This project has received funding from the European Union's Preparatory Action for Defence Research - PADR programme under grant agreement No 800893 [PYTHIA]

D2.2 - Failures in forecasting: cognitive biases and other sources of errors related to the human factors

WP number and title	WP2 – The cognitive factor in foresight
Lead Beneficiary	WAT
Contributor(s)	ENG, Z&P, HAWK
Deliverable type	Report
Planned delivery date	31/08/2018
Last Update	06/12/2018
Dissemination level	PU

PYTHIA Project

PADR-STF-01-2017 – *Preparatory Action on Defence Research*
Grant Agreement n°: 800893
Start date of project: 1 February 2018
Duration: 18 months

1 Disclaimer

The PYTHIA Consortium consists of the following partners:

	Partner Name	Short name	Country
1	Engineering Ingegneria Informatica S.p.A.	ENG	Italy
2	Zanasi & Partners	Z&P	Italy
3	Expert System France	ESF	France
4	Hawk Associates Ltd	HAWK	UK
5	Military University of Technology	WAT	Poland
6	Bulgarian Defence Institute	BDI	Bulgaria
7	Fondazione ICSA	ICSA	Italy
8	Carol I National Defense University	NDU	Romania

Document History

VERSION	DATE	STATUS	AUTHORS, REVIEWER	DESCRIPTION
V0.1	30/04/2018	Draft	Marcin Kowalski, Michał Walczakowski, Artur Grudzień (WAT)	First draft
V0.15	17/05/2018	Draft	Marcin Kowalski (WAT), Graziano Giorgi (Z&P)	Second structure
V0.20	11/06/2018	Draft	Marcin Kowalski, Norbert Pałka, Michał Walczakowski, Elżbieta Czerwińska (WAT)	Inputs to Sections 2 and 4
V0.60	24/07/2018	Draft	Piero Scrima	Inputs to Sections 2 and 4
V.065	01/08/2018	Draft	Graziano Giorgi	Inputs to Sections 2, 3 and 4
V0.7	28/08/2018	Draft	Marcin Kowalski / Tadeusz Szczurek (WAT)	Refinement, inputs to Sec. 1 and 5.
V0.85	05/09/2018	Draft	Norbert Pałka/ Elżbieta Czerwińska (WAT)	Added Kahneman's selection section
V0.95	05/09/2018	Draft	Elżbieta Czerwińska (WAT)/ Michał Walczakowski	Summary and analysis of questionnaire
V0.98	12/09/2018	Draft	Norbert Pałka/ Michał Walczakowski	Introduction and conclusions
V0.99	14/09/2018	Draft	Graziano Giorgi (Z&P)	Refinements by Z&P
V1.0	18/09/2018	Final	Norbert Pałka / Marcin Kowalski (WAT)	Finalization
V1.1	06/12/2018	Reviewed	Giulia Venturi and Graziano Giorgi (Z&P)	Fixes based on PO's concerns

Table of Contents

List of Tables

Executive Summary

This report provides a critical review of the most notable technology foresight/forecast[1] errors made in the past by experts in the field, combined with the results of an investigation on the cognitive factors-related issues behind those mistakes and resulting consequences.

Section 2 reports the most notable forecasting failures in the technology field, accompanied by a brief description of the cognitive issues responsible for them.

Section 3 focuses on findings from previous EC-founded research activities specifically dedicated to the mitigation of cognitive biases including FP7 projects LEILA and RECOBIA, which are explicitly cited in the proposal and in the task description. They are the most notable projects, funded by EU and related agencies, regarding cognitive biases and involving partners of the PYTHIA consortium.

Section 4 contains literature review of the relevant scientific literature on most common human factor-related causes of the considered errors during predictive activities. The theory of two reasoning systems by Kahneman and other human factors like denial, unpredictable interactions etc. have been presented.

To collect experience of PYTHIA Stakeholders and various domain experts regarding forecasting errors, an online questionnaire has been used. The results of this analysis are presented in Section 5.

[1] The forecasting activity requests the topics and research questions to be clarified in advance, is typically quantitative, short-termed and mainly result-oriented, whereas in the foreseeing acivity the research quastions are open and looked for as part of the predictive process, and foresight is typically more qualitative, long-termed and consensus-oriented. The PYTHIA project concerns both foresights and forecasts: technology trends and emerging technologies (discovered by data mining and big data analysis) are used as inputs for technology forecasts, and these forecasts are used as inputs for strategic technology foresights, in the frame of a comprehensive methodology.

1 Introduction

In a world where constant development of technical solutions and scientific research is an obvious requirement, not only the vision of a goal is important. To achieve the assumed result, possible failures must be taken into account. This became an obvious case in the first half of XIX century. Source of this phenomenon is related to the most prosaic thing - money. Rapid development of new technologies and implementation of new discoveries led to always increasing complication of new ventures. World-wide growing markets put a pressure on all competitors and big success is related not only to brilliant solutions but also to limiting costs generated by failures and dead ends.

