	**Value**	**Result**	**Statistical Significance**	**Result**	**Statistical Significance**
Reflex Effect	Q3	A	0.80 × u (4000)	3200	20%		28%	
		B	u (3000)	3000	80%	*	72%	*
	Q9	A	0.80 × u (−4000)	−3200	92%	*	88%	*
		B	u (−3000)	−3000	8%		12%	
	Q4	A	0.20 × u (4000)	800	65%	*	66%	*
		B	0.25 × u (3000)	750	35%		34%	
	Q10	A	0.20 × u (−4000)	−800	42%		48%	
		B	0.25 × u (−3000)	−750	58%		52%	
	Q7	A	0.45 × u (6000)	2700	14%		22%	
		B	0.90 × u (3000)	2700	86%	*	78%	*
	Q11	A	0.45 × u (−6000)	−2700	92%	*	86%	*
		B	0.90 × u (−3000)	−2700	8%		14%	
	Q8	A	0.001 × u (6000)	6	73%	*	72%	*
		B	0.002 × u (3000)	6	27%		28%	
	Q12	A	0.001 × u (−6000)	−6	30%		40%	
		B	0.002 × u (−3000)	−6	70%	*	60%	*
Probabilistic Insurance	Q13	A	N/A	N/A	20%		27%	
		B	N/A	N/A	80%	*	73%	*
Isolation Effect	Q4	A	0.20 × u (4000)	800	65%	*	66%	*
		B	0.25 × u (3000)	750	35%		34%	
	Q14	A	0.25 × 0.80 × u (4000)	800	22%		31%	
		B	0.25 × 1 × u (3000)	750	78%	*	69%	*
	Q15	A	0.5 × u (1000)	500	16%		27%	
		B	u (500)	500	84%	*	73%	*
	Q16	A	0.5 × u (−1000)	−500	69%	*	68%	*
		B	u (−500)	−500	31%		32%	
Value Function	Q17	A	0.25 × u (6000)	1500	18%		29%	
		B	0.25 × u (4000) + 0.25 × u (2000)	1500	82%	*	71%	*
	Q18	A	0.25 × u (−6000)	−1500	70%	*	68%	*
		B	0.25 × u (−4000) + 0.25 × u (−2000)	−1500	30%		32%	
Weighting Function	Q19	A	0.001 × u (5000)	5	72%	*	68%	*
		B	u (5)	5	28%		32%	
	Q20	A	0.01 × u (−5000)	−5	17%		27%	
		B	u (−5)	−5	83%	*	73%	*

Notes: Own preparation. Answers marked with an asterisk (*) present statistical significance at the 1% level, considering the chi-square test. To simulate the *p*-value, the Monte Carlo test was used at a 99% confidence level. N/A means not applicable.

Certainty Effect

Regarding the certainty effect, it appears that the answers to questions 1 to 8 follow the same trend as in the original study and reflect sufficient statistical significance. Contrary to what is explained by utility theory, individuals prefer to opt for a certain event to the detriment of an uncertain event. From this conclusion, hypothesis H1 is supported.

The answers to questions 1 and 3 show that individuals prefer certain gains, while the answers to questions 2 and 4 show that individuals prefer the alternative with the highest probability of gain. The answers to questions 5 and 6 also demonstrate that individuals prefer the option with the greatest possibility of earning. Finally, in question 7, individuals choose the answer with the greatest probability of winning (B), to the detriment of the answer with the highest absolute value, and in question 8 it appears that, when the differences between the probabilities are minimal, there is a tendency to choose the alternative with the possibility of a higher gain (A), forgetting the lower probability.

Reflex Effect

The reflex effect highlights the same characteristics as the original study, in which questions 9, 11 and 12 present statistical significance, unlike question 10. This data suggests that individuals act contrary to matters of gain and loss, preferring lower risk in situations gain and vice versa. From this conclusion, hypothesis H2 is supported.

