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COGNITIVE ABILITY AND RISK AVERSION: THE IMPACT OF SAFE OPTION

Mohamed Rashwan[1]
Associate Professor, Business Department
The British University in Egypt (BUE)
Email: Mohamed.Rashwan@bue.edu.eg

Ahmad M. Abd El-Aziz
Psychology Department
The British University in Egypt (BUE)

Abstract: A large body of experimental research has provided empirical support for the link between cognitive ability and attitudes towards risk. However, the findings have not been consistently confirmed. In this study, we try to investigate whether the relationship between cognitive ability and risk aversion is sensitive to the availability of the safe option condition—the availability of a riskless alternative in which a positive amount of money can be obtained with certainty. The subjects (n = 112) were divided into high- (n = 42) and low (n = 40) cognitive abilities according to their scores on Raven's Colored Progressive Matrices Test (RCPM). We conducted a laboratory experiment in which subjects with two groups made both safe and unsafe risky decisions using the Bomb Risk Elicitation Task (*BRET*). The experimental findings revealed that the relationship between cognitive ability and risk aversion is insensitive to safe option conditions as the high cognitive ability group performed more riskier than the low ability group even with the availability of riskless alternatives. Moreover, introducing the riskless alternative makes both high- and low-cognitive ability groups more risk-tolerant in both high- and low-risk-loving domains.

Keywords: *Cognitive ability, Risk aversion, Safe option, Risk-preferences*

[1] **ORCID ID 0000-0002-0884-2013**

Introduction

Egypt has a diversified and fast-growing economy that is heavily reliant on the country's abundant natural resources in the form of agriculture, industry and services. Despite its diversified economic structure, Egypt is still confronted with considerable economic difficulties, such as a high rate of unemployment, a large trade deficit, and a high public debt that has been exacerbated by a lack of economic growth and a shortage of foreign currency. Hence, the government has implemented a series of economic reforms to boost the country's economic growth, including floating the Egyptian pound, reducing subsidies, and liberalizing policies to address these challenges. However, these measures have also led to increased prices and further strain on the population. In such a considerably uncertain situation, the financial decision is affected by emotion and backed with logic or confirmation.

A large body of experimental research in psychology has concluded that individuals differ in their cognitive ability as not all people approach cognitive activity in the same way. Age, gender, expertise, and stylistic differences among people can influence their efficiency in acquiring and/or processing information. In response, the experimental research in behavioral economics has started to pay attention to how cognitive ability affects economic behaviors for instance saving, debt, investing in stock, and tax-paying. The relationship between cognitive ability and financial and/or economic behavior is also found in the context of an individual's attitude toward risk assumed to be a key determinant of human decision-making especially in the financial context. Hence, the relationship between cognitive ability and attitude toward risk has received much attention in the field of behavioral economics because it may have interesting implications in terms of reforming education and training to improve people's saving and investment habits. However, since neither risk attitude nor cognitive ability can be observed directly, there is no consensus among researchers regarding the nature of that association. Moreover, a lack of consensus among researchers has been found regarding the reasons behind why cognitive ability is associated with risk attitude, and if so, to what extent.

In the past two decades, some studies have found that highly intelligent individuals tend to be less risk-averse (Benjamin, Brown, & Shapiro, 2013; Dohmen, Falk, Huffman & Sunde, 2018; Lareau and Kessler, 2019; Boyer, 2006; Chapman, Snowberg, Wang, & Camerer, 2018), while several studies did not find that cognitive ability could be associated with risk aversion (Brañas-Garza, Guillen, & López del Paso, 2008). The main characteristics correlate with the likelihood of observing heterogeneity of research results: a) the cognitive ability is heavily depends on the elicitation method adopted whether the risk aversion is measured using real-world risky behavior, experimental measures of risky choice, or by self-reported measures, b) the association between the cognitive ability and attitude towards risk may be affected by the incentive conditions of risk-elicitation whether it is hypothetical or real incentive, c) the choice design of decision task used to elicit risk preferences, as the relationship between the cognitive ability and risk aversion may be dependent on the percentage of alternative responses indicating risk aversion whether the percentage is high or low, d) the multidimensional nature of cognitive ability and the presence of many different types of tests for measuring the cognitive ability (e.g., Wechsler Adult Intelligence Scale (WAIS), which refers to a person's global capacity to act purposefully, to think rationally, and to deal effectively with his environment; Raven's Progressive Matrices (RPM) test, which tries to measure abstract reasoning more closely related to fluid intelligence), risk preference might be related to some facets of cognitive ability but not others.

More recently, the safe option defined as the availability of a riskless alternative in which a positive amount of money can be obtained with certainty among the set of alternatives has been studied by Filippin and Crosetto (2017) to observe if it induces gender-specific behavior towards taking decision under risk. Though this attempt does not tackle the issue of investigating relationship between the cognitive ability and risk aversion under the safe option condition, it provides a roadmap for future research in terms of models that are suitable to rationalize the effect of the safe option. To the best of our knowledge, the role of the safe option mechanism in the relationship between cognitive ability and risk aversion has not been investigated. Nor we are not aware of any specific studies on the topic of cognitive ability and risk aversion in Egypt. Our paper fills this gap. Therefore, this study presents experimental evidence of the role of safe option in modulating the relationship between the cognitive ability and the risk aversion. This may provide insight into ways to improve financial decision making and stability in the economy. We hypothesized that the relationship between cognitive ability and risk preferences may be affected by the availability of safe option conditions in the risk-elicitation task. We conducted laboratory experiment in which subjects made both safe and unsafe risky decisions, from which we elicited their willingness to take risks, so that we could observe whether the association between cognitive ability and risk aversion is sensitive to the availability of a riskless alternative.

We find that those with higher cognitive ability tend to engage in behavior that is riskier, while those with lower cognitive ability tend to engage in behavior that is less risky when the experiment mode was designed with both unsafe and safe options. To the best of our knowledge, this paper is the first attempt to systematically investigate the role of safe option mechanism in

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shaping the relationship between cognitive ability and risk aversion. Hence, the findings are informative as it is trying to give some hints about how the safe option might be involved in this association, urging researchers to replicate this study with other cognitive ability measurements and other experimental measures of risky choice to gain a comprehensive understanding of the role of safe option mechanism in shaping this fundamental association.

The remainder of the paper is organized into four sections. The next section briefly provides a brief overview of the literature. Section 3 presents the experimental design, procedures, and descriptive statistics. Finally, Section 4 presents the results and discusses of overall findings. The Arabic experimental instructions are available in the paper's appendix.

