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The Cognitive Reflection Test and Numeracy as a Predictor of Students' Choice of Major in Undergraduate Programs *

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IL TEST COGNITIVO DI RIFLESSIONE E L'ABILITÀ DI CALCOLO COME PREDITTORE DELLA SCELTA DEGLI STUDENTI NEI PROGRAMMI UNIVERSITARI

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Abstract

Currently, choosing a field of study is one of the most important decisions people make. In this regard, the existence of individual differences can affect the decision-making process, as several studies have shown the influence of cognitive bias on how individuals make decisions and employ the process of judgment, which depend on their cognitive abilities. The purpose of this study is to examine the predictive features of the Cognitive Reflection Test and numeracy skills for the probability of choosing a field of study for first-year college students at University of Tabriz. For this purpose, by using a simple random sampling method, a number of 117 freshmen from the faculties of Medicine, Engineering, Humanities, and Economics at the University of Tabriz were selected, and two cognitive reflection and numeracy tests were conducted with them. The results of the regression analysis showed that higher CRT and numeracy have a positive and significant effect on choosing a field in engineering and pharmacy faculties.

Keywords: Cognitive Reflection Test; College students; Field of study; Numeracy; Prediction.

1. Introduction

People are inherently different in some features, and these differences affect the quality of their decision-making as well as judgment processes. Over the past decades, there has been a dramatic interest in analyzing and reviewing these differences (Weber & Johnson, 2009) information integration, and learning, decision research over the past 10 years has also examined the effects of goals, mental representation, and memory processes. In addition to deliberative processes, automatic processes have gotten closer attention, and the emotions revolution has put affective processes on a footing equal to cognitive ones. Psychological process models provide natural predictions about individual differences and lifespan changes and integrate across judgment and decision making (JDM). Due to the complexity and interdisciplinary nature of this issue, one needs to adopt multiple approaches to better understand this phenomenon. With the introduction of cognitive sciences as the main approach, this branch of science has explored these differences from the perspective of the inner processes of the mind, such as problem-solving, perception, cognition, and decision-making.

Since cognitive science deals with the scientific study of the mind, scientists look at the mind as a processor of information (Friedenberg & Silverman, 2006). Cognitive science may impact any discipline related to human actions. The cognitive approach attributes the observed behavior to inner cognition and considers human beings to be a processor of information and problem-solver. Meanwhile, the information entering the mind may not be properly processed, leading to cognitive biases and distortions, and the extent and range of these errors can be a function of individuals' cognitive abilities (Liberali *et al.*, 2012).

Recognition of the thinking or processing systems in humans can offer deep insight into these cognitive biases. Kahneman (2003), by providing different processing systems for humans, has highlighted many of the non-conformities of behavior with the principles of conventional rationality. He divides the human processing system into intuitive and reasoning systems and states that the main characteristic of an agent is not always acting on the basis of reasoning, but often acting based on an intuitive processing system. In other words, these two systems are alternative ways to solve problems faced by individuals. The first system acts on the basis of habit and is thus difficult to modify and monitor; in contrast, the performance of the second system is relatively flexible and regular (Kahneman, 2003). The task of the first system is to answer and deliver results without hesitating and editing, thereby offering propositions constantly produced in the human brain; meanwhile, the task of the second system is laborious and energetic. The cognitive system presented by Kahneman is illustrated in *Figure 1*.

Different names are assigned to these two types of processing systems, such as experimental-rational (Epstein, 1994), associative-regulatory (Sloman, 1996), and System 1 - System 2 (Stanovich & West, 2000).