In response 9, individuals choose the possibility of losing a larger absolute value (A), as opposed to the certainty of losing a smaller absolute value (B). Question 11 demonstrates that individuals, faced with similar losses, prefer the option with a lower probability of loss associated with a higher value (A). The choices in question 12 indicate that individuals ignore very low probabilities and are guided by value, opting for the alternative with the lowest associated loss (B).

The fact that question 10 does not present statistical significance, due to the similarity of choice between alternatives, allows us to maintain the premise of the original study.

Probabilistic Insurance

Probabilistic insurance is generally unattractive. The widespread choice of option B in question 13 converges with the original study and presents statistical significance. This choice demonstrates that individuals do not see probabilistic insurance as an advantage, supporting hypothesis H3.

Isolation Effect

Taking into account the isolation effect, it appears that the answers to questions 14 to 16 follow the original study and are statistically significant. Especially in question 14, there is a preference for alternative B, denoting that respondents ignore the initial part of the problem and prefer the option with the lowest value. Questions 15 and 16 are inverse, so in terms of gain the certainty effect is considered, while in terms of loss there is the search for risk, for the same expected utilities. The finding that individuals ignore common data between alternatives and base their choices on differentiating aspects confirms hypothesis H4.

Value Function

With regard to the value function, both the results obtained for the answers to questions 17 and 18 and their respective statistical significance converge with the original study.

In question 17, individuals prefer the choice with the highest probability of gain, although with a smaller gain (B). In turn, in question 18, opposite to the previous one, individuals prefer the option with the lowest probability of loss, not taking into account the values (A). The results confirm hypothesis H5.

Weighting Function

The weighting function involves questions 19 and 20, which agree with the results obtained in the original study and present statistical significance.

In question 19, for alternatives with the same utility, respondents choose the one with the lowest probability associated with a higher value, to the detriment of the certainty of gaining a lower value (A). In question 20, which presents the same problem in terms of losses, there is a preference for the certainty of losing a reduced amount, compared to the reduced possibility of losing a higher amount (B). Therefore, the results confirm hypothesis H6.

In general terms, it is concluded that the results obtained in this study converge with the results presented in the original study, with only question 10 not showing statistical relevance. More specifically, the effects described in prospect theory were verified, as well as the value function and the weighting function. These results are also consistent with the findings of Gomes and Marques (2018); Krauter and Oliveira (2015); Ramalho and Yoshinaga (2014); Rogers et al. (2007); and Souza (2023), recognizing the timelessness and universality of the original study.

In order to analyze the robustness of the results found, the analysis was replicated, dividing the sample into segments of respondents. In this context, hypothesis H7 was tested, relating to the existence of significant differences between students and non-students, the fact of being a professional trader or not, the fact of being an occasional investor or not and whether or not they know the concept of behavioral finance.

Regarding the student characteristic (or not), with the exception of question 10, all questions present statistical significance, confirming the effects and components previously mentioned. Therefore, the results confirm H7, in that there are no relevant differences between the responses of these two categories.

Given the professional trader characteristic (or not), the results of both categories follow those listed previously for the majority of respondents and the original study by Kahneman and Tversky (1979), and again only question 10 does not present statistical significance. Therefore, the results also contribute to confirming H7, as there are no relevant differences between the responses of these two categories.

For the occasional investor characteristic (or not), once again, the questions show results close to those obtained for most respondents and the original study, with only questions 10 and 12 not showing statistical significance. Thus, the results generally validate H7, suggesting that there are no relevant differences between the responses of these two categories.

Finally, given the fact that respondents know (or not) the concept of behavioral finance, it appears that both categories of respondents present responses similar to the

general responses and those of the original study. Once again, question 10 is the only one that does not present statistical significance for both categories, while question 12 only does not present statistical significance for individuals familiar with the concept.