For many years, companies all around the world has been aware of potential losses when its idea or product does not meet the customer expectations. From technical point of view, any potential threat can be minimized by simulation, rigorous quality control, extended testing in the first stages of technology life cycle, etc. The big question is how to make decision about new technology when it is just an idea or it is in an experimental phase? Predictions and assumptions are made by people, and many mistakes are connected with human deficiencies. In this document it is shown that many other reasons, even very surprising and small, are enough to cause a big failure.

The aim of the report is to present comprehensive review of technology forecasting failures in various categories together with a study on related human factors. The analysis is complemented by the overview of relevant scientific literature, including seminal work by Kahneman on two competing human reasoning systems. The report also summarizes outcomes of two EU-funded projects related to the issue of human factors and mitigation of human biases – LEILA and RECOBIA. Finally, the report shows a summary of inputs collected by the online questionnaire from PYTHIA Stakeholders and various domain experts regarding forecasting errors.

2 Technology forecasting failures - case studies

This chapter aims at reporting a few notable examples of technology forecasting failures. This selection is intended to cover the most common cognitive issues affecting predictions, like denial and confirmation bias, but also highlights other common issues, such as the lack of evidence or available data (see case study 2.1).

This issue is also related to another well-known issue, that is the ability or not to quickly update one's beliefs when new, disrupting evidence is provided.

In the scientific field, this also refers to the fact that scientist should never take anything for granted and completely, unchangeably true beyond every possible doubt. They should always bear in mind that science regards modeling the reality, and models are subject to validity frames and technologic limitations. Even the speed of light in vacuum ceases to be an absolute invariant when one deals with the singularity at the center of a black hole (see case study 2.2, 2.6 and 2.9).

Wrong assumptions can be dangerous by themselves within the forecasting/foreseeing activities but can also lead to another dangerous consequence: the anchoring bias; the most valuable and thoughtful reasoning about an estimate can be fully compromised if one fails to assess a good starting point (see case study 2.5).

Wrong assumptions may also raise from the so-called CEO "bubble" or "disease", that is when a leader is walled in by self-importance and isolated from needed information (see case study 2.7).

Another similar issue is represented by selective perception, that is the tendency for expectations to affect perception (see case study 2.3 and 2.4).

Moreover, the tools, techniques and methods used to deliver correct predictions may not have been available at the time (see case study 2.11).

These and other cognitive issues will be described in detail in chapter 3.

2.1 Kalinin K-7 (aeronautics)

The Kalinin K-7 was a heavy experimental aircraft built in the Soviet Union in the early 1930s. Designed by World War I aviator Konstantin Kalinin, the K-7 was one of the biggest aircraft built before the jet age. Measuring over 92 feet long, it had a 174-foot wingspan, seven engines, seven gunners and 12 crew members were needed to operate it.

In the late 1920s, Kalinin predicted that the future perfect aircraft would have been "a single flying wing". The idea to build the K-7 represented the transition from contemporary planes to the desired flying wing, following the "everything is in the wing" concept. The Soviet Union planned to use the massive K-7 both as a bomber and as passenger plane. In the latter version, seats were arranged inside the 2.3-meter thick wings and the plane was able to transport up to 120 people.

The K-7 first flew on 11 August 1933. The very brief first flight showed instability and serious vibration caused by the airframe resonating with the engine frequency. The solution to this problem was to shorten and strengthen the tail booms, little being known then about the natural frequencies of structures and their response to vibration [1].

On the 11th flight, during a speed test, the port tail boom vibrated, fractured, jammed the elevator and caused the giant aircraft to crash to the ground, killing 15 people [2].

Undaunted by this disaster, Kalinin's team began the construction of two further K-7s in a new factory, but the vicissitudes of Stalin's Russia saw the project abandoned, and in 1938 the arrest and execution of Kalinin on trumped up espionage and sabotage charges.

To investigate causes of the crash few competent committees were created, with participation of the most prominent aviation experts of the country. It was concluded that destructive vibration was caused by surfaces during some regimes of the seventh engine. But there were no “theoretical” proof of this conclusion. Only few years later, M.V. Keldysh explained this and many other similar crashes and found a solution to fight the flutter - weight balancing of elevators.

ANALYSIS:

This specific case study regards the failure in the technology forecast performed by the Soviet Union’s analysts involved in the planning, resource allocation and orientation of the aviation strategic research agenda. They allocated resources for the research on a heavy experimental aircraft, defined, indeed, “experimental”, as they judged it would be strategic, based on the opinion of an expert in the field, *id est* Konstantin Kalinin, who had made a forecast about the “future perfect aircraft”. The project ended in a disaster once the speed test went wrong and the plane crashed on the ground, killing 15 people.

We cannot judge if Kalinin’s forecast was actually wrong, given that other massive aircrafts’ projects were brought on later by many other countries such as Germany (Messerschmitt Me 323, Blohm & Voss BV 238) during WW II, but we can state that the main reason behind the failure of the Kalinin K-7 project was due to a lack of scientific information: the knowledge about the dangers of natural frequencies of structures and their response to vibration was insufficient.