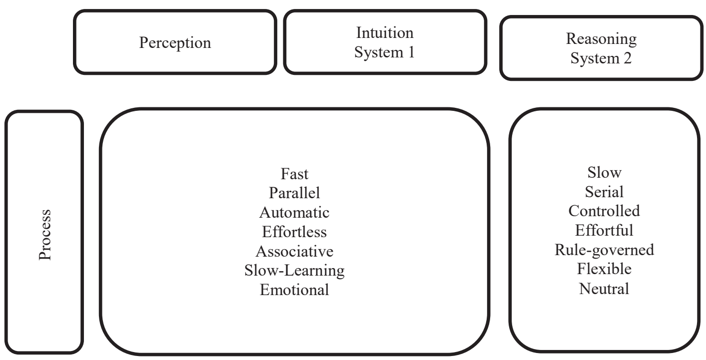

Figure 1. – Cognitive system (Source: Kahneman, 2003).

In order to evaluate the cognitive ability of individuals, the Cognitive Reflection Test (CRT) was designed by Frederick (2005). Questions related to CRT are given in *Table 1*. At first glance, the answers to these questions seem clear, but in fact the purpose of designing these cognitive questions is measuring the degree of lure in individuals and their resort to intuitive responses or willingness to think analytically, i.e. checking responses based on the first or second systems.

Table 1. – CRT.

(1)	A bat and ball cost \$1.10 in total. The bat costs \$1.00 more than the ball. How much does the ball cost? ---- cents
(2)	If it takes 5 machines 5 minutes to make 5 widgets, how long would it take 100 machines to make 100 widgets? ---- minutes
(3)	In a lake, three is a patch of lily pads. Every day, the patch doubles in size. If it takes 48 days for the patch to cover the entire lake, how long would it take for the patch to cover half of the lake? ---- days

In response to the first item, for instance, the first number coming to mind is probably 10 cents. This response is just a quick, satisfying, and incorrect hunch. The accurate revision and analysis of the first response indicate that if the ball is worth 10 cents, then the total price will be 1 dollar and 20 cents (10 cents for the ball, 1 dollar and 10 cents for the racquet), and not 1 dollar and 10 cents. Therefore, the correct response will be 5 cents.

In his experiments on university students in the USA, Frederick showed how people with high CRT (faster reaction times are correlated with longer lifetimes and higher earnings) and low CRT used System 2 and System 1 to answer to the three issues raised, respectively (Frederick, 2005). He also concluded that individual differences in having high or low CRT plays an important role in how people decide and judge (Cokely & Kelley, 2009; Campitelli & Labollita, 2010; Hoppe & Kusterer, 2011).

In addition to cognitive reflection ability like CRT, numerical skill and numeracy are other cognitive abilities influencing the process of decision-making. Numeracy refers to the ability, recognition, and use of numbers, knowledge of statistics and basic probabilities, four main actions in elementary arithmetic (addition, subtraction, multiplication, and division), and the perception of fraction and percentage. This cognitive skill includes 11 questions designed by Lipkus (Lipkus, Samsa, & Rimer, 2001). Numeracy has different applications for daily tasks such as medical decisions (risk of disease and surgery), insurance purchases, and loans. It is also suggested that low numeracy knowledge can increase the sensitivity to types of cognitive bias and false arguments in individuals in different situations. Usually, people are divided into two categories, having high numeracy (numerate) or low numeracy (innumerate) knowledge, showing that individuals have different numerical skills and numeracy, affecting their decision-making (Peters *et al.*, 2006; Reyna & Brainerd, 2008).

It seems that the performance of individuals in cognitive skills such as CRT and numeracy can act as a suitable predictor for choosing the field of study. Various studies have emphasized on the predictive value of performance on CRT, including the prediction of religious belief (Browne *et al.*, 2014), belief in paranormal phenomena (Pennycook, Fugelsang, & Koehler, 2015), correlation with many standard heuristics-and-bias tasks (such as belief bias in syllogistic reasoning, framing effect, and temporal discounting) (Frederick, 2005; Toplak, West, & Stanovich, 2014); impulsivity (Toplak, West, & Stanovich, 2011), thoughts, moral judgment, and creativity (Pennycook, Fugelsang, & Koehler, 2015). Also, several studies have demonstrated that students' satisfactory performance on CRT can be a strong predictor of their performance in mathematics which can be attributed to the greater use of the second system compared with the first system (Gómez-Chacón *et al.*, 2014).