Related Literature

Cognitive ability which usually refers to the individual's ability to think, reason, remember, learn, and understand information plays a substantial role in decision-making, as it outline how people acquire and process information to make informed decisions (Fisher, Chacon, & Chaffee, 2019). In the context of behavioral economics and finance, a growing body of literature has been published on investigating the association between cognitive ability and decision under risk, aiming to understand the fundamental background that shapes this association, and how it may affect the financial decision(s). Within this body of literature, some research attempts examine the association between risk attitude and cognitive ability. Risk attitude can be defined as any consciously or non-consciously controlled behavior with a perceived uncertainty about its outcome, and/or about its possible benefits or costs for the physical, economic, or psycho-social well-being of oneself or others (Trimpop,1994). The attempts assess the attitude towards risk aversion using several standardized tasks in which participants are presented with a binary choice between a lottery and a predetermined sum of money. Others involve either real or hypothetical gambling choices. However, these research attempts also differ in terms of measuring the cognitive ability and the aspects of cognition they consider, as well as for risk aversion behavior across different contexts of demographic and socioeconomic characteristics. It is worth mentioning that the relationship between cognition and Risk-Taking Behavior has been investigated in different nonexperimental settings. Boyer (2006) reviews four strands of research in the developmental psychology literature on risk-taking behaviors in situations that involve undesirable real-world risks, such as substance use, alcohol consumption, unsafe sexual behavior, or criminal behavior. Also, Agarwal and Mazumder (2013) relate a measure of cognitive skills that is based on the Armed Forces Qualifying Test (AFQT) score to the optimal use of credit cards for convenience transactions and to financial mistakes on a home equity loan application.

To support the notion that cognitive ability plays a substantial role in the performance of financial tasks (i.e., informed investment decision-making) under experimental settings. Lusardi & Mitchell (2011) show that higher cognitive ability leads to better performance on investment decisions such as budgeting and saving. Greenwood and Shleifer (2017) conducted a study to explore the association between cognitive ability and investment choice. They used a natural experiment to explore this association. The results showed that higher cognitive ability was associated with more cautious investment decisions. They concluded that cognitive ability is an important factor to consider when studying and understanding the individual's investment behavior. Ebert and Roider (2019) conducted laboratory experiment to investigate the effect of the cognitive ability on participants' investment decisions. the results have shown that the participants with higher cognitive ability made more rational investment decisions and were less prone to biases in decision-making.

Regarding the risk attitude, the association between cognitive ability and risk attitude has been studied extensively. In 1998, Weber & Hsee conducted one of the earliest studies to demonstrate that people with higher cognitive ability are less likely to be risk averse in task involving financial decision-making, and that association was mediated by their ability to process and analyze intricate information. Subsequent studies have also found similar results. According to Malmendier and Nagel (2011), cognitive ability plays a significant role in investment decision making and individuals with higher cognitive ability are more likely to invest in stocks and other risky financial assets. Based on research of Dohmen et al. (2018), an individual with a higher cognitive ability is significantly more willing to take risks in the lottery experiments compared with those with lower cognitive ability. Similar results are found by Sunde et al. (2010) and Burks et al. (2009).

However, the findings are more mixed than it seems. Sapienza & Zingales (2018), investigate the relationship between cognitive ability and investment risk-taking. The study is based on field data from a large sample of investors in Italy and the United States. The results show that cognitive ability is negatively associated with investment risk-taking. This means that individuals with higher cognitive ability tend to take fewer risks in their investments compared to those with lower cognitive ability. The study also outlines that the relationship between cognitive ability and risk attitude is robust across different countries, age groups, and levels of education. Similarly, Lareau and Kessler (2019) found that cognitive ability is a strong predictor of risk attitudes in financial decision making and individuals with higher cognitive ability are less likely to engage in risky financial behavior. Breaban et al. (2016) observed that larger cognitive ability as measured by Raven test scores can be associated with greater prudence (precautious) that acts as predictor of risk aversion.

A study by Brouwer et al. (2011) found that individuals with higher cognitive ability were more likely to avoid risky investments, and that this relationship was mediated by their ability to understand and analyze financial information. This study provides evidence that cognitive ability may lead to more risk-averse behavior as individuals with higher cognitive ability tend to be more aware of the potential risks and rewards, and as a result, may avoid certain investments that seem too risky. Moreover, the association between cognitive ability and risk aversion is rather weak (Benjamin, Brown, & Shapiro, 2013) and evidence of no association between the two is found in Brañas-Garza, Guillen, and del Paso (2008) and Eckel et al. (2012). For instance, Lusardi and Mitchell (2011) have found no significant correlation between cognitive ability and risk-taking behavior. These studies suggest that other factors, such as personality traits or cultural background, may play a substantial role in determining an individual's attitude towards risk. There are other attempts aim to study the association between cognitive ability and risk aversion that moderated by several factors such as 1) demographic characteristics (i.e., age, gender, race, income, education, and employment); 2) class of decision task used to measure risk aversion (i.e., was it incentivized, was the payoffs varied or kept constant, and if there was a certain option or not); 3) personality traits, 4) cultural background; and 5) life experiences. One of these factors that studied recently is the availability of riskless alternative or safe option (Lilleholt, L., 2019).

Frederick (2005) examines the relation between performance measured by Cognitive Reflection Test (CRT) and risk and time preferences. Using a variety of hypothetical choices between a certain amount of money and a gamble, he finds that subjects with high CRT, were more willing to choose the gamble option over the safe one in the domain of gains than subject with low CRT (those who scored zero). In the domains of losses, however, the high CRT group was more willing to play safe and accept a sure loss instead of playing a lottery with a worse expected value. Benjamin et al. (2013), conduct three laboratory studies with high school students in Chile in which they examine the influence of standardized test scores and school grades, proxies for cognitive ability, on risk and time preferences. In his second experiment, the participants were asked to choose between option (A) (*the safe bet*) 250 pesos [$0.49], and option (B) (*the risky bet*) 0 pesos with probability 50% and *X* with probability 50%. They find that the association between risk aversion and cognitive ability is weak under the safe option condition.

Recently, the safe option has been studied by Filippin and Crosetto (2017) to observe if it induces gender-specific behavior towards taking decision under risk. They manipulate three widely used risk elicitation methods (Holt and Laury Task (HL), The Bomb Risk Elicitation Task (BRET), and the classic Eckel and Grossman task) finding that the availability of a safe option causally affects risk attitudes. Though this attempt does not tackle the issue of understanding the association between the cognitive ability and risk aversion, it provides a roadmap for future research in terms of models that are suitable to rationalize the effect of the safe option on risk attitude.

In conclusion, the literature on the relationship between cognitive ability and attitude towards risk is diverse, with studies providing different perspectives on this association. Some studies have found a positive correlation, while others have found no significant correlation or even a negative correlation. Additionally, the literature suggests that the availability of safe option may moderate the relationship between cognitive ability and risk-taking behavior. However, the results of this studies are mixed due to the payoff structure of the safe option and the decision task used to measure risk aversion. Though most of these studies used different risk aversion measures with safe option format such as Multiple Price List (*MPL*), One Gambling Task (*OGT*), Lottery Task (*LT*), and Portfolio Choice Task (*PCT*)…etc. They do not look at the safe option version of *BRET* in exploring the association between cognitive ability and risk aversion. We are not aware of any such study. This is an important gap in the literature, particularly given the rather mixed results of studies interest in investigating the association between cognitive ability and risk aversion. By conducting the experiment in Egypt, we aim to enlighten policy and decision makers about the importance of the cognitive ability in the financial literacy specifically risk behavior.