The lack of statistical significance in Question 10 can be attributed to the close similarity between the two presented alternatives, which resulted in a high degree of overlap in the responses. The participants were requested to select either Option A, which entailed a potential loss of €4000 with a probability of 20%, or Option B, which involved a potential loss of €3000 with a probability of 25%. The marginal difference in expected loss between these two options may have led respondents to perceive the choices as nearly equivalent, which in turn likely contributed to the uniformity of the responses. This uniformity reduces the variability necessary to achieve statistical significance, as the chi-square test relies on distinct differences between observed and expected frequencies across categories. The decision between two similar prospects involving losses may be influenced by the weighting of probabilities and individual perceptions of risk. However, given that both options entail comparable outcomes, the reflection effect—which posits that individuals frequently encounter difficulties in differentiating between analogous risks involving losses—may have contributed to the reduction in divergence between responses.

Consequently, the lack of statistical significance in Question 10 lends further support to the proposition that, in scenarios where the distinctions between risk levels are minimal, individuals tend to exhibit analogous decision-making patterns.

Therefore, the results globally confirm hypothesis H7, suggesting that there is no evidence of relevant differences between the responses of the different segments of individuals analyzed.

4.2. Cognitive Reflection Test (CRT)

The second part of the questionnaire and, in turn, the empirical study, is dedicated to CRT. As mentioned, respondents are classified into two groups: Individuals with high cognitive ability (get the answers to the three questions—21, 22 and 23—of the questionnaire correctly) and individuals with low cognitive ability (do not get any answer right). On the other hand, the test presents three possible classifications for answers: Correct, intuitive (even if incorrect) and another type of answer[1].

The percentage of correct and intuitive answers is quite similar (according to **Table 3**), although correct answers are more frequent. The correct answer with the highest number of hits (54.5%) is question 23, while the question with the most incorrect answers (44.4%) is 21 and the question with the highest number of "other" answers is 22.

Table 3. Type of answers to CRT (percentage).

Question	Right Answer	Intuitive Answer	Another	*p-value*
21	52.1%	44.4%	3.5%	0.00**
22	53.5%	39.6%	6.9%	0.00**
23	54.5%	41.8%	3.7%	0.00**

* *p*-value < 0.05; ** *p*-value < 0.01.

The CRT is a test in which individuals generally tend to choose the intuitive answer, although this evidence is not a condition for the validity of the study.

The results of this article, in relation to the frequency of responses, are close to those presented by Frederick (2005). As highlighted by Reips and Stieger (2016), this study identifies one of the main limitations of CRT: Familiarization. In fact, most respondents are familiar with the area of investments and, therefore, may have already carried out similar tests, justifying more correct answers than intuitive ones. These results support hypothesis H8. This evidence calls for the need to update the content of the questions covered in the test.

In order to analyze the robustness of the results found, the analysis was replicated, dividing the sample into segments of respondents. In this context, the existence of significant differences was tested considering the age group, being a student or not, being knowledgeable or not about the concept of behavioral finance and gender.

The age group between 18 and 34 years old had the highest percentage (34.80%) with all correct answers, with the difference being statistically significant in question 22. The age group over 65 years old has the highest frequency (32.60%) in case of no correct answer.

Around 30.5% of individuals who were not familiar with the concept of behavioral finance got the three correct answers, but only 27.40% of those who knew the concept. Again, only in question 22 are the differences between the categories of respondents statistically significant.

Non-student respondents have a higher percentage of three correct answers (29.20%) and, interestingly, they also have a higher percentage of intuitive answers (48.1%). In question 22, students have a greater propensity to choose correct answers (56%), while non-students have a higher percentage of intuitive answers (46.5%). Only this question presents statistical significance for the student or non-student categories.

Regarding gender, men have a higher percentage of correct answers, while women have a higher frequency of intuitive answers, although there is only statistical relevance in the answers to question 23. In the context of the questions asked, it is concluded that the male gender reveals a greater cognitive capacity than females.