The first recorded flutter incident was on a British Handley Page O/400 twin engine biplane bomber in 1916, and since then different solutions were proposed to avoid this problem such as interconnecting the elevators with a torque tube or using a mass balance about the control surface hinge line. After World War I, higher airspeeds and a shift from external wire-braces biplanes to aircraft with cantilevered wings resulted in more wing flutter incidents. Primary surface flutter began to appear around 1925, then servo tab flutter in the 1930’ (Kehoe). Given this, Kalinin should have taken more attention during the design phase, although it should be said that this sort of flutter-related problems was very hard to discover and fix in the design phase, and caused dozens of incidents world-wide. Thus, for this specific case, the failure of the technology forecast was due to a combination of epistemic and aleatory uncertainty. As stated by Tetlock (Tetlock & Gardner, 2015), forecasters should be well aware of this irreducible unknowable and take it into account when delivering their estimations. Another important point concerns the fact that the Soviet Union strategic research agenda in the aviation field appears to have been mainly oriented by the opinion of one single expert. Nowadays, governments and institutions rely on experts’ teams and encourage the share and merge of opinions from different contributors. This has proved to be essential to fight individuals’ confirmation bias, paying attention to the danger of groupthink, on the other hand.

2.2 Space travels (astronautics)

Dr. Lee De Forest was one of the American most famous scientists of his age, often referred to as “Father of electronics”. Amongst other things, he invented the Audion, the first triode, making possible radio broadcasting, televisions, radars and other countless applications.

However, despite his great scientific experience, he always rejected the idea of space travels. In 1952 he claimed that “spaceships to the moon or Mars” would have been technically impossible and that “mortals must live and die on Earth or within its atmosphere!".

De Forest firmly maintained his beliefs even when the first space missions were approaching. In 1957 he declared to the Lewiston Morning Tribune that space flight by the means of rockets constituted “a wild dream worthy of Jules Verne”. Furthermore, he also stated that that kind of voyage would have never occurred, regardless of all future advances [5].

In 1961 Yuri Gagarin completed an orbit of the Earth on a spacecraft and one year later Neil Armstrong and two others were the first men to step on the Moon.

ANALYSIS:

This specific case study regards the fact that Lee De Forest believed space travels to be impossible and refused to change his mind, in principle. Scientists should always bear in mind that science describes the world through models and theories which can change and even be revolutionized by new discoveries as the technology evolves and more empirical results become available. Thus, this is an evident example of denial (see paragraph 4.2.2).

2.3 Tata Nano (automotive/marketing)

In 2005 Indian automaker Tata Motors began the development of a very cheap compact city car, the Tata Nano, designed to appeal to riders of motorcycles and scooters, primarily in India. The launch price was expected to be of one lakh rupees or US$2000 in the year 2008 (New York Times, 2008). The price had been brought down by eliminating all the nonessential features, including: the removal of the passenger's side wing mirror, having one wiper blade, having only three lug nuts per wheel, the removal of the fuel filler cap from the fuel tank, and the removal of airbags, radio or CD player, base power steering and air conditioning.

Expectations created for the car were spectacular: a 2008 study, by Indian rating agency CRISIL, forecasted that the Tata Nano would expand the nation's car market by 65% (The Economic Times, 2008). It was anticipated that its 2009 debut would greatly affect the used car market, and prices did drop 25–30% prior to the launch (The Motor report, 2008).

The Tata Nano was small but unbelievably roomy inside, thanks the engine being at the back of the car. It was extremely robust in long-trips challenges and it had major fuel efficiency and correspondingly low levels of emission.

Nonetheless, the expectations happened to be way out of proportion with reality: sales in the first two years after the car's unveiling remained steady at about 70,000.

In July 2012, Tata's Group chairman Ratan Tata, who retired in January 2014, said that the car had immense potential in the developing world while admitting that early opportunities were wasted due to initial problems. Due to the sales drops, only a single unit was produced in June 2018.

ANALYSIS:

This specific case study regards the fact that the Tata Nano marketing analysts thought they could attract the market segment of Indian motorcycle and scooter riders by proposing a very low-price mini car, more comfortable and safer than a scooter or motorcycle. What went wrong?

First, several Nano cars caught fire in the first two years. Tata Motors rectified the glitches and offered an extended warranty for both new and existing cars, but the reputational damage was done. Second, there was a production delay (having to shift from Singur, West Bengal to Sanand, Gujarat) of 18 months which was acutely felt because of high expectations created by the hype over the car. Third, it was low on riding comfort, lacking the stability that greater weight gives. Fourth, the biggest initial selling point – the cheapest car you can get – boomeranged. Value-conscious Indians, particularly those who would like to switch from a scooter to a car, should have embraced it with open arms but didn't. This reaffirmed the widely-held notion that a car does more than taking you from point A to point B. It is an aspirational symbol. Prospective buyers felt that to be seen owning the "cheapest" was to acquire a lowly social status. Finally, Nano was never the "one lakh" car, as was originally indicated by Ratan Tata whose brainchild it was, but instead around 2.5 lakh (Roy, s.d.).

A *Harvard Business Review* (Eyring, 2011) study of why Nano failed makes the general point that a "novel" product (Nano was one) has to address the following questions: is it wanted, who wants it and under what circumstances will people use it? The answer to these will help formulate a value proposition, differentiating the product from the competition, which will have to be clearly targeted. The targeting of the scooter owner was wrong as he was more concerned in social mobility and less worried about climate change.