In this paper, we aim to explore the influence of safe option measured by *BRET* in shaping the association between cognitive ability and risk aversion by testing whether individuals with high and low cognitive ability would change their attitude toward risk if the riskless alternative were available. We hypothesized that if the baseline version of the *BRET* induces difference in risk aversion between the high and low cognitive ability, we should expect to observe these differences in the $BRET_{safe}$ condition.

Experimental Design and Procedures

The study uses the computerized "Psychology lab" at the Basic and Applied Psychology department, the British University in Egypt (BUE). All the students at the British University in Egypt from preparatory to seniors in the academic year (2021-22) are eligible to participate in this study. In November 2021, an official invitation was sent to all students by the standard

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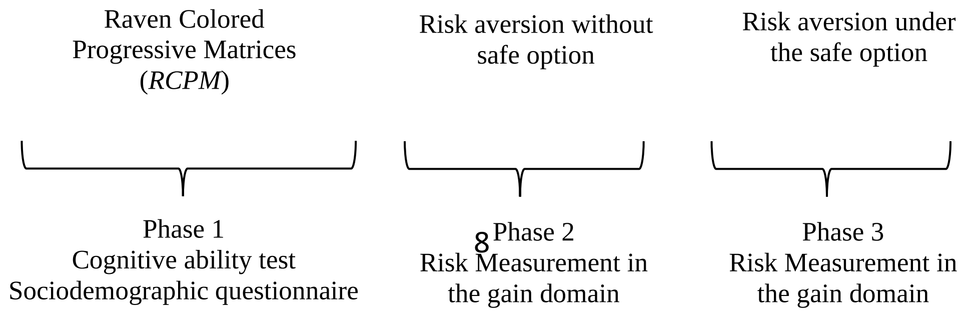
university e-mail. After clarifying the main aim and nature of the study, we asked the students to participate in a scientific experiment. We explained that the study will take place in three phases. In its first phase: “Pre-experimental Implementation”, a test of cognitive ability will be administered to all participants with no incentives or compensation. Then they might be re-invited to participate in the next two phases, “Experiment 1” and “Experiment 2”, in which money could be earned in cash. By the end of the invitation message, we clarify that their participation implied full of confidentiality of their responses. The two laboratory experiments follow the standards that routinely direct laboratory experiment such as no deception, the payment will be earned based on participant’s decision in the risk aversion elicitation task, and procedures respect to instructions.

In the pre-experimental implementation”, we administered the Raven Colored Progressive Matrices (*RCPM*) to all participants who respond to our experiment’s call. The main aim of this phase is to assess the participants’ cognitive ability. This phase ended with administering a sociodemographic questionnaire. We divide the participants based on their test scores into two groups (high and low) using the interquartile range. Figure 1 describes the timeline of this experiment.

In the second phase, we invited the subjects who received high and low cognitive ability scores to participate in the Experiment 1. The main objective of this phase is to measure risk aversion by using the classic *BRET* in which participants are required to decide how many boxes to collect in a matrix containing 100 boxes, one of which hides a bomb (Crosetto and Filippin, 2013). The payoff of each box collected is the same. Hence, the potential earning increases linearly. In case the box with the bomb is collected, the payoff for the whole round is zero.

In the third phase, we re-invited the same subjects (high and low groups) to participate in Experiment 2. The main objective of this phase is to measure the risk aversion under the safe option. We follow Filippin and Crosetto (2017) using the *BRET* in the safe option condition in which a riskless alternative is made available by preventing the time bomb to be in the first 25. In the remainder of this section, we will give a more detailed description of the relevant parts of each phase.

Figure 1. *Timeline of Experiment*



The complete subject characteristics were examined using means, standard deviation, and percentages. We used the two-way mixed design to investigate whether the relationship between cognitive ability and risk aversion is affected by the safe option of *BRET*'s elicitation task. The interquartile range was calculated to divide the complete sample into high and low cognitive ability groups. SPSS Statistics 23.0 (IBM SPSS Statistics) was used. The *p*-values below 0.05 were statistically significant.

Pre-experimental Implementation

Design

This phase involved two sections. In the first section, we elicit subjects' cognitive ability test by administering the Arabic version of *RCPM* that standardized on a sample of Egyptian society[2] contains 14000 child (*M* = 5.5 to 16.4 years) and 11100 adults (*M* = 16.5 to 68.4). It is a non-verbal and cross-cultural test used to assess the subjects' reasoning and their general ability of organized thinking. The Arabic Egyptian version of the test contains 3 sections (A), (AB), and (B) each of which has 12 items. The test in its final version includes 36 items, each one presented a drawing with one missing symbol that exists in six alternatives. For the answer, the subject required to choose one out of six offered response-symbols. Each next drawing has a unique design, but the changes from one symbol to the next consequently follow a certain principle. This principle has to be inferred by the subject. To assess the cognitive ability, a raw score of one point was given for each correct answer, and the total raw score was the sum of the correct answers, with a maximum score of 36. Additionally, on the basis of the raw score of correct answers and the age of each subject the intelligence quotient was estimated according to a standardized key norms table conduced on Egyptian sample (see Appendix A). Section two was implemented after the subjects had finished the *RCPM*. They were asked to fill out a brief questionnaire containing information regarding their socioeconomic status.

Administration

We received 112 responses; all of them took part in the pre-experimental implementation phase. We conducted 5 sessions with average (*M* = 18.67) participants in each session. The experiment was conducted in a timeless and paper-and-pencil format with average session time 22.8 minutes. Upon their arrival, subjects sat at isolated desks. Before reading the instructions, we clarify again that this phase will be administered to assess

[2] Hassan, E. A. (2016). *Raven Colored Progressive Matrices*. The Anglo Egyptian Publisher, Cairo.

their cognitive ability with no incentives. Then Instructions of *RCPM*'s sections (A), (AB), and (B) were read aloud by the experimenter. After the subjects completed the *RCPM*, they were asked to fill out the sociodemographic questionnaire. After completing the questionnaire, we announce that we may invite some of them to participate in the next two phases on our experiment.

Descriptive Statistics

A total 112 students at the British University in Egypt respond and attend the pre-experimental phase see Table 1. Most of the sample are female with an average age of 19.69 years. Most students attending the sessions were enrolled in Arts and Humanities major (56.30%) and less than half of them were distributed among business, technology, engineering, and medical majors. The average month income for all samples was 7517.86 L.E. ($481.14).