Finally, the last part of the CRT analysis concerns the comparison of results between individuals with high cognitive ability (with 3 correct answers) and individuals with low cognitive ability (with 0 correct answers). **Table 4** presents the questions, taking into account the segmentation between high/low cognitive capacity of the individual, and the results of the chi-square test:

Table 4. High cognitive ability versus low cognitive ability (prospect theory effects).

					High Cognitive Ability		Low Cognitive Ability	
Effects	**Question**	**Alternative**	**Expected Utility Function**	**Value**	**Result**	**Statistical Significance**	**Result**	**Statistical Significance**
Certainty Effect	Q1	A	0.33 × u (2500) + 0.66 × u (2400)	2409	18%		31%	
		B	u (2400)	2400	82%	*	69%	*
	Q2	A	0.33 × u (2500)	825	85%	*	75%	*
		B	0.34 × u (2400)	816	15%		25%	
	Q3	A	0.80 × u (4000)	3200	30%		35%	
		B	u (3000)	3000	70%	*	65%	*
	Q4	A	0.20 × u (4000)	800	80%	*	59%	
		B	0.25 × u (3000)	750	20%		41%	
	Q5	A	0.05 × u (3 weeks)	0.15	34%		33%	
		B	u (1 week)	1	66%	*	67%	*
	Q6	A	0.05 × u (3 weeks)	0.15	81%	*	60%	
		B	0.10 × u (1 week)	0.1	19%		40%	
	Q7	A	0.45 × u (6000)	2700	24%		22%	
		B	0.90 × u (3000)	2700	76%	*	78%	*
	Q8	A	0.001 × u (6000)	6	79%	*	62%	
		B	0.002 × u (3000)	6	21%		38%	
Reflex Effect	Q3	A	0.80 × u (4000)	3200	30%		35%	
		B	u (3000)	3000	70%	*	65%	*
	Q9	A	0.80 × u (−4000)	−3200	88%	*	84%	*
		B	u (−3000)	−3000	12%		16%	
	Q4	A	0.20 × u (4000)	800	80%	*	59%	
		B	0.25 × u (3000)	750	20%		41%	
	Q10	A	0.20 × u (−4000)	−800	51%		40%	
		B	0.25 × u (−3000)	−750	49%		60%	
	Q7	A	0.45 × u (6000)	2700	24%		22%	
		B	0.90 × u (3000)	2700	76%	*	78%	*
	Q11	A	0.45 × u (−6000)	−2700	84%	*	85%	*
		B	0.90 × u (−3000)	2700	16%		15%	
	Q8	A	0.001 × u (6000)	6	79%	*	62%	*
		B	0.002 × u (3000)	6	21%		38%	
	Q12	A	0.001 × u (−6000)	−6	42%		37%	
		B	0.002 × u (−3000)	−6	58%		63%	
Probabilistic Insurance	Q13	A	N/A	N/A	33%		23%	
		B	N/A	N/A	67%	*	77%	*

Table 4. (*Continued*).

					High Cognitive Ability		Low Cognitive Ability	
Effects	**Question**	**Alternative**	**Expected Utility Function**	**Value**	**Result**	**Statistical Significance**	**Result**	**Statistical Significance**
Isolation Effect	Q4	A	0.20 × u (4000)	800	80%	*	59%	
		B	0.25 × u (3000)	750	20%		41%	
	Q14	A	0.25 × 0.80 × u (4000)	800	33%		33%	
		B	0.25 × 1 × u (3000)	750	67%	*	67%	*
	Q15	A	0.5 × u (1000)	500	28%		26%	
		B	u (500)	500	72%	*	74%	*
	Q16	A	0.5 × u (−1000)	−500	77%	*	59%	
		B	u (−500)	−500	23%		41%	
Value Function	Q17	A	0.25 × u (6000)	1500	30%		35%	
		B	0.25 × u (4000) + 0.25 × u (2000)	1500	70%	*	65%	*
	Q18	A	0.25 × u (−6000)	−1500	77%	*	62%	
		B	0.25 × u (−4000) + 0.25 × u (−2000)	−1500	23%		38%	
Weighting Function	Q19	A	0.001 × u (5000)	5	79%	*	58%	
		B	u (5)	5	21%		42%	
	Q20	A	0.01 × u (−5000)	−5	31%		26%	
		B	u (−5)	−5	69%	*	74%	*