This is an example of how focusing effect and selective perception (see paragraph 3.1.4).

2.4 Fukushima earthquake and nuclear incident (geosciences)

The 2011 earthquake off the Pacific coast of Tōhoku was a magnitude 9.0–9.1 (Mw) undersea megathrust earthquake off the coast of Japan that occurred on Friday 11 March 2011.

Immediately after the earthquake, the active reactors of the Fukushima Daiichi Nuclear Power Plant automatically shut down their sustained fission reactions. However, the tsunami disabled the emergency generators that would have provided power to control and operate the pumps necessary to cool the reactors. The insufficient cooling led to three nuclear meltdowns, hydrogen-air explosions, and the release of radioactive material.

Tepco, the company that ran the plant, stated for a year and a half that the magnitude 9.0 earthquake and 45-foot tsunami were far larger than anything that scientists had predicted, but in 2012 it had to admit that with the necessary precautions, the worst could have been avoided: "When you look at the accident, the problem was that preparations were not made in advance"[32]

Tepco's internal reform taskforce, led by the firm's president, Naomi Hirose, noted that Tepco had not made any safety improvements to the Fukushima Daiichi plant since 2002, and had dismissed the possibility of being hit by a massive tsunami, even though it could not produce supporting data. The Tepco had insisted that Fukushima Daiichi's 5.7m seawall was high enough to withstand a tsunami.

ANALYSIS:

This case study regards the importance of making decisions based on structured, robust data and estimates. In this specific case, decision makers at the head of Tepco failed to correctly assess the likelihood of an earthquake or tsunami to impact on the Fukushima Daiichi Nuclear Power Plant, they denied this possibility despite the lack of supporting data, based on the fact that it had never happened before. This represents a severe and heavy consequence of confirmation bias, denial, anchoring, experimental limitation ad availability heuristic (see paragraph 3.1.4).

2.5 Biosphere 2 experiment (biology)

Biosphere 2 was a project in which it was expected that an artificial biosphere that reproduced the terrestrial ecosystem in a small way would autonomously be regulated and made self-sufficient. It was a huge structure containing a sample of all ecosystems, capable of supporting a human population of "biospherians" –

indefinitely. Four men and four women began their isolation in September 1991. They would have been locked in Biosphere-2 for 2 years. Within a few weeks of the start of isolation, the oxygen level in the atmosphere had dropped from 21% to 14% [33], roughly as in the rarefied air on a 4000 meter mountain, just enough to keep the 8 members of the crew in health. At the same time, the CO2 level had increased incredibly, to the point of being close to the safety limit. All internal attempts to keep the situation under control aggravated the conditions of the structure. Nineteen of the twenty-five species of vertebrates, including all the fish, became extinct, as did all the pollinating insects, condemning most of the plants not to produce seeds. Most insects died quickly, with the exception of cockroaches and ants. The artificial sea became acid and the corals began to die.

ANALYSIS:

This case study regards the danger of setting up large-scale, expensive and high-expectation research projects without first checking the fundamental scientific assumptions at the base of the research. The project management and scientific management under-estimated the complexity of the Earth's natural biosphere, which is calibrated to cover an entire planet and not a small structure. Scientists failed in assessing the (very low) scalability of Nature: This is an example of anchoring bias (see paragraph 3.1.4).

2.6 Rutherford's moonshine (physics)

Sir Ernest Rutherford and his team were responsible for the discovery of the atomic in experiments between 1908 and 1913. This and other results earned him the title of "father of the nuclear physics" and a Nobel Prize in Chemistry in 1908.

On September 1933, he stated in an interview on the New York Herald Tribune that there would have been no chance to produce energy breaking down atoms in laboratories. "Anyone who expects a source of power from transformation of these atoms is talking moonshine" was a declaration that remained in the history of science [6].

Leo Szilard, a Hungarian-American physicist that was working on that specific problem during those days, read about Rutherford's declaration and was quite irritated by the great physicist's categorical statement. However, Rutherford was not alone in his negative opinion. Einstein compared the feasibility of transforming matter into energy to "shooting birds in the dark in a country where there are only a few birds [7]."

Szilard, though, remained undeterred and few months later proposed the idea of a nuclear chain reaction, turning things around. Without a chain reaction, Rutherford was effectively correct, but Szilard's idea opened the way to nuclear fission and made the first nuclear reactor possible.

ANALYSIS:

This specific case study regards the fact that Ernest Rutherford doubted that atomic manipulation would provide a viable source of energy, as indicated in a 1933 citation. The citation is extracted from an interview delivered to the New York Herald Tribune, a quite prestigious newspaper, reasonably read by a vast public, so that Rutherford's statement can be thought of having reached lots of people, including other scientific researchers, thus having impact also on the research orientation at that date.

Connected to the previous forecast, also Einstein's opinion on the topic is reported, corroborating Rutherford's point of view.