Table 1. *Sociodemographic features of sample (N = 112)*

	N (%)	Mean	SD	1st Q	3rd Q	Min	Max
Gender							
Male	48 (42.86)	-	-	-	-	-	-
Female	64 (57.14)	-	-	-	-	-	-
Age (in years)	-	19.55	.96	-	-	18	23
Monthly income (in L.E.)	-	7517.86	3784.11	-	-	1000	15000
Field of study							
Humanities	63 (56.30)	-	-	-	-	-	-
Business	19 (17.00)	-	-	-	-	-	-
Technology	5 (4.50)	-	-	-	-	-	-
Engineering	16 (14.30)	-	-	-	-	-	-
Medical	9 (8.00)	-	-	-	-	-	-
Cognitive Ability							
RCPM Percentile rank		72.10	19.12	50	90	25	95

***Q = Quartile**

Experiment 1: BRET (Baseline condition)

In this section, we report the first experiment to examine the relationship between cognitive ability and risk aversion in BRET baseline condition. Before introducing the experimental design, administration, and descriptive statistics, we report that we implemented a version of BRET introduced by Crosetto and Filippin (2013) using C# programming language (Microsoft Visual Studio® 2019, .Net framework 4.7.2, Version 1803) to provide an Arabic Interface to non-English speakers.

Design

In this experiment, we follow Crosetto and Filippin (2013) in which subjects who sat at isolated desks Infront of computer screen face a 10 × 10

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square where each cell represents a box. 99 boxes are blank, while one is a time bomb. Every second one box is automatically collected (opened). Subjects must decide how many boxes they want to collect, i.e., $k^* \in [0,100]$, by clicking the Stop button. The position of the time bomb $b \in [1, 100]$ is determined after the choice is made by the subjects who draw a number randomly from 100 from an urn. If $k_i^* \geq b$, this implies that the subject acquired the bomb, which by exploding it takes away all their money. On the other hand, if $k_i^* < b$, subject *i* leaves the minefield with no bomb and earns 2 L.E. ($ 0.13)[3] for every box collected. The *BRET* interface displays probabilities visually, enabling subjects to track the number of boxes collected and the number of boxes remaining. This is clearly shown in Figure 1.

$$L_{BRET} = \begin{cases} 0 & \frac{k}{100} \\ k & \frac{100-k}{100} \end{cases}$$

The degree of risk aversion negatively correlates with the choice of *k* and a risk-neutral subject should choose $k^* = 50$. In this experiment, we used The *BRET* version that does not provide safe options as the only amount of money that can be secured with certainty is zero, when subject *i* chooses $k = 0$ or $k = 100$. Hence, the choice of *k* implies a comparison between uncertain amounts only and it can therefore be used to build a pure measure of risk aversion in which certainty effects play no role.

Figure 2 presents a screenshot of the baseline *BRET*. Subject *i* starts the game by pressing start button. After 15 seconds the subject collected 15 boxes (k =15) and decides to stop the game. The screen presents that collected boxes are 15, the remaining boxes are 85, and the subject may earn 30 L.E. ($1.91). by the end of the game, the subject will be requested to pick a number from $b = [1, 100]$ randomly from an urn. If $b \leq 15$, then the subject leaves the minefield with no money. Otherwise, the subject will earn 30.00 L.E. ($1.91). Since the subject decided to stop at $k = 15$ (< 50), then the subject's degree of risk aversion is high.

[3] At the time, 1.00 L.E. = US $ 0.064

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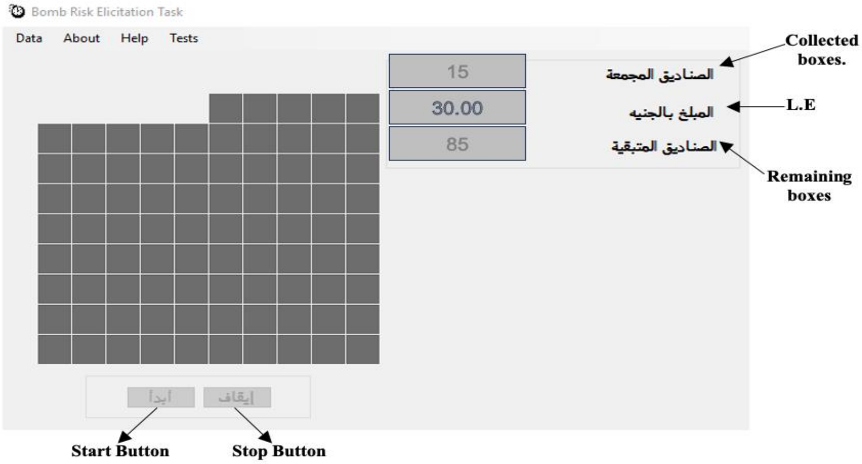
***Figure 2**. The Arabic Interface of Baseline BRET after 15 Seconds*



Administration

A total of 82 subjects invited and took part in the experiment 1 after excluding 30 cases from the analysis who received *RCPM* scores < 90 and >50 (30 cases of interquartile). 42 subjects included in the high cognitive ability group who received *RCPM* score ≥ 90 and 40 subjects included in the low cognitive ability group who received *RCPM* score ≤ 50. The experiment was computerized and used the baseline *BRET* with Arabic interface. We ran the experiment in 4 sessions in which 2 sessions were held for each group over four days. Sessions lasted about 51 minutes.

Upon their arrival, the subjects sat at isolated desks. The Arabic instructions of the experiment 1 were read aloud by the experimenter (see Appendix B). After we explained what *BRET* task would look like, the subjects started completing the task with the understanding that location of the bomb would be selected at random at the end of the experiment to determine their earnings. If they selected a number less than or equal the number of collected boxes they decided, then they will earn no money. Otherwise, they will receive the payoff according to the number of collected boxes multiplied by 2 L.E. On average, high cognitive ability group earned 107.14 L.E. (US $6.86) and low cognitive ability groups earned 53.53 L.E. (US $3.43).

Descriptive Statistics

Table 2 presents overall statistics for the hi- and low-cognitive ability subjects in Experiment 1. There are more female students in low cognitive ability group, while more males are engaging in the high cognitive ability group. Most students attending experiment 1 were enrolled in Arts and Humanities major in both groups. engaging on the activities, and most are

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white with average age of 19 years. The socioeconomic background information for both high- and low cognitive ability group indicated that they had approximately the same average monthly income. The high cognitive ability group earned more amount of money (107.14 L.E.; $6.86) than low cognitive ability group.

Table 2. *Sociodemographic Features of High and Low Cognitive Ability Groups*

	High Cognitive Ability (N=42)			**Low Cognitive Ability (N=40)**		
	N (%)	Mean (SD)	Min-Max	N (%)	Mean (SD)	Min-Max
Gender						
Male	30 (71.43)	-	-	9 (22.50)	-	-
Female	12 (28.57)	-	-	31 (77.50)	-	-
Age (in years)	-	19.40 (.83)	18-22	-	19.73 (.99)	18-23
Monthly income (L.E.)	-	7583.33 (2958.90)	4000-15000	-	7862.50 (4639.56)	1000-15000
Field of study						
Humanities	21 (50.00)	-	-	25 (62.50)	-	-
Business	7 (16.70)	-	-	5 (12.50)	-	-
Technology	2 (4.80)	-	-	2 (5.00)	-	-
Engineering	11 (26.20)	-	-	3 (7.50)	-	-
Medical	1 (2.40)	-	-	5 (12.50)	-	-
Cognitive Ability						
RCPM Percentile rank	-	92.26 (2.52)	90-95	-	48.75 (5.52)	25-50
Payoff						
Amount of money (L.E.)	-	107.14 (20.36)	64-128	-	53.53 (17.65)	20-90