Note: Own preparation. Answers marked with an asterisk (*) present statistical significance at the 1% level, considering the chi-square test. To simulate the *p*-value, the Monte Carlo test was used at a 99% confidence level. N/A means not applicable.

In general, there is evidence that both the responses of individuals with low cognitive capacity and individuals with high cognitive capacity converge with what is suggested in the prospect theory of Kahneman and Tversky (1979).

The answers (1 to 8) in the certainty effect have statistical relevance in the category of individuals with high cognitive capacity. With the exception of questions 4, 6 and 8, both categories present answers that coincide with the original study by those authors and with the results reported in this article for most respondents. In answers 4 and 6, respondents with high cognitive ability show a clear preference for answer A, with respondents with low cognitive ability following the same trend, but less expressive and without statistical relevance.

Regarding the reflex effect, as occurred in the original study, question 10 does not present statistical significance for both categories. Furthermore, question 12 also does not present a statistically significant answer in both cases.

In the case of probabilistic insurance, these categories of individuals continue to recognize little importance.

In the isolation effect, the questions converge with the original study, with the exception of question 16, which does not present statistical significance in individuals with low cognitive capacity.

In the value function, question 17 presents statistical significance for both categories, while question 18 only presents statistical significance for individuals with

high cognitive ability. Although the results of question 19, in the weighting function, are in agreement with the original study, they do not present statistical significance for the segment of individuals with low cognitive capacity.

4.3. Underconfidence and overconfidence

This section of the article begins with an analysis of confidence by identified segment of individuals, measured through six questions. The main objective of this part is to identify a profile for the individual who is most confident.

It is assumed that all individuals in the sample have a basis of confidence as a characteristic, justified by the fact that their responses depend on effective decision-making in risk environments.

The analysis considers two types of individuals: Underconfident and overconfident. In question 1, respondents are faced with probabilities of 0 to 100% of making gains if they had money to invest. Thus, the higher the chosen probability, the greater the overconfidence: For probabilities between 0% and 50%, the individual presents underconfidence; for probabilities greater than 50%, the individual is overconfident. In question 2, it is assumed that a respondent who prefers to frequently sell and buy their shares is confident, as this presupposes greater knowledge than investors on the opposite side of the negotiation. In question 3 it is assumed that if a respondent considers that his performance in the market would exceed 3 times (on a scale of 0 to 5) that of other investors, then he presents a confidence bias. In question 4 it is assumed that a respondent who prefers to invest in the international market is overconfident. In question 5, it is assumed that a respondent who considers giving investment advice is overconfident in their abilities. Finally, in question 6 it is assumed that if a respondent considers making choices 3 times riskier with increasing age (on a scale of 0 to 5), then he presents an overconfidence bias.

Subsequently, a relationship is made between confidence and prospect theory, with the aim of understanding how under/over confidence can impact the responses of that theory. In this context, possible differences are analyzed in terms of gender, age, being a student or not, being a trader or not, being an occasional investor or not and knowing or not knowing the concept of behavioral finance.

In terms of gender, and regarding questions 1, 3, 5 and 6, it is concluded that men show greater overconfidence than women, although the differences are not statistically significant. For question 2, women are more overconfident, statistically different when compared to men. In question 4, the differences are statistically significant and suggest that men are more predisposed to invest in international markets than women.

The results show that age differences are statistically significant in question 3, suggesting that respondents aged 35–64 are overconfident in their decisions. The remaining questions are not statistically significant.

