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NUMERACY AND LOGICAL ABILITIES IN COGNITIVE HEURISTICS AND BIASES

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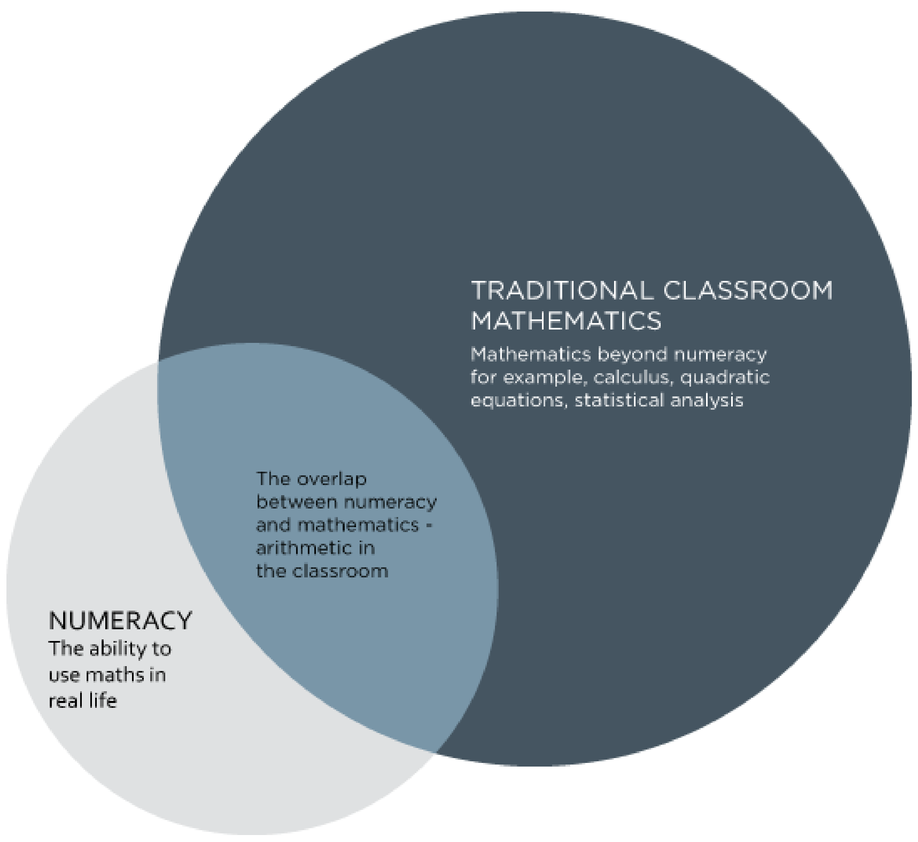

Image 1: What is Numeracy? Numeracy does include significant aspects of what is taught in school mathematics but it also includes skills that many feel are not adequately learnt in the classroom - the ability to use numbers and solve problems in real life (from http://www.nationalnumeracy.org.uk).

Introduction

The current research presents the empirical approach in order to establish relations between the most well-known heuristics and biases on one hand, and numeracy and logical abilities on the other.
Over the years, many studies conducted by such psychologists as Daniel Kahneman, Amos Tversky and Paul Slovic have demonstrated the presence of heuristics and biases in people's decision making. A cognitive bias is the human tendency to make systematic decisions in certain circumstances and often violate the assumptions of rationality as ruled by logic, statistics, expected utility theory or other normative models of rational decision making (Simon, 1955). Instead of making decisions or judgments based on those models, humans tend to use heuristics that sometimes lead them to commit systematic errors or biases (Tversky & Kahneman, 1974, 1983).
Daniel Kahneman proposed the general concept of cognitive thinking – the dual process theory, where he described two different kinds of thinking: System 1 (intuition) and System 2 (reasoning). Compared to System 2, System 1 performs fast and usually influenced by emotional bonds. This intuition system is more similar to associative reasoning and it could be described as an automatic and unconscious process. Instead, System 2 is a conscious process and therefore slower. This system allows the abstract hypothetical thinking that is not permitted in System 1 and is distinct to humans.
The current research shows an empirical approach in order to study underlying cognitive mechanisms of the numerical or logical abilities related to System 2 process.
Numeracy can briefly be explained as the ability to process basic probabilities and numerical concepts (Peters, 2006). Just as literacy affects the way we process information from written words, numeracy affects how we process information from numbers. At its core, numeracy refers to one's ability to represent, store, and accurately process mathematical operations (Dieckmann, 2007; Peters et al., 2006). As with all complex skills, individual differences in numeracy reflect interactions of many cognitive and affective mechanisms.
Logical abilities are measured with the Watson Glaser Critical Thinking Test (WGCT). The WGCT was defined by Watson and Glaser (1980) as a composite of attitudes, knowledge and skills. This study is an essential component of precise communication, problem-solving ability, theoretical and conceptual understanding of concerns.

Aims

Using a statistical explorative analysis, we intend to investigate the role of individual differences in System 2 process using numerical and logical concepts. Aims of our research were divided into two steps:
1) investigate the relationship between numeracy and logical abilities;
2) explore biases and heuristics more connected to the System 2 and to the numeracy and logical abilities.

