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***Navigating through Cognitive Biases: Design of a Tool
for Managers and Researchers***

SINTESI

RELATORI

Prof. Antonella Martini
*Dipartimento di Ingegneria dell'Energia,
dei Sistemi, del Territorio e delle Costruzioni*

Ing. Filippo Chiarello
*Dipartimento di Ingegneria dell'Energia,
dei Sistemi, del Territorio e delle Costruzioni*

CANDIDATO

Valentina Sale
v.sale1@studenti.unipi.it

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Navigating through Cognitive Biases: Design of a Tool for Managers and Researchers

Valentina Sale

Sommario

Al giorno d'oggi sono numerosi i temi di ricerca che stanno conoscendo una crescita continua del numero di pubblicazioni, rendendo difficile agli utenti interessati rimanere al passo con il loro avanzamento e aggiornamento. Su questi presupposti si basa il presente lavoro di tesi, che ha lo scopo di progettare e sviluppare uno strumento di navigazione e analisi di temi di ricerca complessi, al fine di renderne più agevole la conoscenza e l'approfondimento. Lo strumento è stato progettato per essere replicabile, di facile utilizzo e completo nell'analisi dell'argomento scelto. Le funzionalità proposte sono state progettate a seguito di una previa profilazione degli utenti target, individuati da un lato nei manager e dall'altro nei ricercatori. Al fine di illustrare sia la metodologia di progettazione e sviluppo, sia le potenzialità offerte dallo strumento, è stato scelto un argomento di ricerca che sta suscitando un notevole e crescente interesse, sia in ambito accademico, che industriale ed è, quindi, un candidato ideale come tester per lo strumento. L'argomento scelto per il caso studio riguarda i bias cognitivi. Lo strumento sviluppato è liberamente accessibile al seguente indirizzo https://valentinas.shinyapps.io/dashboard_bias/.

Abstract

Nowadays, there are many research topics that are experiencing a continuous growth in the number of publications, making it difficult for interested users to keep up with their progress and updating. This is the basis of this thesis work, which aimed at designing and developing a tool for the navigation and analysis of complex research topics, to facilitate the knowledge and investigation of these arguments. The tool has been designed to be replicable, intuitive, and complete in its treatment of the chosen topic. The proposed functionalities were designed following a careful profiling of the target users, identified on the one hand as managers and on the other as researchers. To exemplify the design and development methodology, and the potential offered by the tool, a research topic has been chosen that is currently arousing considerable interest both in academia and industry and is therefore a perfect candidate to be analysed and proposed through the tool. The chosen topic is cognitive bias. The interactive dashboard is accessible from the web, at the address https://valentinas.shinyapps.io/dashboard_bias/.

1. Project Context

This thesis is the result of a project activity to design and develop a tool for the use of valuable data and information on a topic of interest. The aim of the tool is to enable the analysis of complex topics in a fast, intuitive, and navigable way for its users. The most important step in the tool development is the profiling of the user, thanks to which it is possible to identify the needs that will have to be satisfied through the characteristics and potential of the tool itself. The target users of this work have been identified in the managers on one side and in the researchers on the other side. Furthermore, the methodology proposed for the design and development of the tool is intended to be as general and replicable as possible, regardless of the chosen topic. To exemplify the design and development methodology, and the potential offered by the tool, a research topic has been chosen that is currently attracting considerable interest in both the academic and industrial fields and is therefore a perfect candidate to be analysed and offered through the tool. The chosen topic is *cognitive biases*.

Cognitive biases are, by definition, systematic patterns of deviation from norm, leading to irrationality in judgment. They are common to all human beings, often without their awareness, affecting their judgment capabilities, decisions, feelings, perceptions, and thoughts.

Cognitive Bias phenomenon has grown significantly in the last decades, capturing the attention of both academia and industry.