Still in question 3, the results show that non-students are overconfident to the extent that they believe that their investment performance will exceed that of other investors. This question is the only one that presents statistical significance in this segment.

Regarding the characteristic of being a trader or not, it appears that question 4 presents statistical significance. The results suggest that trader respondents have an overconfidence bias, despite having experience working in capital markets.

None of the questions are statistically significant for the category of whether or not the respondent is an occasional investor. However, the results suggest that occasional investors tend, in general, to decide with overconfidence.

Finally, in relation to the characteristic of being or not familiar about the concept of behavioral finance, it appears that questions 3 and 4 are statistically significant. The results suggest that respondents who are knowledgeable about the concept are overconfident, as they believe that their investments produce gains, considering that their performance would exceed 5 times that of other investors and are more likely to invest in international markets.

4.4. Profile of the overconfident individual in comparison with prospect theory

In the previous section, the categories of individuals who are overconfident were identified, highlighting their respective profile: Male, aged between 35 and 64 years old, non-student, trader and familiar about the concept of behavioral finance.

This context suggests that individuals with knowledge and experience in financial markets often tend to be overconfident in their abilities, supporting hypothesis H9.

The majority of individuals in the study sample are not overconfident (93.6%). Although individuals generally have a basis of confidence that motivates them to make decisions that may involve risk, with the perspective of being able to obtain corresponding gains, the results of the study do not suggest that respondents overvalue their abilities. In this context, the conclusions presented in section 3.3.1, suggesting that the results for all categories segmented by this empirical study follow the results of the original study by Kahneman and Tversky (1979), without significant differences, are also explained by this phenomenon. Given that the majority of respondents are not overconfident, they will choose the alternative—from among the issues listed by the prospect theory—that presents greater aversion to risk, corresponding to the option predicted according to the principles of that theory.

Therefore, it is expected that no category of individuals will present relevant differences in terms of preference between alternatives, even if they have different characteristics, to the extent that they are underconfident, therefore supporting hypothesis H10.

In summary, **Figure 1** illustrates the relationship between confidence and prospect theory:

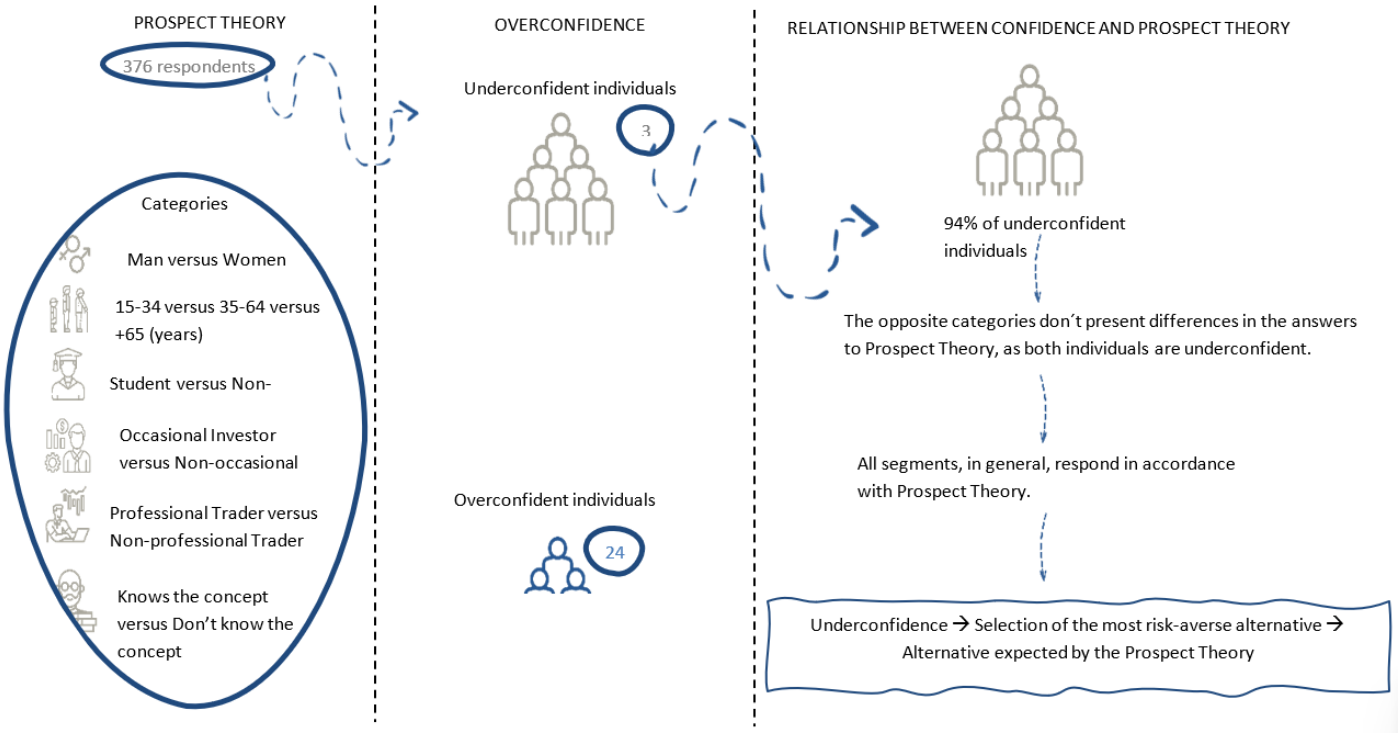

Figure 1. Relationship between under and over confidence and prospect theory.

5. Conclusion

The main objective of this article was to understand the biases that influence decision-making in environments of risk and uncertainty, in light of prospect theory, and the relationship with individuals' confidence.

In the empirical study, all the effects of prospect theory were verified, corroborating the hypotheses formulated by Kahneman and Tversky (1979). The universality and timelessness of the original study is recognized, as the proposed hypotheses appear to remain valid. Furthermore, interestingly, the segments of individuals with opposite characteristics did not show significant differences when choosing alternatives. This phenomenon can be explained by the relationship between prospect theory and respondents' underconfidence.

Regarding the Cognitive Reflection Test, the fact that some of the respondents are familiar with investment areas seems to justify their tendency to choose the correct answers.

It was found that male respondents, aged 35–64, non-students, traders and familiar with the concept of behavioral finance, represent the profile of an overconfident individual. However, the majority of respondents present an under-confident profile. Considering the reduced frequency of individuals with overconfidence, it is concluded that the results adhere to the prospect theory in all segments, despite presenting opposite characteristics, insofar as the choice of the alternative with less risk aversion converges with the principles proposed by Kahneman and Tversky (1979).

The article's conclusions are important for investment and risk assessment and suggest the importance of financial literacy in education. Overconfidence significantly drives individuals towards riskier investments (Hu et al., 2024). Additionally,

overconfident CEOs employ more debt within the capital structure of their firms, exposing them to higher financial risks (Banda and Silva, 2022). Since our results point to the presence of underconfident individuals, those problems seem to be contained. Financial educators and planners can use our results to develop programs specifically designed to increase awareness of the risks associated with overconfidence and promote balanced and informed investment behaviors.

In terms of limitations, there were some difficulties in obtaining responses to the survey. On the other hand, the apparent effortlessness with which individuals may have responded to similar problems in their daily lives was notable, thus potentially influencing our results through familiarity and self-reporting biases.

As suggestions for future research, it would be interesting to replicate the confidence measurement model in an organizational aspect, with the aim of relating management decisions to the overconfidence bias. In addition, it is suggested to update the degree of difficulty of the CRT accompanied by the inclusion of a greater number of questions and explore cultural differences and market volatility impacts in overconfidence.

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Notes

[1] The last classification, beyond the non-intuitive incorrect answers, includes incorrect answers due to the individual's lack of attention, such as an error in decimal places.

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