Participants and Procedure

197 subjects took part in the research. Participants come from the simulation Stock Market Learning and they had the minimum mathematical knowledge required to complete the survey. Heuristics and biases have been tested by using the same classical experiments drawn from the dedicated scientific literature. Starting from several empirical cognitive studies (Bruine de Bruin, Parker, & Fischhoff, 2007; Frederick, 2005; Slugoski, Shields, & Dawson, 1993; West, Toplak, & Stanovich, 2008), and considering the most important heuristics (Tversky & Kahneman, 1974) and several classifications of biases (Carter, Kaufmann, & Michel, 2007; Stanovich, Toplak, & West, 2008), 22 heuristics and biases and the connected tasks-experiments used to identify them have been extracted (see Table 1 on the right).
Numeracy includes essential skills such as solving problems, understanding and explaining the solutions, making decisions based on logical thinking and reasoning, and interpreting data, charts and diagrams. In our research, numeracy has been tested by using the Berlin Numeracy Test (BNT) (Cokely, Galesic, Schulz, Ghazal, & Garcia-Retamero, 2012) and the Subjective Numeracy Scale (SNS) (Fagerlin et al., 2007). The Berlin Numeracy Test is a psychometrically sound instrument designed to quickly assess statistical numeracy and risk comprehension in educated samples.
As for the logic abilities, the WGCT has been used (Watson & Glaser, 1980).
An explorative statistical analysis has been applied in order to determine the relations between heuristics and biases and the skills investigated. Some relations between statistical biases and numeracy have been found (see Table 2).

FALLACIES	DEFINITIONS
Anchoring heuristic	It drives people to be dependent in judgment and valuations by a reference point.
Aversion to ambiguity	Decision makers dislike ambiguity
Availability heuristic	This disposition drives people to consider what is more available in their mind.
Base rate fallacy	It is the tendency to ignore base rate in favor of representativeness.
Confirmation bias	It is a tendency that induces people to prefer information that confirms their hypothesis and to avoid contrary possibilities.
Conjunction fallacy	The conjunction fallacy is a violation of a logical norm and occurs when representative events are considered more probable than they really are.
Distinction bias	When people make predictions or choices, they could be influenced by the joint evaluation mode or the single evaluation mode.
Endowment effect	It is the tendency for people to evaluate something that they already own higher than it really is.
Framing	It is a phenomenon that influences people perception in decisions, on the basis of a positive or negative bordered context of decision.
Gambler's fallacy	It is an effect that induces people to consider small sequences of random processes influenced by previous changes.
Hyperbolic discounting	Hyperbolic discount functions induce dynamically inconsistent preferences, implying a motive for consumers to constrain their own future choices.
Information bias	This bias is due to an irrational management of information, in particular when a plus researched information does not provide to a better choice.
Loss aversion	It is the tendency to strongly prefer avoiding losses to acquiring gains.
Opportunity cost	Opportunity cost is the cost of the option not chosen; in general it drives people to give a higher value at the choice already chosen.
Prominence effect	Prominence effect appears when an option presents a prominent attribute that influences the preferences regardless of a direct comparison between options.
Pseudo certainty effect	It is an effect seen in choices that induces people to see an outcome as more certain than it really is.
Reference price	It is the tendency to assign a price of an object on the basis of the context. It derives by Anchoring heuristic.
Regression toward the mean	It is a phenomenon that induces people to not consider the effect of randomness in a set of chances.
Sunk costs fallacy	In economy, sunk costs are parts of a budget already sustained and often high valued that could compromise the future management of budget.
The extra-cost effect	It is an effect that drives people to consider a certain sum more important than it is because already sustained.
Representative bias	It is the disposition to violate the Bayesian calculation of probability in front of a different and more representative option.
Zero risk bias	It is a bias that induces people to avoid any form of risk and to strongly prefer option that could eliminate any type of threat.

		Berlin Numeracy Test	Subjective Numeracy Scale
Distinction bias	*r.*	**.326**	.192
	p.	**.021**	.181
Framing	*r.*	**.400**	-.142
	p.	**.004**	.327
Loss aversion	*r.*	**-.189**	-.244
	p.	**.059**	.287
Endowment effect	*r.*	**-.458**	-.190
	p.	**.001**	.186
Opportunity costs	*r.*	**-.165**	**-.267**
	p.	**.052**	**.060**
Gambler's fallacy	*r.*	**-.305**	**-.282**
	p.	**.031**	**.047**
Information bias	*r.*	-.145	**-.333**
	p.	.315	**.018**

Table 2: Correlations among heuristics and biases and scores of BNT and SNS.

Results and discussion

Results show the presence of a correlation between the BNT score and the SNS score ($r = .21$, $p < 0.05$). The WGCT showed no significant correlations with the numeracy tests and the heuristics and biases tasks. Interesting relations were found between some fallacies and the numeracy tests. In particular, positive correlations were found between the Framing effects (Framing and Distinction bias) and the BNT score. Instead, negative correlations were found with loss and costs fallacies (Loss Aversion, Opportunity Costs, Endowment effect). The SNS showed a correlation with the Information bias. Both showed negative correlation with the Gambler Fallacy.
All results related to numeracy skills and heuristics and biases are perfectly arguable. Successive research will find explanations for these first preliminary results.

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