Experiment 2: BRET (Safe option condition)

We report in this section the second experiment to examine the relationship between risk aversion and cognitive ability in a safe option setting. Before introducing the design, procedures, and descriptive statistics we note that we experimented on the same participants who participated in experiment 1. Thus, the descriptive statistics information is the same except for the amount of money earned. We follow the standards that routinely direct experiment 1 except for some changes in the instructions that related to the

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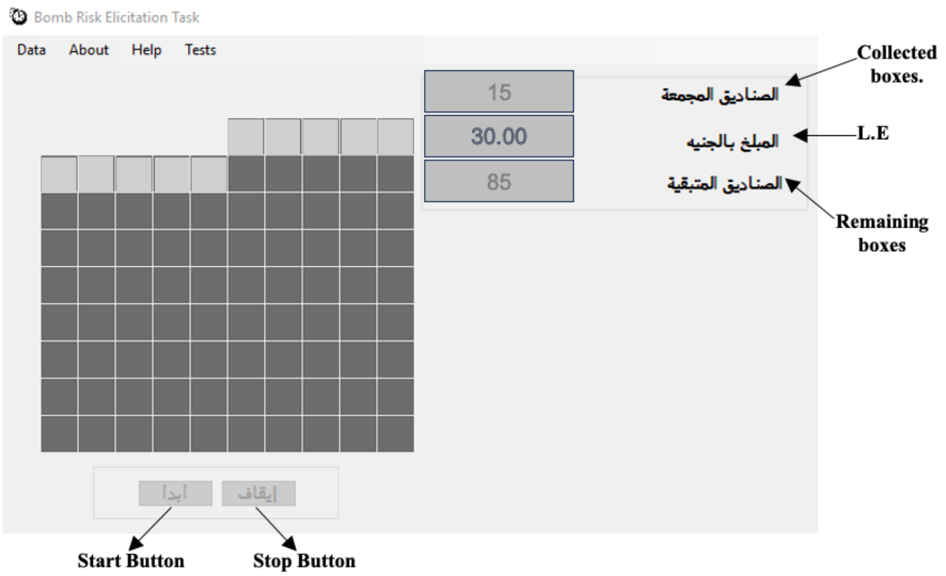
safe option condition, the payments were earned the same way in experiment 1.

<u>Design</u>

In experiment 2, we follow Filippin and Crosetto (2017) to measure the differences between high- and low- ability groups in risk aversion in a safe option condition. The $BRET_{safe}$ is designed by preventing the time bomb in the first 25 boxes. In other words, by choosing $k \leq 25$ subjects can secure a positive amount without incurring any risk (earning probability = 1). Figure 3 displays the graphical interface of the $BRET_{safe}$. As an example, by choosing k = 20 the subject earns 40 L.E. ($2.56) for sure which is the value of 20 boxes because the time bomb can only be in $b \in [26, 100]$. Note that each box k is worth for 2 L.E. ($0.13). In contrast, if the choice is k = 40, the underlying lottery implies earning 80 L.E. ($5.12) with probability (100 – 40) / 75 or nothing with probability one fifth ((40 – 25) / 75). More generally, each lottery is then characterized by:

Figure 3. *The Arabic Interface of Safe-BRET after 15 seconds*



$$L^k = \begin{cases} [\,k & with\ prob.\ 1 \quad if\ k \leq 25 \\ 0 & with\ prob.\ \dfrac{k-25}{75} \\ k & with\ prob.\ \dfrac{100-k}{75} \quad 25 \leq k \leq 100 \end{cases}$$

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Note that for $k \geq 25$ the expected utility in the $BRET_{safe}$ condition is a linear transformation of the Baseline under the reasonable assumption that $u(0) = 0$. Therefore, an expected utility maximizer should make the same choice in the two conditions as long as his optimal choice is $k \geq 25$. The only effect of the safe manipulation is that of inducing the more risk-averse subjects to choose the highest safe option $k = 25$. Any $k < 25$ violates the monotonicity assumption and would be irrational. As a result, we can expect to observe a slightly higher average choice in the $BRET_{safe}$ (Filippin and Crosetto, 2017).

Administration

All 82 subjects are reinvited and took part in experiment 2 after 18 days (after receiving a confirmation from students on the date and time of second experiment). The experiment used the *BRET* in a safe option condition with Arabic interface. Like experiment 1, experiment 2 conducted in 4 sessions in which 2 sessions were held for each group over four days. Sessions lasted about 48 minutes. The experiment followed the same procedures of experiment 1 in terms of organization and settings. The instructions of experiment 2 were like the instructions of experiment 1. After we explained what safe *BRET* task would look like, the subjects started completing the task with the understanding that a riskless alternative is made available by preventing the time bomb to be in the first 25 boxes. So, if they selected a number less than or equal 25, then they will receive the payoff according to the number of collected boxes multiplied by 2 L.E ($0.13). Otherwise, the Safe *BRET* followed the *BRET* procedures.

Descriptive Statistics

Since we conducted the experiment 2 on the same sample. The overall statistics for the hi- and low cognitive ability subjects are the same (see Table 2). On average, high cognitive ability group earned amount of money of 123.33 L.E. ($7.89) with standard deviation 14.24 L.E. ($0.91) and low cognitive ability group earned amount of money of 73.65 L.E. ($4.71) with standard deviation 11.48 L.E. ($0.73).

Results and Discussion

A two-way unbalanced mixed ANOVA was conducted to analyze the effect of cognitive ability (high vs. low) and the experimental mode (BRET vs. Safe) on risk aversion in terms of the number of collected boxes *k*. The mean and standard deviations for risk aversion are presented in Table 3. A

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paired samples *t*-test, Mann Whitney and effect size[†] were performed to highlight the comparison between baseline BRET and safe option treatment in risk aversion.

Table 3. *The Comparison Results of Average Number of Boxes chosen by Cognitive* Level and treatment in the BRET

		N	Mean Choice	Std. Dev.	Cohen's *d*	Mann Whitney	Norm. Test*	*t*-test (one-tailed)
Baseline (BRET)	High Cognitive Ability	42	59.57	11.15	2.75	< 0.001	0.003	< 0.001
	Low Cognitive Ability	40	29.98	10.38				
	Diff (High-Low)		29.59					
Treatment $BRET_{safe}$	High Cognitive Ability	42	63.62	8.02	2.86	< 0.001	0.0002	< 0.001
	Low Cognitive Ability	40	39.62	8.77				
	Diff (High-Low)		24.00					

*Shapiro Wilk test (*p*-value < 0.05 means not normally distributed)