The growing interest in the subject is demonstrated by the rising number of

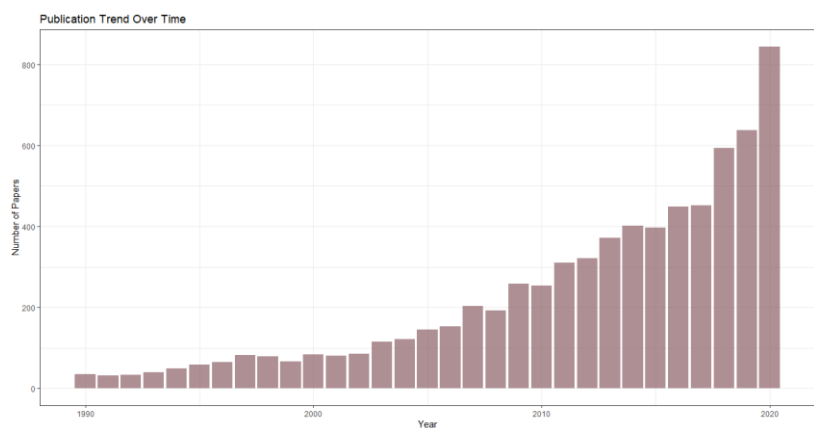


Figure 1. Time trend in scientific publication

scientific articles (see Figure 1), making the field vast and in-depth but also difficult to analyse and study using traditional methods. The literature on cognitive bias counts more than 63,000 scientific articles to date. The topic therefore lends itself to being analysed, synthesised, and offered through a tool that can summarise and offer insights, and analysis in an intuitive and rapid manner to all those interested in learning more about the subject.

2. Project Scope and Objectives

The objective of this work is twofold: on the one hand, a literature review was conducted to extract in-depth and scientifically accurate information about the status of the research, using an academic methodological approach; on the other hand, an interactive and dynamic tool was developed to disseminate the information obtained in an intuitive and navigable way, both to academia and to industrial world. The two objectives of the work must be seen as two sides of the same coin, as the link between them is strong and consequential. Indeed, the tool needs data and information to be valuable for its users, and these data and information needs to be gathered in a solid and efficient way, proper of the research field.

To achieve the twofold objective of the thesis, different solutions and methods have been used. Table 1 shows the macro phases to the objectives of the work.

Phase	Methodology	Outcomes	Thesis chapter
(1) State of the Art	Literature analysis	Selected papers	Chapter 2
(2) Scoping Review	Text-Mining	Graphs, Insights	Chapters 3 and 4
(3) Tool Design	Shiny R	Tool Prototype	Chapters 3 and 4

Table 1. Work Phases

3. Phase 1: State of the Art

The first phase involved the collection of scientific articles that could provide information about the state of the art of research on cognitive bias, to highlight the limits and potentialities that exist to date.

3.1 Methodology

The methodology followed in this phase is composed of two steps: the first one concerns the search for articles in the field of interest through query and interrogation of the Scopus database, while the second one concerns the reading and manual analysis of the documents found to build a picture of the literature of interest.

3.2 Results

The results of this phase were divided into three sections: a first section dedicated to the literature on cognitive bias as a phenomenon, a section dedicated to the studies conducted to classify biases, and a final section dedicated to the potential of text mining for literature review.

3.2.1 Literature on Cognitive Biases

Kahneman and Tversky, the first scientists who have studied cognitive biases as they are known, have brought the knowledge of bias to everyone, defining it, and making it known to the rest of the scientific community first and then to the public. Their scientific works¹ represent the foundations of knowledge on biases and paved the way to the following research activities which produced the tens of thousands of papers written until today. The granularity achieved by research activities conducted on cognitive biases has reached a very low level, producing papers focused on one or few biases at a time, in specific situations or fields, thus addressing the attention to a very single aspect of the broad field (e.g., Ely et al.²). The field is, indeed, broad enough not to be understood and analysed in a single picture, leading to the need of dividing it into single smaller problems to manage.

3.2.2 Literature on Classifications and Taxonomies

Nevertheless, the literature misses a unique structure, organized in classes, as inclusive as possible that would help further research activities to be standardized. Several attempts of classification are found in the literature, and they are of two types, qualitative and quantitative. Most existing taxonomies belong to the qualitative dimension of analysis, and they are typically explanatory works, meaning that they organise biases according to the reason they occur, considering cognitive mechanisms and explanatory reasons (e.g., Dimara et al.³). By analysing some of these papers there is a major deficiency, represented by a lack in the link among works. The different domains working on defining a valuable taxonomy for biases might work together the most to improve the knowledge in the field and to bring benefits to all the researchers interested in the phenomenon.