On the other hand, some studies have used numeracy to predict the performance and behavior of individuals regarding the correct assessment of risk (Reyna *et al.*, 2009), the quality of decision-making in choices (Hanoch *et al.*, 2010), and being caught up in some traps of cognitive bias such as the framing effect (Peters, Hart, & Fraenkel, 2011)

One of the most important decisions individuals are faced with after completing high school is choosing a field of study, both because it is both socially and economically important (Humphries, Schrøter, & Veramendi, 2017) and because the result of this decision will have a significant impact on their future (Daymont *et al.*, 2014). The choice of the field of study can be influenced by several factors, including the individual's interest (Fricke, Grogger, & Steinmayr, 2018), personality traits (Humburg, 2012), and cognitive abilities (Päßler & Hell, 2012).

2. Present research

The present study intended to examine the predictive value of CRT and numeracy for choosing the field of study for first-year college students at the University of Tabriz (Iran). The general question of the present study was whether students' performance on CRT and numeracy could be a strong predictor of their choice of field of study? This question was answered in two experiments. In the first experiment, the predictive features of the Cognitive Reflection Test and, in the second experiment, the predictive feature of the numeracy test were evaluated.

Prior to commencing the study, ethical clearance was sought from the Ethics Committee of the University of Tabriz. The permit was registered as IR.TBZMED.REC.1397.027 on the National Research Ethics Committee. The participants were reminded that participation in the study was voluntary, that their answers were completely confidential, and no one would have access to their responses.

3. Results

3.1. *CRT*

In this study, to assess the cognitive ability of students at different colleges of the university, the CRT test was administered according to the method described by Frederick (2005).

The random sampling method was used for selecting undergraduate students from the faculties of medicine, engineering, mathematics, economics, and social sciences (humanities) at the University of Tabriz. The research sample consisted of 117 students (59 female and 58 male) aged between 17 and 31 years old. Moreover, two of the participants were 43 and 46 years old (M = 21.2, SD = 3.82).

Table 2 shows the scores obtained and correct answers provided by participants on the CRT. The score of this test represents the number of correct answers provided by students for three questions. For example, score 2 indicates that the student has correctly answered only two questions out of three.

Table 2. – CRT scores by faculty.

Faculty	Mean score on CRT	Low CRT ≈ System 1 (Intuitive)		High CRT ≈ System 2 (Reasoning)		N
		0	1	2	3	
Economics	0.69	61.5%	15.4%	15.4%	7.7%	13
Mathematics	0.54	53.8%	38.5%	7.7%	0.0%	13
Engineering	1.33	0.25%	33.3%	25.0%	16.7%	24
Social Science	0.32	76.3%	18.4%	2.6%	2.6%	38
Medicine	1.45	24.1%	27.6%	27.6%	20.7%	29
Total	0.87	48.7%	25.6%	15.4%	10.3%	117

It is evident that the highest percentage of complete correct answers belonged to the medicine and engineering faculties. About 21% of students of the faculty of medicine correctly answered all three questions. In addition, about 17% of the students at the faculty o engineering provided correct answers to all three questions.

Overall, 48.3% and 41.7 % of students from the faculties of medicine and engineering correctly answered two or three CRT questions. It seems that these faculties are at the same level. The faculty of economics ranked the second, where 23.1% of students correctly answered the questions. The percentage of correct answers in the faculties of mathematics and social sciences equaled 7.7% and 5.2%, respectively.

Based on the results, students with a higher CRT ability may be more interested in pursuing the fields of medicine and engineering compared to economics, mathematics, and social science. Although students in the two fields of medicine and engineering scored higher on the CRT test, the important role of the intervening variables cannot be ignored.