These two forecasts, delivered by prominent world-famous vanguard physicists, were certainly due to an objective lack of knowledge at the time (here, a combination of epistemic and aleatory uncertainty), but they were also boosted by cognitive biases, since scientists should always bear in mind that science describes the world through models and theories which can change and even be revolutionized by new discoveries as the technology evolves and more empirical results become available. In this case, to the contrary, Rutherford and Einstein denied the possibility of atomic power due to denial (see paragraph 4.2.2), confirmation bias and focusing effect (see paragraph 3.1.4).

2.7 Digital Equipment Corp. (information science)

Digital Equipment Corp. (DEC) was a major American company in the computer industry from the 1950s to the 1990s, founded in 1957 by Kenneth Harry Olsen, Harlan Anderson and Stan Olsen. The company grew to $14 billion in sales and employed an estimated 130,000 people worldwide at one point. In 1977, as DEC was leader on the market with 41% of minicomputer sales in the world, referring to computers used in home automation at the dawn of the home computer era, Olsen said "there is no reason for any individual to have a computer in his home”. The rapid rise of the business microcomputer in the late 1980s, and especially the introduction of powerful 32-bit systems in the 1990s, quickly eroded the value of DEC's systems. With the strong rise of the Silicon Valley, where companies that were experimenting with new markets and new technologies were growing, the era of the personal computer was coming. Within 10 years DEC would have no longer existed.

ANALYSIS:

This case study regards the so-called CEO “bubble” or “disease”, that is when a leader is walled in by self-importance and isolated from needed information. Kenneth Olsen based his marketing strategy and its productive chain orientation on a wrong assumption, forecasting that people would never need to have a computer in their home. Again, this is an example of anchoring bias (see paragraph 3.1.4).

2.8 Blackberry (information science)

BlackBerry was one of the most prominent smartphone vendors in the world, specializing in secure communications and mobile productivity, and well-known for the keyboards on most of its devices. At its peak in September 2013, there were 85 million BlackBerry subscribers worldwide. However, BlackBerry has since lost its dominant position in the market due to the success of the Android and iOS platforms; the same numbers had fallen to 23 million in March 2016. Blackberry stopped producing its smartphones in 2016 (the brand will be used under licensing agreements by an Indonesian company) and became a company entirely dedicated to software and security. The decision came after years of decline for the mobile phone that marked an era, an undisputed must for all the top managers, with that distinctive keyboard.

ANALYSIS:

This case study regards a company that has failed to evaluate the impact on emerging technologies such as touch technologies. They failed to predict the evolution of telephony, which is running faster and sees mobile phones brought not to call, send SMS and emails, but rather for taking pictures and videos, performing payments, exploiting biometric authentication and other advanced applications that do not need the keyboard. This is a clear example of how technology forecast and business Intelligence failures can impact the economy.

2.9 Astronomic spectroscopy (astronomy)

In 1842, French philosopher Auguste Comte wrote "The Positive Philosophy". Students of this book will note, beyond the long sentence structure, one particular line that was written about the stars: "We can never learn their internal constitution, nor, in regard to some of them, how heat is absorbed by their atmosphere." Comte went on to state, in relation to the planets: "We can never know anything of their chemical or mineralogical structure; and, much less, that of organized beings living on their surface."

In the early 19th century, William Hyde Wollaston and Joseph von Fraunhofer independently discovered that the 'spectrum of the Sun contained a great many dark lines' and by 1859 these had been shown to be 'atomic absorption lines'. Each chemical element present in the Sun 'could be identified by analyzing this pattern of lines, making it possible to discover just what a star is made of'. (Marshall, 2008)

ANALYSIS:

An influential writer of the time, Comte was making a basic assumption (his 'incorrect argument') that due to the distance of the stars and planets they are 'beyond the limits of everything but our sense of sight and geometry'. His reasoning was based on the false assumption that, while we could actually work out their 'distance, their motion and their mass', nothing more could 'realistically be discerned'. There was 'certainly no way to chemically analyze them.' The very concept of this, for Comte, was unfathomable, and he was happy to state his predictions for his readers. As for the case study in paragraph 2.6, his beliefs were certainly due to an objective lack of knowledge at the time (here, a combination of epistemic and aleatory uncertainty), but they were also boosted by cognitive biases.

2.10 The Petrol Cavalry (defence)

In military history, it is a much-debated question as to why British (and subsequently allied forces) tank doctrine did not evolve between the first and second world wars to sufficiently combat the tank doctrine and prowess of the German armed forces. The main problem for the British was that during the inter-war years nobody had a clear idea about how tanks should be used. Whilst the British invented the tank and were the first to use it in WWI, doctrines for effective use were not developed until later in the Second World War. The Germans, on the other hand, developed an effective doctrine that was used to lethal effect in WWII.

The wrong assumption by the British was twofold: firstly, that tanks were 'infantry support weapons', and they should therefore advance together with infantry; secondly, that tanks were essentially mechanised cavalry and therefore should be used for tasks traditionally performed by the cavalry. This gave birth to 'two types of tank: slow but well armored infantry tank (the "land battleship") and fast but fragile cruiser tank ("petrol cavalry").'

An easy comparison is made with Ancient and Medieval warfare, with the infantry tanks acting in much the same way as the war elephants, while cruiser tanks were 'not unlike light horse'.