3.2.3 Literature on Text Mining

Besides, conducting literature reviews is becoming increasingly time consuming, due to the growth of sources from which to extract information, typically in text format (Ananiadou et al.⁴). Text mining can be seen as the solution to these problems, allowing huge amounts of

¹ Tversky, A., & Kahneman, D. (1974). Judgment under uncertainty: Heuristics and biases. *Science*, 185(4157), 1124-1131.

² Ely, R. J., Ibarra, H., & Kolb, D. M. (2011). Taking gender into account: Theory and design for women's leadership development programs. *Academy of Management Learning & Education*, 10(3), 474-493.

³ Dimara, E., Franconeri, S., Plaisant, C., Bezerianos, A., & Dragicevic, P. (2018). A task-based taxonomy of cognitive biases for information visualization. *IEEE Transactions on Visualization and Computer Graphics*, 26(2), 1413-1432.

⁴ Ananiadou, S., Rea, B., Okazaki, N., Procter, R., & Thomas, J. (2009). Supporting systematic reviews using text mining. *Social Science Computer Review*, 27(4), 509-523.

textual data to be analysed in ways that would be manually difficult if not impossible, and analysing and organising the current literature on cognitive biases, since until today a total of zero paper includes a massive use of text analysis techniques in this field.

4. Phase 2: Scoping Review

The state of the art revealed that the literature on cognitive bias is now so vast that it cannot be analysed using classical manual review approach. Moreover, it is evident that the proposed classifications are not universally recognised or aligned, increasing the complexity and confusion on the topic. For this reason, the second phase of this work involved reviewing the literature using text mining techniques to extract data and information in a fast, scientific, and replicable way.

4.1 Methodology

The literature review methodology that has been chosen is Scoping Review (SR) (Arksey et al., 2005⁵), conducted on the literature on cognitive biases in management field. It has been chosen this review method because of its broader scope. Indeed, SR aims at mapping, identifying, and scoping relevant literature and at answering less specific research questions, giving the analysis a wider breath and a comprehensive and multi-dimensional view.

Figure 2 shows the process adopted and followed in the SR phase.

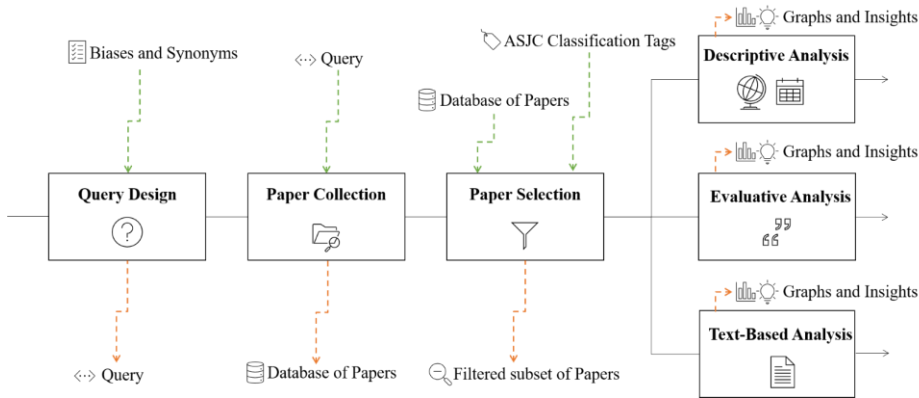


Figure 2. Scoping Review Process

⁵ Arksey, H., & O'Malley, L. (2005). Scoping studies: towards a methodological framework. *International Journal of Social Research Methodology*, 8(1), 19-32.