3.2. *Numeracy test*

Eleven items were designed based on the method described by Lipkus *et al.* (2001) to assess students' numeracy, and participants were asked to answer these questions after the CRT test. The number of correct answers indicated numeracy performance. Thus, 11 was the highest score any student could earn, and if none of the 11 questions was correctly answered, a zero score would be assigned. *Table 3* presents the distribution of students based on their numeracy in different faculties. To summarize this table, the distribution of sample students based on their numeracy power and different faculties in two groups of high numeracy power and others is reported below. In this table, a high numeracy power is allocated to students providing correct answers to 10 questions out of 11 questions on the numeracy test.

The percentage of numeracy skill of students in engineering, medicine, and mathematics faculties is 70%, 69%, and 69%, respectively, showing the highest percentage from among faculties.

Next, to investigate the predictive role of CRT and numeracy for choosing a field of study by college students at the University of Tabriz, a discrete regression model (Multinomial Probit) suitable for qualitative dependent variables was used.

Table 3. – Numeracy scores by faculty.

Lipkus *et al.*'s (2001) Objective Numeracy Scale (NS)	Percentage of Correct Response				
Faculties	Economics	Mathematics	Engineering	Social Sciences	Medicine
1. Imagine that we roll a fair, six-sided dice 1000 times. Out of 1000 rolls, how many times do you think the dice would show an even number (2, 4, or 6)? Correct response: 500 Intuitive response: 0.5, 5, 50, 5000, 3000, 333.33	53%	62%	63%	58%	72%
2. In the Persian Lottery, the chance of winning a $1000 prize is 1%. What is your best guess about how many people would win a $1000? Correct response: 10 Intuitive response: 50, 1, 1000	67%	62%	42%	42%	61%
3. In the Persian Institute, the chance of winning a car is 1 in 1000. What percent of tickets of AB company win a car? Correct response: 10 Intuitive response: 0.001, 0.01, 10, 100, 1, 1000	33%	62%	71%	33%	83%
4. Which of the following numbers represents the biggest risk of getting a disease? 1 in 100, 1 in 1000, 1 in 10 Correct response: 1 in 10 Error response: 1 in 100, 1 in 1000	87%	100%	92%	94%	90%
5. Which of the following represents the biggest risk of getting a disease? 1%, 10%, 5% Correct response: 10% Error response: 1%, 5%	93%	85%	96%	83%	97%
6. If Person A's risk of getting a disease is 1% in 10 years, and Person B's risk is double that of A's, what is B's risk? Correct response: 2% Error: 1% in 5 years, 2% in 20 years	73%	92%	92%	72%	90%

7. If Person A's chance of getting a disease is 1 in 100 in 10 years, and Person B's risk is double that of A, what is B's risk? Correct response: 2 out of 100 Intuitive response: 1 out of 100 in 5 years, 1 out of 50 in 5 years, 2 out of 200, 2 out of 200 in 20 years	80%	92%	92%	53%	83%
8. If the chance of getting a disease is 10%, how many people would be expected to get the disease out of 100? Correct response: 10 Intuitive response: 1, 100	93%	92%	92%	75%	90%
9. If the chance of getting a disease is 10%, how many people would be expected to get the disease out of 1000? Correct response: 100 Intuitive response: 1, 10, 1000	67%	85%	88%	67%	83%
10. If the chance of getting a disease is 20 out of 100, this would be the same as having a ____ % chance of getting the disease. Correct response: 20 Intuitive response: 0.2, 2, 100/20	80%	92%	100%	81%	93%
11. The chance of getting a viral infection is 0.0005. Out of 10 000 people, approximately how many of them are expected to become infected? Correct response: 5 Intuitive response: 0.000005, 0.00005, 0.005, 0.5, 5, 50, 500, 5000	67%	100%	88%	42%	76%
Mean Score	7.93	9.23	9.13	7.03	9.14

3.3. *Discrete regression analysis*

In this section, using the Multinomial Probit model, the effect of CRT and numeracy variables of students is examined on the probability of choosing their field of study. The results of estimating of this model are reported in *Table 4*. It is noteworthy that age and sex variables entered the model as control variables; as results showed that these variables did not have a significant effect on choosing the field of study, they were excluded from the model.