It was the German armed forces that understood that tanks were the 'knights of the 20th century' and should be used like knights: on 'concentrated formations, aimed at one point on the enemy front, to crush themselves through the enemy lines with speed, mobility and firepower, and create a gap which the infantry could then employ.' These tactics have been likened to late Medieval knight tactics.

The British doctrine proved less effective than the German doctrine. Although the British tanks performed well at the tasks they were designed for, the Germans had better tactics and doctrine. They also 'continuously up-armored and up-gunned their existing tanks'.

It wasn't until 1943 that the British finally realized their doctrine was wrong. This 'gave birth to the concept of the main battle tank'. The last infantry tank was Churchill, after which the 'infantry tanks were discontinued and emphasis based on balance between mobility and protection. The first forerunner of the main battle tank was Cromwell, which was comparable to Panzer IV, and whilst under-gunned, superior in other respects'.

ANALYSIS:

This case study regards the facts that the British were so long in adapting their tactics and failed to realize that the development of a main battle tank would be a huge military advantage.

Conservatism, a distinct lack of willingness to change what has worked before, false planning fallacy, selective perception and focusing effect can all help to explain this – these cognitive biases perhaps prevalent with those decision makers in the British armed forces at this time (see paragraph 3.1.4). The lack of technology foresight (from the end of the first world war up until 1943) proved costly in terms of human lives and territorial advancements.

2.11 Euler's conjecture (mathematics)

Leonhard Euler (1707-1783) is referred to by some as the greatest mathematician of the 18th century. He published 886 papers and books in his career and his mathematical formulas are still widely in use today. Yet Euler made an assertion that intuitively seemed correct at the time but took over two hundred years to be proved wrong: he claimed that at least n nth powers are required to sum to an nth power, for every n>2 (Dickson, 1952).For two hundred years nobody could prove Euler's conjecture. Conversely, 'nobody could disprove it by finding a counter-example'. Manual searches were the initial method of disproving this mathematical prediction - with no proof forthcoming. Later, computer 'sifting' or processing failed to find a solution. Lack of a counter-example indeed 'appeared to be strong evidence in favor of the conjecture'.

It wasn't until 1966 when L. J. Lander and T. R. Parkin discovered the following solution by a direct search on the CDC 6600 (mainframe computer systems manufactured by Control Data Corporation):

$$27^5 + 84^5 + 110^5 + 133^5 = 144^5$$

Despite all the previous evidence, 'Euler's conjecture turned out to be false'. In 1988 Noam Elkins discovered another solution and went on to prove there are infinite solutions to the equation.

ANALYSIS:

This case study regards the fact that one cannot use evidence from the first million numbers to prove absolutely a conjecture about all numbers, and similarly this would be true for any analyst making a prediction using limited data (recency effect bias for example).

Trends 'do not indicate proof' and perhaps most importantly from this case study, we should appreciate that 'our human brains are powerful, but we must increasingly work in concert with machines, to help us place bounds on our intuition.' (Arbesman, 2014)

3 Outcomes of related EU-funded projects

3.1 Leila

3.1.1 About LEILA

LEILA (Law Enforcement Intelligence Learning Applications) was an EC-funded project under the FP7 programme and lasted from February 2012 to January 2015. The aim of the LEILA project was to provide law enforcement organisations with an innovative learning methodology to address the improvement of capabilities useful for Intelligence Analysis (IA) like critical thinking, awareness of cognitive biases, improved capabilities in filtering and analysing massive amount of data, decision making under social and time pressure, collaboration skills, creative intelligence, communication skills.

The radical innovation of the LEILA approach was brought by the combination of several knowledge fields which are normally explored and applied separately such as:

- psycho-sociological and cognitive factors in decision making (e.g. decision biases, critical thinking, multiple reasoning strategies, creativity);
- decision making strategies under uncertainty (e.g. Bayesian approaches, game theory);

A variety of learning experiences (e.g. games of deterrence, intelligence analysis under stress, emergence in highly collaborative situations) are elaborated and computerised in different serious games, that offer the possibility to actively acquire new IA skills from different angles.

Several findings from LEILA may be useful for the PYTHIA project. A summary of these findings is reported below, mainly concerning failures in intelligence activity and cognitive biases.

3.1.2 Intelligence failures

Like many other domains of human activity, Intelligence Analysis (IA) has encountered a lot of successes, but also has faced a significant number of failures, which led IA specialists to develop a protracted research on the causes of these failures. To that end they have notably undertaken an in-depth research on two categories of biases that may trigger failures and may be closely related to the process, practice and goals of Intelligence Analysis. These two categories of biases are *cognitive biases* on the one hand, and *decision biases* on the other. While being different from a semantic perspective, these two categories are nevertheless connected.

Thus a “wrong decision” may be taken because the decision maker has incorrect or irrelevant information. But the decision made may also be wrong because on the basis of the correct and relevant information available, the decision making process is erroneous, or to use the terms of operations research, irrational. The two categories of biases that are referred to have already been the subject of protracted exploration in other fields of research like Cognitive Science, Experimental Psychology, Behavioural Economics or Game Theory.