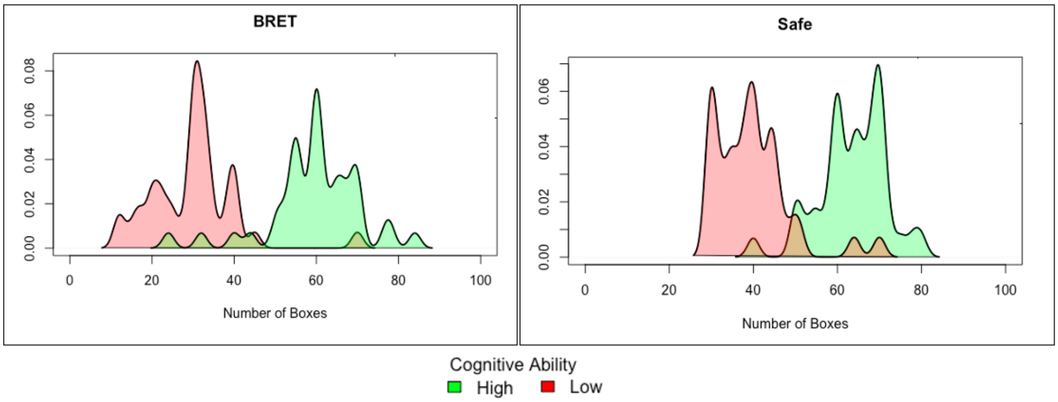
The results indicated that there was a statistically significant interaction between the effect of cognitive ability level and experimental mode on risk aversion, $F(1, 80) = 4.48$, $p = 0.03$, □□ = 0.15[*] , significant main effect for cognitive ability $F(1, 80) = 246.47$, $p < 0.001$, □□ = 0.79; and significant main effect for experimental mode ($F(1, 80) = 28.56$, $p < 0.001$, □□ = 0.35). As shown in Table 3 we test the differences between the average number of boxes *k* collected by both high and low in experiment 1 (baseline BRET) and experiment 2 (treatment $BRET_{safe}$). The results indicated that the high ability group turn out to be riskier than the low cognitive ability group according to a Mann Whitney test ($p < 0.001$) and also to a *t*-test ($p < 0.001$). Moreover, The Cohen's *d* results indicated that the average number of boxes *k* chosen by high cognitive ability group in the BRET is 2.75 standard deviation above the average of number of boxes *k* chosen by low cognitive ability group, and 2.86 in the $BRET_{safe}$.

[†] the effect size was calculated by Cohen'*d* that is independent of sample size. It is computed as $d = (\bar{x}_h - \bar{x}_l)/\sigma$; where $\bar{x}_h$ and $\bar{x}_l$ are the average group (high and low) choices and σ is the pooled standard deviation. The threshold for interpreting *d* is: $d = 0.2$ considered as small effect, $d = 0.5$ considered as medium effect, and $d = 0.8$ considered as large effect. see Cohen, J., 1988. Statistical Power Analysis for the Behavioral Sciences. L. Erlbaum Associates.

[*]partial $\eta^2 = 0.14$ and more are large effect; $\eta^2 = 0.06$ and more are medium effect; $\eta^2 = 0.01$ or more are small effect. see Miles, J and Shevlin, M (2001) Applying Regression and Correlation: A Guide for Students and Researchers. Sage:London.

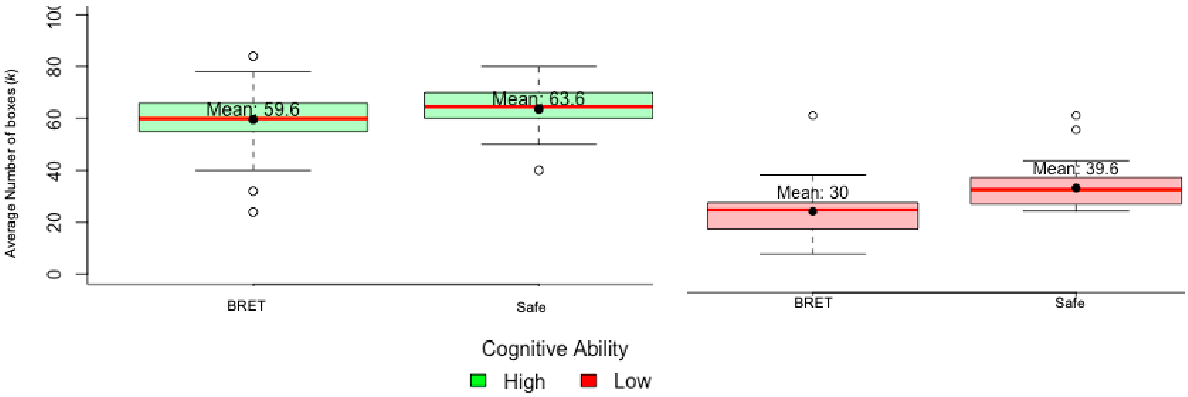
To illustrate the results, Figure 4 shows a kernel density of choices by cognitive ability groups and treatment. In the BRET (left panel) the two distributions are highly separated with high cognitive ability group tends to make more disperse choices *k* (the peak is approximately 60) compared with low cognitive ability group (the peak is approximately 30). In $BRET_{safe}$ (right panel) where the riskless alternative (50 L.E. ($3.2) can be obtained with certainty) is available, the behavior of high and low ability distributions remains the same in terms of high ability group tends to make more disperse choices *k* as compared to that of low ability. However, the distribution of low ability group is nearly bimodal with one peak close to the safe option $k = 25$ (20% of participants opted for $k = 30$) and the second peak is < 50 (15% of participants opted for $k = 40$). Additionally, the results revealed that subjects performed riskier when the experiment's mode was designed with safe option. As shown in Figure 4 (right panel), the availability of riskless alternative makes both distributions (high and low ability) shifted to the right compared to that of BRET (left panel).

***Figure 4**. Kernel density (bandwidth adjusted 1.4) of the choices by High and Low Cognitive Ability Groups in the BRET*



However, the low ability group is still presented in the low risk loving domain ($k < 50$). Figure 5 highlights the effect of introducing safe option on decisions under risk for both high and low ability groups. In the high ability (left panel) the average number of choices *k* in $BRET_{safe}$ is significantly greater than in BRET, $t(41) = -2.46$, *p*-value = 0.02. Similarly, In the low ability (right panel), $t(39) = -4.99$, *p*-value < 0.001.

Figure 5*. Boxplot of the average number of collected boxes by Cognitive Ability Groups and treatment of the BRE*



Our experimental results suggest that the relationship between cognitive ability and risk aversion is insensitive to safe option condition as the high cognitive ability group performed more riskier than the low ability group even with the availability of riskless alternative. The results also revealed that introducing the riskless alternative makes both high- and low-ability groups more risk tolerant by choosing greater number of bokes *k* in both high- and low-risk loving domains.