To conduct a SR, it is necessary to collect scientific papers to statistically analyse them. To obtain all and only the papers of interest it is necessary to build a good query. Hence, the query can be seen as a tool to discriminate between relevant literature and irrelevant literature. The quality of a query can be measured by means of two inversely proportional measures: *precision* and *recall*. In this work, precision has been chosen to be the most important parameter to maximise, settling a goal of 95%, to obtain a database of papers suitable and pertaining to the cause. Subsequently, to address a multi-dimensional review, a three-step analysis has been designed:

- (1) Descriptive analysis: it represents a top-down approach, aiming at identifying patterns of information and their evolution, both geographically, temporally and in terms of subject areas.
- (2) Evaluative analysis: it represents a bottom-up approach, is composed of typical bibliometric analysis techniques, based on the mapping of science. Specifically, two analyses are proposed, "co-citations" and "co-words".
- (3) Text-based analysis: it transforms data to extract useful information and facilitate the drawing of logical conclusions. The main scopes of this analysis have been to discover which biases were the most studied (i.e., word frequency analysis), which were studied together (i.e., pair frequency analysis), which was the magnitude of correlation between biases cited together (i.e., co-occurrence analysis), which groups could be created (i.e., clustering analysis), which was the trend in the discovering, research, and study on biases (i.e., trend evolution analysis).

All of the three steps have been conducted using text-mining techniques to propose an efficient and replicable method of analysis. The purpose of text-mining is to transform free, unstructured text in normalized, structured data suitable for analysis.

Another important role in this phase has been played by data visualization. Each analysis conducted, indeed, has been accompanied by visual representations and plots carefully chosen to enhance understanding and reaching intuitive insights of the results of the analysis itself.

4.2 Results

The results obtained from this phase of literature review allowed (1) to obtain a complete and in-depth picture of the state of progress of research on cognitive bias, and (2) to obtain data and information that can be interpreted and offered to the target users. Through the

analyses proposed it has been tried to assess the impact and the actual trend and direction of the research about cognitive biases. By means of a descriptive analysis first, followed by an analysis on the text, more evaluative of the content, was tried to lay the foundations for deeper and specific analyses.

Initially, a selection of areas to consider has been made, the purpose of this analysis was, to consider the impact of cognitive biases in fields concerning the *business (BUSI)* and *economics (ECON)* world, together with the *engineering (ENGI)* and the *decision science (DECI)* ones.

The research field on cognitive biases has grown up over time, from the first paper published in 1946 the publications have increased until today. Figure 3 shows, by means of a slope graph, the trend over time of the most prolific areas.

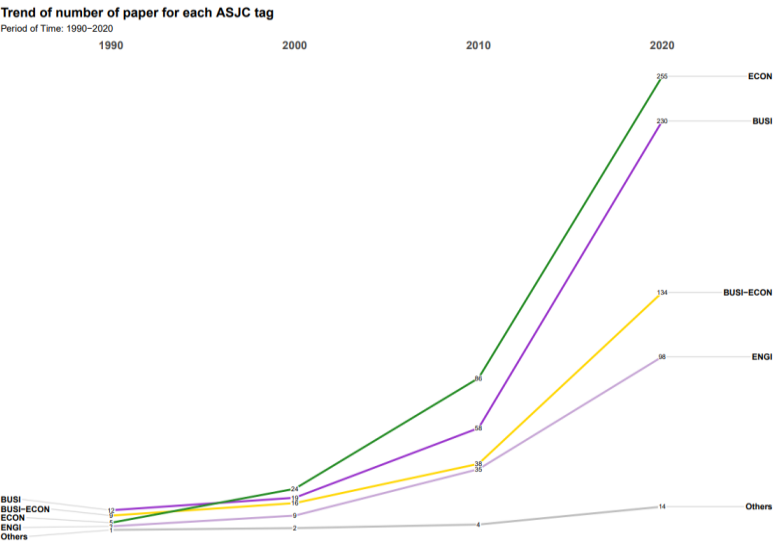


Figure 3. Slope graph showing trend over time

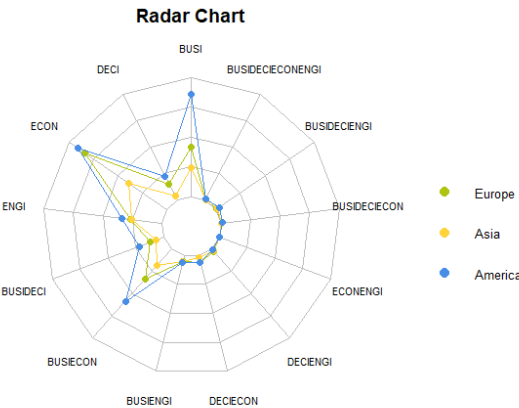


Figure 4. Radar chart with the distribution among the Continents

By geographical dimension, instead, America and Europe are the most prolific areas concerning a comprehensive view, followed by Asia. Figure 4 shows the distribution of research of the three most prolific continents.