In this estimation, the faculty of social sciences was selected as the base group, and the parameters must be interpreted and analyzed based on this assumption.

Table 4. – Results of the Multinomial Probit model.

Variables	Coefficients	Z Statistics	P-value	Marginal effect dy/dx
Economics				
CRT	0.35	1.35	0.17	-0.01
Numeracy	0.09	0.92	0.35	-0.01
Constant	-1.65	-2.11	0.03	
Mathematics				
CRT	0.04	0.13	0.89	-0.06
Numeracy	0.31	2.59	0.01	0.03
Constant	-3.31	-3.26	0.001	
Engineering				
CRT	0.72	3.09	0.002	0.09
Numeracy	0.22	2.19	0.028	0.02
Constant	-2.69	-3.19	0.001	
Social Sciences		Base outcome		
Medicine				
CRT	0.8	3.56	0.000	0.14
Numeracy	0.21	2.29	0.022	0.02
Constant	-2.61	-3.30	0.001	

The results of the Multinomial Probit method indicate that CRT and numeracy have no significant effect on the choice of field of study at the faculty of economics. These results reveal that an increase in the cognitive ability and numeracy of students does not have a significant effect on choosing the field of economics rather than social sciences, and the field of economics will not be prioritized, while other disciplines will be. In the faculty of mathematics, CRT did not have a significant effect on the probability of choosing the field of study, while numeracy had a positive and significant effect on the likelihood of choosing the field of study. Also, in faculties of engineering and medicine, CRT and numeracy had a positive and significant impact on the chance of choosing a field of study, suggesting that by increasing the cognitive ability and numeracy of students, the chance of choosing engineering and medicine disciplines increases.

Therefore, it can be concluded that cognitive ability and numeracy are important parameters in students' choice of the field of study. With increasing the CRT index, students tend to choose either medicine or engineering disciplines. The increase in this index does not have a significant effect on the choice of mathematics and economics.

Moreover, the result of estimating the Multinomial Probit model demonstrates that the effect of numeracy on the choice of academic field is another effective factor whose impact is slightly different from that of the CRT index. By increasing numeracy similar to the CRT index, the chance of choosing a field in medicine and engineering versus social sciences increases, and the chance of choosing the field of economics does not increase. The main difference between the numeracy index and the CRT is observed in mathematical disciplines, whereas raising numeracy index causes an increase in the chance of choosing mathematical disciplines in addition to increasing the likelihood of choosing a field in medical sciences and engineering.

The mean numeracy score for faculties of social sciences and economics was 7.3 and 7.93, respectively, which is almost in the same range. However, in the faculties of engineering, medicine, and mathematics, mean numeracy score was 9.12, 9.14, and 9.23, respectively. This result suggests that the mean CRT score must not differ significantly in social sciences, economics, and mathematics. As shown in *Table 2*, the mean score of CRT for social sciences, mathematics, and economics equaled 0.32, 0.54, and 0.69, respectively. Although these numbers show a relative difference between the three faculties, the faculty of economics is at a higher level than the average CRT index, followed by the faculty of mathematics. It should be noted that the standard deviation of the three faculties is also ranked accordingly. The mean CRT index-to-standard deviation ratio was applied to compare the three faculties. The ratio for economics, mathematics, and social science was 2.4, 2.9, and 2.9, respectively, which is almost in the same range. At a higher level, the faculties of medical sciences and engineering were placed with an average CRT of 1.45 and 1.33, respectively.

To investigate the predictive power of the model, the students were divided into two groups according to the CRT index and also with regard to the significance of model coefficients. The first group comprised students with the first level of CRT, including students of economics, mathematics, and social sciences. The second group consisted of students in the second level of CRT in the faculties of medicine and engineering. The predictive power of the model is given in *Table 5*.