Nevertheless, some caution is in order regarding these conclusions. First our experimental design is fully incentivized where the real payoff is at stake. Since the incentive in risk-elicitation tasks plays a sensitive role in the relationship between cognitive ability and risk aversion as it could generate different responses depending on the context in which the decisions are made (Almeida, S., 2019), our findings will be interpreted in the context of gain domain and incentivized experimental design. Second, using the same elicitation task between baseline and safe option condition with same subjects may create a confounding problem such as choice biases (in case of value-based decision) that influence decision of the same subject in the second trail. Subjects could think to repeat their decision (if they won in the first trial) than to switch to a different choice in the second trial. Third, it is well known that the score of an individual on different psychometric cognitive tests can be significantly different between such tests depending on format, length, and timing conditions. Moreover, the assessment of cognitive ability was conducted based on the Egyptian version of *RCPM* that was standardized on Egyptian sample. The *RCPM* is used to assess abstract thinking and reasoning that related to fluid intelligence. In the light of these caution, we claim that our findings are informative to help understanding the role of safe option in the relationship between cognitive ability and risk aversion.

Regarding our findings that suggest that the high cognitive ability performed more risker than the low cognitive ability, our findings are in line with findings from Andersson, Holm, Tyran, and Wengström (2016). They suggest that higher cognitive ability is associated with more risky decisions as the noisy decision making can bias individual responses in risk elicitation tasks in ways that are related to cognitive ability. Our findings also are in line with the results of Dohmen et al. (2017) which says that individuals with higher cognitive ability are significantly more willing to take risks compared with those people who have a lower cognitive ability who are more likely to be risk averse. Moreover, our findings are consistent with results found by Sunde et al. (2010) and Burks et al. (2009). Our explanations are consistent with the rationale suggested that people with high cognitive ability are associated with confidence that they can evaluate the costs and benefits of risky decisions accurately and are therefore more willing to take risk and are more risk seeking (Frederick, 2005). In contrast, people with lower cognitive ability are less confident that they evaluate the cost and benefits of risky decisions accurately. Moreover, if the person with low cognitive ability sees an opportunity to get great results but has a high risk, he/she tends to retreat and do not want to move forward to get that great result and can be regarded as a risk-averse person. From other perspective, we add additional explanation associated with the nature of cognitive ability assessed by *RCPM* that mainly measures the reasoning, problems solving, and abstract thinking (fluid intelligence). We suggest that people with high *RCPM* scored are showing high abstract mind-set that promotes some sort of sensitivity to desirability considerations (i.e., value of an end-state of an action: for instance, amount of money gained within a risky task), and people with low scores in *RCPM* are associated with concrete thinking that promotes some sort of sensitivity to feasibility considerations (i.e., ease of achieving the end-state. Hence, the high abstract mind-set showed an increased risk behavior when compared with those with a concrete way of thinking (Lermer et al. 2014; Lermer et al., 2016; Raue, Streicher, Lermer, & Frey, 2015; Sagristano, Trope, & Liberman, 2002). On the other hands, our experimental findings seem striking in light of several experimental studies that since Frederick (2005), have reported evidence that higher risk aversion is associated with lower cognitive ability such that Sapienza & Zingales (2018) who indicated that individuals with higher cognitive ability tend to take fewer risks in their investments and Lareau &

Kessler (2019) and Boyer (2006) as they who found that individuals with higher cognitive ability are less likely to engage in risky financial behavior. Similarly, Almeida, S., 2019, finds that while higher cognitive ability (measured by different tests) leads to more risk-taking behavior in hypothetical tasks, there is no such relation when real money is at stake which contradict with our findings that depend on incentives. We are not suggesting that these studies that claim that higher cognitive ability tend to take less risks are invalid. Rather, we simply highlight the role of safe option condition in shaping the relationship between cognitive ability and risk aversion. This supports our claim that our findings are informative.

Regarding the explanation of the insensitive role of safe option on risk aversion between the high- and low cognitive ability, we assume that introducing the safe option that not directly chosen (based on *BRET*'s game design) makes subjects more risk tolerant and induce them to choose more boxes *k* than what have been chosen in the baseline *BRET*. This could be explained by the classic certainty effect that introduced in prospect theory. The certain effect resulting from the reduction of probability from certain to probable (Tversky & Kahneman 1986). In the case of safe the amount of money that can be obtained with certainty creates a psychological effect induces subjects to be more risk tolerant by choosing more boxes *k* than what have been chosen in the *BRET*. However, it does not move the low ability group from low to high risk loving domain. The findings were also reported by Crosetto and Filippin (2017) when they investigated the effect of safe option in induing differences in risk aversion between males and females.

Conclusion

An increasing number of studies have been addressing this issue empirically. They investigate how economic behavior differs between cognitive groups. Part of this literature has focused on the role played by cognitive ability on attitudes towards risk. The study contributes to the growing literature that investigates the relationship between cognitive ability and decision under risk with two main goals. The first is to test whether the differences in the level of cognitive ability induce differences in decisions under risk. The second is to ask whether the availability of safe option plays a role in shaping these differences (if exist). A simple laboratory experiment was designed and implemented by using the *BRET* and $BRET_{safe}$ elicitation methods introduced by Crosetto and Filippin (2017) to test the hypothesis that the relationship between cognitive ability and risk aversion is not affected by the availability of riskless alternative. Our results revealed that there is a significant difference between high and low cognitive ability in risk aversion, where the high cognitive ability group is significantly taking more risk than the low cognitive group even in the availability of riskless alternative (safe option). Moreover, the availability of safe option causally induces both high and low cognitive ability to behave in taking more risk compared with their behavior in the absence of safe option.

Our findings supported that high cognitive ability groups take more risks even with a safe option available, and that the mere availability of a safe option can increase risk-taking in both high and low cognitive ability groups, which add a layer of complexity to our understanding of risk behavior. These results imply that cognitive ability affects not only the evaluation of risk but also the tendency to engage in risk-taking, regardless of the safety nets provided. This has profound implications for fields ranging from behavioral economics to finance and insurance, where understanding the drivers of risk behavior can inform better policy and product design. Our results can alert decisions makers in several sectors for instance in the financial sector, understanding the correlation between cognitive ability and risk aversion can lead to more personalized financial advice, where investment strategies are tailored to an individual's cognitive profile. In the realm of public policy, these insights can inform the design of educational programs that enhance decision-making skills and abstract thinking, particularly in managing risks and uncertainties. Moreover, insurance companies could use these findings to develop new products or adjust premiums based on cognitive risk profiles.

Limitations and future research

The study's scope was constrained due to the sample consisting solely of students from an Egyptian private university. For a more comprehensive understanding, it is recommended that the study be replicated with diverse participant groups across various societal contexts. Additionally, factors such as cognitive load and real effort were not accounted for in our research. Future studies should consider these elements, as they may significantly influence the participants' responses to risk, potentially altering the outcomes. Finally, we are urging researchers to replicate this study with different elicitation tasks and different cognitive ability tests and addressing the interplay of individual differences, cognitive processes, and the different demographical characteristic (e.g., financial income and field of study) that may enrich the understanding the role of safe option in shaping the relationship between cognitive ability and risk aversion.