The analyses conducted on the text allowed to gather information about the most studied biases in the areas of interest, how they are correlated, which biases occur together and how they can

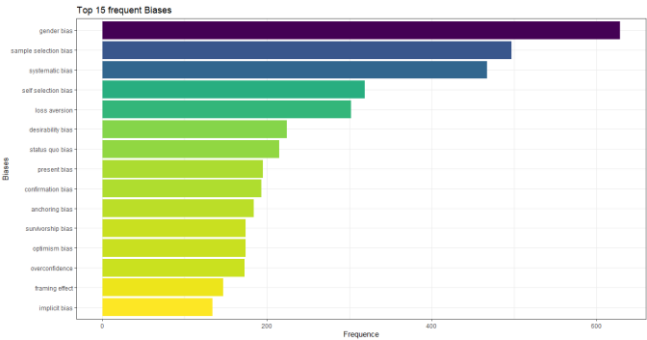


Figure 5. Topmost frequent bias

be grouped. Figure 5 shows the bar chart containing the topmost frequent biases, according to their appearance in the literature.

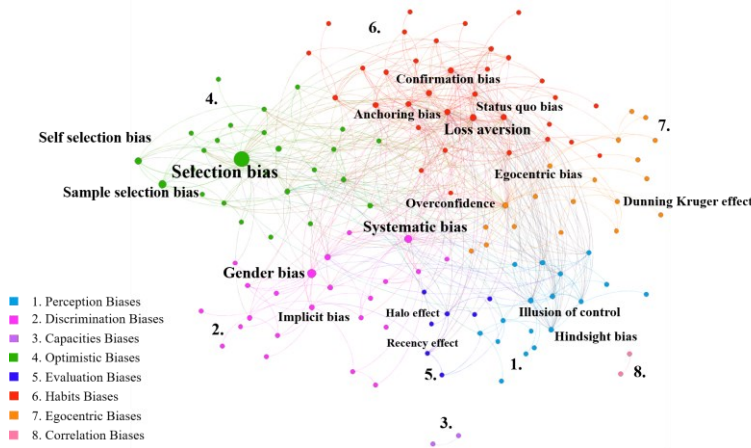


Figure 6. Clusters

5. Phase 3: Tool Design

After conducting an in-depth analysis of the literature on the chosen topic of interest, the last phase concerned the heart of the work, namely the design and development of the tool to disseminate the information gathered through the previous phases.

5.1 Methodology

The tool, indeed, aims at delivering data and information about the phenomena of cognitive biases to users who may be interested in it but do not have time, experience, and methods to access scientific sources to do a complete and deep analysis.

Figure 7 shows the process adopted and followed in the Tool Design (TD) phase.