Table 5. – Multinomial Probit prediction.

	Model	Predication in the first level of CRT	Predication in the second level of CRT
Number of correct predictions	85	48	37
Total observations	117	64	53
The percentage of correct predictions	72.65	75	69.81

Based on the calculations, from among the 117 field observations within the sample, the estimated model was able to correctly identify 85 items and its prediction power was more than 72%. Furthermore, at the first level of CRT, the model correctly estimated 75% of the observations, i.e, From among 64 students who chose the faculties of economics, mathematics, and social sciences, 48 students enrolled in this group of disciplines. This prediction power for the second group of students with a high CRT was about 70%.

4. Discussion

The purpose of this research was to examine the exploratory and predictive role of the two well-known cognitive skills, CRT and numeracy, on the choice of the field of study among first-year students of the University of Tabriz. It seems that this research is the first report in Iran, as the researchers did not find any study in this area, nor did any of the participants encounter such tests.

The operational analyses of students in these cognitive skills indicated a significant relationship between these two cognitive skills and their choice of field of study; individuals who had a better performance in the respective skills were generally attracted to the fields of medical sciences and engineering. Undoubtedly, the personality characteristics of individuals and their skills can be intervening variables affecting the results of this study. A major limitation of this study (known as the intervening variable) was intelligence that could have affected the results and should have been matched among participants. There are clearly further research agenda here, which could fruitfully be pursued. Of course, as previously noted, several individual or environmental factors are involved in choosing a university discipline, but our focus in this study was solely on the role of cognitive skills.

In this study, it was reasonable to expect students of mathematics to achieve the best performance in both cognitive skills, but the results indicated that they were superior only in numeracy. One possible explanation for this result can be that, during the course of their studies, students of mathematics practice this skill more than other disciplines. In other words, this skill is categorized in the acquiring skills group.

Fields such as economics, humanities, or even mathematics are not welcome by the public due to the intense competition among students on university entrance examinations and the desire of the vast majority of students in the choice of medical and engineering disciplines. As a result, people are attracted to the disciplines that gain relatively weak results in competing with popular groups. It seems that those who are attracted to medical and engineering disciplines tend to be more inclined to use analytical thinking in solving problems, which is synonymous with the ability to further develop the CRT skill. Considering the positive and significant relationship between the performance of medical and engineering groups in the CRT skill test, it seems that skill in this case test is completely inherent and may not have much to do with teaching. Finally, the predictive power of the model for observations inside the sample was about 72.6%, indicating a good predictive power.

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Riassunto

Attualmente, scegliere un campo di studio è una delle decisioni più importanti che le persone prendono. A questo proposito, l'esistenza di differenze individuali può influenzare il processo decisionale, infatti diversi studi hanno dimostrato l'influenza del pregiudizio cognitivo su come gli individui prendono decisioni ed esercitano il processo del giudizio, il quale dipende anche dalle loro capacità cognitive. Lo scopo di questo studio è quello di esaminare le caratteristiche predittive del test sulla riflessione cognitiva e le abilità di calcolo sulla probabilità di scegliere un campo di studi da parte degli studenti del *primo anno dell'Università di Tabriz. A tale scopo, utilizzando un semplice metodo di campionamento casuale, sono stati selezionati un totale di 117 matricole delle facoltà di Medicina, Ingegneria, Scienze Umane ed Economia dell'Università di Tabriz e sono state condotte due prove di riflessione cognitiva e di calcolo. I risultati dell'analisi di regressione hanno mostrato che un coefficiente di riflessione cognitiva (CRT) e una abilità numerica più elevati hanno un effetto positivo e significativo sulla scelta del campo di studio nelle facoltà di ingegneria e farmacia.*

Parole chiave: Abilità numerica; Campo di studio; Previsione; Studenti universitari; Test di riflessione cognitiva.

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