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Appendix A: Percentile norms for Raven Colored Progressive Matrices for Adults from (16.5 – 68.4) years

	Age from 16.6 – 68.4 years												
Percentile Rank	16.5 - 20.4	20.5-24.4	24.5-28.4	28.5-32.4	32.5-36.4	36.5-40.4	40.5-44.4	44.5-48.4	48.5-52.4	52.5-56.4	56.5-60.4	60.5-64.4	64.5-68.4
95	30	31	31	32	32	33	33	34	35	34	32	30	28
90	29	30	30	31	31	32	32	33	34	33	31	29	27
75	28	29	29	30	30	31	31	32	32	31	29	27	25
50	27	28	28	29	29	30	30	31	31	30	26	24	21
25	25	26	26	28	28	29	29	30	30	28	23	17	16
10	19	20	21	22	23	24	24	25	25	17	15	14	21
5	15	16	16	17	18	19	19	20	20	14	13	12	10

Appendix B: Arabic version of BRET instructions with Egyptian colloquial

- في البداية أحب أوجه الشكر لكم جميعاً لأنكم وافقتم على الاشتراك في التجربة.
- أحب أقولكم إن الهدف من التجربة العلمية دي أننا نتعرف على اتجاهكم نحو المخاطرة. والتجربة دي ضمن سلسلة من التجارب العلمية اللي بتهدف لنشر سلسلة من الأبحاث في مجال Behavioral Finance.
- وأحب أقول ان جميع بيانات المشاركين في التجربة هي بيانات سرية ونتعهد بعدم نشرها بأي وسيلة من الوسائل. وكل اللي هيتم نشره بس هي نتائج التجربة بدون أي إشارة او تلميح بأي بيانات شخصية للمشاركين في هذه التجربة.
- قدامك على شاشة الكمبيوتر اللي قدامك مربع متقسم لـ ١٠٠ صندوق صغير. تحت واحد من الصناديق دي فيه لغم مستخبي؛ وباقي الـ٩٩ صندوق مفيهومش أي الغام.
- انت متعرفش اللغم ممكن يكون تحت انهو صندوق. الحاجة الوحيدة اللي تعرفها أن اللغم ممكن يكون تحت أي صندوق من الصناديق الموجودة في المربع اللي قدامك يعني من الصندوق رقم ١ الى الصندوق رقم ١٠٠ بنفس الاحتمال.
- بعد ما تضغط على زرار "ابدأ" الموجود تحت المربع اللي قدامك هتبدأ اللعبة. وفي كل ثانية هيتجمع فيها صندوق من فوق عالشمال بالترتيب. وكل صندوق هتجمعه هتكسب ٢ جنيه.
- اول ما الصندوق يتجمع هيختفي من على الشاشة. وبالتالي، المبلغ اللي هتكسبه هيظهرلك جمب كلمة "المبلغ". في أي لحظة تقدر تشوف المبلغ اللي ممكن تكسبه على الشاشة.
- بس المبلغ اللي هتوصله ده مبلغ احتمال تاخده واحتمال متخدوش. لان فيه احتمال يكون اللغم ورا واحد من الصناديق اللي انت جمعتهم وبالتالي دا ممكن ميخلكش تاخد المبلغ وتخسر.
- كمان لو انت جمعت الصناديق ووقفت اللعبة في أي وقت، وكان ورا واحد من الصناديق دي اللغم مش هتعرف رقم الصندوق اللي كان وراه اللغم الا في اخر التجربة.
- المطلوب منك بس إنك تقرر امتى هتوقف تجميع الصناديق. ودا مش هيحصل الا لما تدوس على زرار "ايقاف" تحت المربع في الوقت اللي انت عايزه.
- بعد ما التجربة تخلص. هتتفضل مشكوراً تخرج من المعمل من الباب المخصص للخروج. وبعد ما تخرج هتلاقي حد مستنيك بصندوق فيه ورق مكتوب عليه ارقام من ١ لـ١٠٠ بشكل عشوائى.
- انت مش هتكون شايف الأرقام وهتسحب ورقة بشكل عشوائي والرقم المكتوب هو اللي هيحدد رقم الصندوق اللي وراه اللغم.
- لو حصل والرقم اللي انت وقفت عنده في اللعبة واللي بيعبر عن عدد الصناديق اللي انت جمعتها كان أكبر من او يساوي الرقم اللي على الورقة اللي انت اختارتها بشكل عشوائي، مش هتاخد المبلغ اللي ظهرلك على شاشة الكمبيوتر.
- أما لو حصل والرقم اللي انت وقفت عنده في اللعبة واللي بيعبر عن عدد الصناديق اللي انت جمعتها كان اقل من الرقم اللي على الورقة اللي انت اختارتها بشكل عشوائي هتاخد المبلغ اللي ظهر قدامك على الشاشة واللي هوه عبارة عن عدد الصناديق اللي انت جمعتها مضروبه في ٢ جنيه.
- هنبدأ نعمل تجربة دلوقتي علشان نتاكد إنك فاهم اللعبة. بعدها اللعبة هتبدأ.

Appendix C: English version of BRET instructions

- Firstly, I would like to thank all of you because you agreed to participate in the experiment.
- I would like to tell you that the goal of this scientific experiment is to learn about your tendency toward risk. This experiment is part of a series of scientific experiments that aim to publish a series of research in the field of Behavioral Finance.
- I would like to say that all data of participants in the experiment is confidential, and we pledge not to publish it by any means. All that will be published are the results of the experiment, without any reference or hint to any personal data of the participants in this experiment.
- On the computer screen in front of you is a square divided into 100 small boxes. Under one of these boxes there is a mine hidden; The remaining 99 boxes do not contain any mines.
- You don't know, mine might be under a box. The only thing you know is that the mine could be under any of the boxes in the square in front of you, meaning from Box No. 1 to Box No. 100 with the same probability.
- After you press the “Start” button located under the square in front of you, the game will start. Every second, a box will be collected from above to the left in order. For every box you collect, you will earn 2 pounds. You can win it on screen.
- But the amount you will receive is an amount that you are likely to take, and you are likely to not be scratched. Because there is a possibility that the mine is behind one of the boxes that you collected, and therefore this may not allow you to take the money and lose.
- Also, if you collected the boxes and stopped the game at any time, and there was a mine behind one of the boxes, you will not know the number of the box that had the mine behind it until the end of the experiment.
- You are only required to decide when you will stop collecting boxes. This will not happen unless you press the “Stop” button under the box at the time you want.
- After the experiment is over. You will be kindly requested to exit the laboratory through the designated exit door. After you leave, you will find someone waiting for you in a box containing paper with numbers from 1 to 100 written on it randomly.
- You will not see the numbers, and you will draw a paper randomly, and the written number is what will determine the number of the box that the mine saw.
- If it happened that the number you stood at in the game, which represents the number of boxes you collected, was greater than or equal to the number on the paper that you chose randomly, you will not take the amount that appeared to you on the computer screen.
- But if it happened that the number that you stood at in the game, which expresses the number of boxes that you collected, was less than the number on the paper that you chose randomly, you will take the amount that appeared in front of you on the screen, which is the number of boxes that you collected multiplied by 2. fairy.
- We will start an experiment now to make sure that you understand the game. Then the game will start.

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Appendix D: Demographic information screen