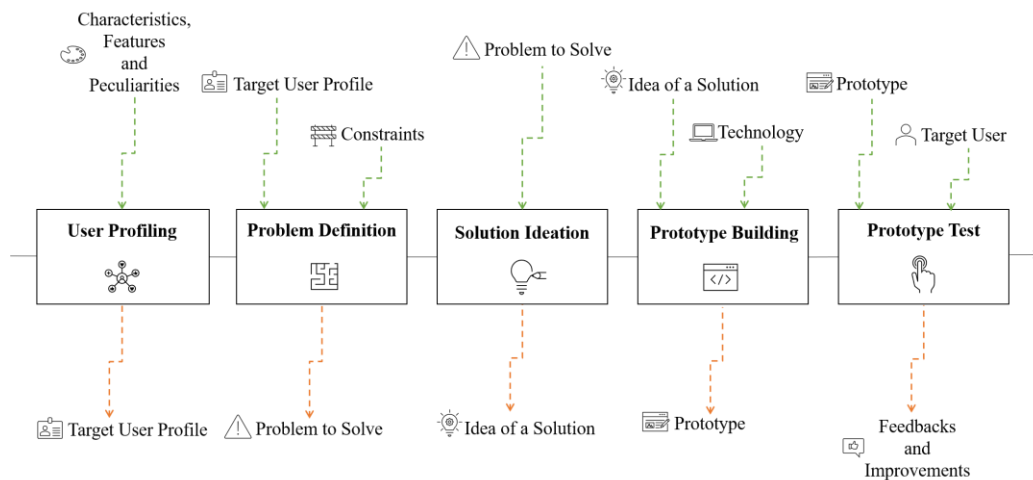


Figure 7. Tool Design Process

The process of designing and developing the tool started with the profiling of the target user. Clearly understanding who the target is helps in the other steps of the design process,

because features of the user act like constraints to be met to satisfy them and offer them with a product or service that match with their expectations.

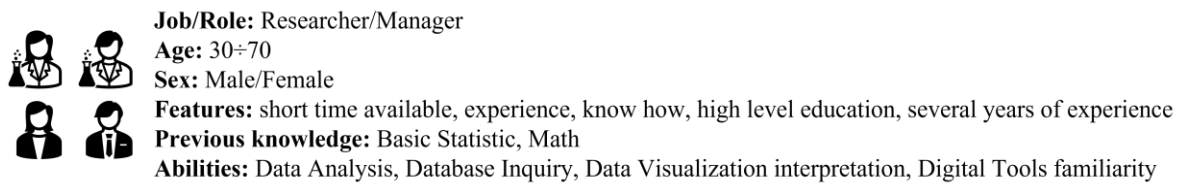


Figure 8. Target User Profile

After identifying and describing the target user (see Figure 8), it was possible to define the technical choices to be made to develop a tool which fit with the features, needs and expectations of them. The design process followed can be synthetize as follows: (1) definition of the problem, (2) ideation of a solution, (3) building of a prototype and (4) test of the solution. To develop the tool, it has been chosen to use the web application framework for R, *Shiny*, which is a package to build interactive web applications.

An **interactive navigable dashboard** has been chosen as the solution since it enables data-driven analyses and graphic visualizations in a dynamic and interactive way, as well as being highly customizable. The tool's functionalities were chosen to be user friendly, intuitive, understandable, and efficient for both managers and researchers. Through an interactive interface, the aim was to allow users to explore the data, offered in a synthetic, intuitive, and brain-friendly way, and at the same time to reach in-depth analyses and draw conclusions in total autonomy.

5.2 Results

After conducting the various steps of literature review, the results obtained were filtered, selected, synthesised, and then inserted into the developed interactive tool.

The tool, as a whole, represents a showcase of the results obtained through the research approach used to conduct the scoping review.

Thus, by analysing the tool, with its features it is possible to comprehend the broadness of the results obtained and the many dimensions of analysis and interpretation that result from them. What it is wanted to deliver to the users is the freedom to navigate the tool different times and learning something new each time, by simply modifying the research inputs. Every attempt to offer pre-thought considerations has been avoided, not to influence the users with subjective opinions about the phenomenon.

With this tool the aim is to give freedom of interpretation, to enrich the field by always offering new insights and possible new ideas for research.

The dashboard (Figure 9), as it has been thought and designed, is intended to act as a bridge between the academic and the industrial worlds, thus supporting the idea that greater communication and exchange between academia and industry can benefit both,

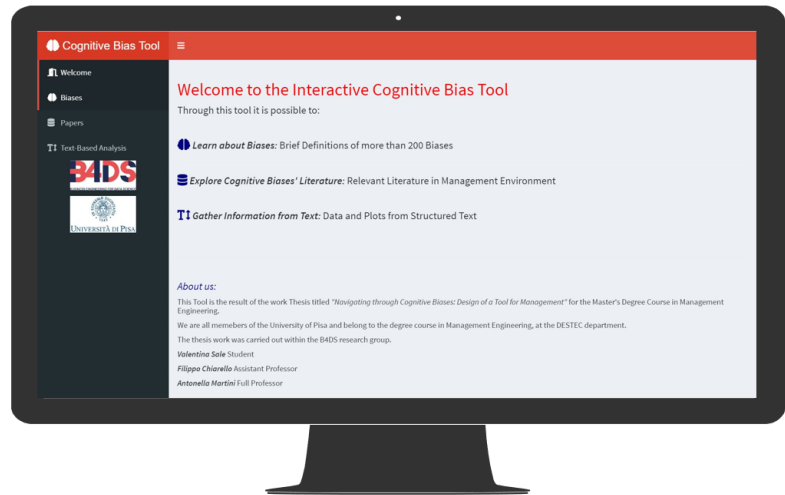


Figure 9. Interactive Cognitive Bias Tool Dashboard

with the common aim of enriching knowledge. The interactive dashboard is accessible from the web, at the address https://valentinas.shinyapps.io/dashboard_bias/.

The dashboard design has been thought to be plain and simple, without excessive frills, so to convey from the outset the idea of order and immediacy that will be reflected in the functionalities. It is provided of four main pages, which are “Welcome” page, “Biases” page, “Papers” page, and “Text-Based Analysis” page.

- The “**Welcome**” page aims at presenting the tool, its main sections and a brief description of the work and its authors. Through this page it is possible to rapidly understand what the tool allows to do, which macro information it is possible to gather, and which is the field of interest.
- The “**Biases**” page offers a brief and rapid overview about the phenomenon of cognitive biases. In this page, indeed, it is presented a general definition of bias and a comprehensive list of biases with brief definitions for each of them. The list comprehends more than 200 biases, considering synonyms. The comprehensive list of biases, their definitions and the identification of synonyms are the result of the first steps of analysis conducted in the SR phase. Firstly, starting from the query, a *lexicon* containing all the biases, including all the synonyms, was constructed. This lexicon was then used as a starting point to associate each element with a brief description and to create a dictionary of synonyms, to offer the definition of only one of the many versions with which each bias is named.
- The “**Papers**” page, instead, contains relevant literature about biases contained in the papers databased created in the first phase of the analysis. Not all the biases listed in the lexicon have been studied and are present in the papers belonging to the database

created. The page also shows a bar chart which aims at showing the top frequent biases, according to the number of occurrences of them into the literature. The bar chart resulted from the text-based analysis conducted and aims at delivering information about which biases are the more interesting in the management field.

- The fourth and last page, named **“Text-Based Analysis”** contains insights into the literature on bias based on text analysis. The page is subdivided into three tabs, which are “Network Graph”, “Bias Pairs” and “Trend Evolutions”. The first tab contains a network graph which aims at showing how the biases are linked, according to their correlation, and how they are distributed among clusters. Information and data concerning how biases are correlated between them are contained in the second tab, where a bar plot shows, for each bias, the most linked biases. The last tab, instead, concerns the evolution of the study of biases over time, by means of line charts.

6. Conclusions and Future Work

The underlying aim of this thesis work has been precisely to use methodologies and design a tool that could offer dynamism and simplify the accessibility to highly complex subjects. The subject used as case study in the present work - cognitive biases - is a topic that has grown significantly in the last decades, thus representing a perfect case study due to its complexity and broadness.

This work proposes an interactive, navigable tool, to offer valuable data and information to both academia and industrial users interested in cognitive biases field, which would be difficult to understand and study by means of manual techniques. The methodology proposed is based on text mining techniques, which facilitate the analysis of large amounts of textual documents reducing time-consuming manual tasks and which aim at being replicable to any chosen topic. Text-mining techniques coupled with web application frameworks make it possible to offer users with up-to-date information in a timely and accurate manner.

In conclusion, with this study, an initial step has been taken, nevertheless, the dashboard is still in its prototype phase, and this implies that it will need to be further tested and refined with developments and improvements, to be evaluated following its use and the feedback received from users.

Conference paper:

SALE V., MARTINI A., CHIARELLO F. (2021), *"Cognitive Biases: A Text-Mining Driven Scientific Literature Approach"*, 4th Economics, Business and Organization Research (EBOR) International Conference "Changes in Uncertainty", Poland, 21-23 May, ISBN 978-605-68816-8-8.