Why does Intelligence Analysis fail? Some theorists argue that intelligence failures are strictly related to politics failures. Other theorists argue that, by its nature, war is preceded by a crisis and crises implicitly involve intelligence failures. “Why intelligence fails” is the title of book published in 2010 by Robert Jervis, Professor of International Affairs at Columbia University (USA). From his point of view, “intelligence is a game between hiders and finders, and the former usually have the easier job”. Perhaps, the hiders are “the hidden forces that shape our decisions" according to Dan Ariely and as stated it before, this is particularly meaningful for LEILA project. In fact, his focus is the intelligence analyst and the main causes of intelligence failure. The education and lifelong learning of the intelligence analysts seem to be the right ingredients to reduce the number of failures, but education is not complete without training.

Naturally arises the question "what to train?". Based on Heuer's theories [11], cognitive biases have been identified as one of the main causes that have an impact over the every facet of the intelligence process. Some possible solutions include a system of education and training on avoiding the trap of cognitive biases.

Although there is an increasingly recognition in the academic community regarding "what to train" from the perspective of current trends of intelligence analysis, very few assume to attack the problem at its roots – reducing the impact of common perceptual and cognitive biases that can make the difference in life and death decisions. Analysing the post-9/11 studies that looked at intelligence failures, Donald Kretz, from University of Texas, said: "What they found was that there are a number of significant obstacles to good and thorough intelligence analysis, but what gets mentioned over and over in these studies is cognitive bias." In a world where information is accessible to all good and bad guys and the difference is made by being quick or being dead, it appears necessary to emulate as much as possible the real world inside the intelligence analysts training.

In this context, most researchers have suggested to use simulations, games and other interactive and experiential teaching devices as ways to train analysts to overcome biases. Based on psychological factors and cognitive processes relevant for intelligence analysis, and on the diagnosis of intelligence analysts training approaches which have been presented before, LEILA has established a list of cognitive and decision making biases which, if not taken properly into account, may hamper appropriate Intelligence Analysis.

LEILA has also analysed how the design of serious games can take into account cognitive and decision biases. These biases represent the cornerstone of user requirements analysis and learning needs for improving the training of intelligence analysts through using serious games platforms, and thus enabling to bridge the gap between human mistakes and logic.

3.1.3 Cognitive biases definition and categorisation in LEILA

When dealing with complex choices and uncertainty, individuals rely on a limited number of heuristic principles reducing the complex tasks of assessing probabilities and predicting values. Cognitive biases – as defined by Tversky and Kahneman – are "patterns of deviation in judgment that occur in particular situations, leading to perceptual distortion, inaccurate judgment, illogical interpretation, or what is broadly called irrationality" [12]. Research in social and cognitive psychology in the '70s challenged the idea that human beings are rational actors, brought about by the theory of rational choice, and demonstrated that human judgment in decision-making deviates from what is considered normative rationality.

In the 90's, Heuer defined cognitive biases as mental errors caused by individuals' simplified information processing strategies. According to Heuer, cognitive biases are similar to optical illusions in that the error remains compelling even when one is fully aware of its nature. It is important to distinguish cognitive biases from other forms of biases, such as cultural biases, organizational biases, or biases that result from one's own self-interest. In other words, a cognitive bias does not result from any emotional or intellectual predisposition toward a certain judgment, but rather from subconscious mental procedures for processing information"[11].

Based on Heuer's theories, cognitive biases have been identified as one of the main causes of intelligence failure, impacting every facet of the intelligence process from tasking and collection to dissemination and evaluation. Cognitive biases are subject to "scale" effects, with false assumptions rippling through the hierarchies of government and impacting the policy and decision-making process, as evidenced by intelligence failures of the last few years, and in particular by the mistaken assessment concerning Iraqi weapons of mass destruction.

3.1.4 Cognitive biases in the context of the intelligence cycle

The intelligence process is often described through the traditional five step cycle: planning and direction, collection, processing, analysis, dissemination. LEILA studied the relation between these five phases and cognitive biases. The project reported that some of the cognitive biases tend to be experienced by analysts horizontally throughout all phases of the intelligence cycle. They are:

- **Confirmation bias**: the tendency to search for or interpret information in a way that confirms one's preconceptions. The term confirmation bias was coined by the English psychologist Peter Wason [13], who found that when attempting to discover or test a rule, people typically generate instances that are consistent with the hypothesized rule. With regards to the impact on intelligence analysis, confirmation bias is considered to be particularly concerning as it can compromise objectivity of analysts and organizations' decision making, through neglect of conflicting evidence and judgments not reflective of the entire evidence spectrum. Confirmation bias can lead to many of the cognitive errors listed within Heuer's classification. For example, it can result in the identification of false correlations in the perception of cause and effect.
- **Representativeness:** the tendency to estimate probability by judging how representative the object, person, or event is of a certain category, group, or process. When judging the probability of an event by representativeness, one compares the essential features of the event to those of the structure from which it originates. In this manner, one estimates probability by assessing similarity or connotative distance [15]. Tversky and Kahneman argue that in answering many of the probabilistic questions, such as "what is the probability that object A belongs to class B?", individuals typically rely on the representativeness heuristic, in which probabilities are evaluated by the degree to which A is representative of B. "Steve is very shy and withdrawn but with little interest in people or in the world of reality. A meek and tidy soul, he has a need for order and structure, and a passion for detail." [15] In this example, the probability that Steve is engaged in a particular occupation, such as the librarian, is assessed by the degree to which he is representative of, or similar to, the stereotype of the librarian.
- **The availability heuristic**: the tendency to estimate what is more likely by what is more available in memory, which is biased toward vivid, unusual, or emotionally charged examples. For example, one may assess the divorce rate in a given community by recalling divorces among one's acquaintances; one may evaluate the probability that a politician will lose an election by considering various ways in which he may lose support; and one may estimate the probability that a violent person will "see" beasts of prey in a Rorschach card by assessing the strength of association between violence and beasts of prey [17]. Availability heuristic is relevant in the context of intelligence analysis as in many events of concern to intelligence analysis, analysts have to construct scenarios leading from the present situation to the future possible events. "The plausibility of the scenarios that come to mind, or the difficulty of producing them, serve as clues to the likelihood of the event. If no reasonable scenario comes to mind, the event is deemed impossible or highly unlikely. If several scenarios come easily to mind, or if one scenario is particularly compelling, the event in question appears probable" [18].
- **Anchoring**: the tendency to rely too heavily, or "anchor" on a past reference or on one trait or piece of information when making decisions. Tversky and Kahneman (1974) requested the participants of an experiment to guess the percentage of African countries that are part of the UN. Participants were given a random number and were asked to estimate whether the correct value was higher or lower than that number. Half received the number 10 and the other half received 65. After answering this

first comparative question, participants were asked to assess the number of countries located in Africa in absolute terms. Those who had received an anchor of 10 estimated the percentage to be 25; those receiving 65 estimated the percentage to be 45. This shows that low anchor numbers biased judgments towards a lower value compared to the effects of high anchors. Anchoring is a prominent heuristic in intelligence activities, in so far as first few arriving information sources tend to be given greater weight on the final integration product. When cues relative to an intelligence assessment arrive over time there is a tendency for the human to give greater weight to the first arriving piece of evidence.

LEILA studied other cognitive biases, each of them related to a specific phase of the Intelligence Analysis. An overview of other examined cognitive biases which may be useful for the PYTHIA project is reported below.

Table 1 LEILA's cognitive biases

Bias	Definition
Focusing effect	Tendency to place too much importance on one aspect of an event, causing error in accurately predicting the utility of a future outcome
Groupthink	This bias occurs within a group of people, in which the desire for harmony or conformity in the group results in an irrational or dysfunctional decision-making outcome
Asymmetric insight	Tendency of an individual or organization to overestimate their knowledge and understanding of others and underestimate others' knowledge and understanding of them
Curse of knowledge bias	Tendency for better-informed parties to find it extremely difficult to think about problems from the perspective of lesser informed parties.
Experiential limitation	Inability or unwillingness to look beyond the scope of past experiences, or rejection of the unfamiliar
Frequency bias	The illusion in which a word, a name or other thing that has recently come to one's attention suddenly appears "everywhere" with improbable frequency
Selective perception	Tendency for expectations to affect perception
Availability heuristic	Estimating what is more likely by what is more available in memory, which is biased toward vivid, unusual, or emotionally charged examples
Anchoring	Tendency to rely too heavily, or "anchor" on a past reference or on one trait or piece of information when making decisions
Base rate fallacy	If presented with generic or general information (base rate) and specific information, the mind tends to ignore the former and focus on the latter.
Conservatism	People tend to prioritize their prior views or forecasts at the expense of acknowledging new information.
Confirmation bias	Tendency of people to favour information that confirms existing beliefs or hypotheses
Illusionary correlation	Inaccurately perceiving a relationship between two unrelated events and inaccurately remembering a relationship between two events
Fundamental attribution error	The tendency to judge behaviours observed in others according to personality-based explanations while underestimating the role and power of situational influences on the same behaviour.
Confirmation bias	Tendency of people to favour information that confirms existing beliefs or hypotheses

Curse of knowledge bias	Tendency for better-informed parties to find it extremely difficult to think about problems from the perspective of lesser informed parties.
Hindsight bias	Inclination, after an event has occurred, to see the event as having been predictable, despite there has been little or no objective basis for redicting it, prior to its occurrence
Loss aversion	People's tendency to strongly prefer avoiding losses to acquiring gains

3.1.5 IT-induced cognitive biases

In the digital era, the aid of technology in carrying out intelligence related activities is of fundamental importance. The huge amount of (big) data accessible to intelligence officers is often unstructured. IT tools, when not compulsory, are nonetheless extremely useful to help organizing, processing, better understanding and determining the potential significance of available data.

However, IT tools do not prevent intelligence officers from being affected by cognitive biases. These instruments may in fact both amplify the effects of already existing and well-known cognitive biases or, even worse, prompt the emergence of entirely new types of biases. For instance, by using search and filtering technologies (such as Internet search engines), a dangerous bias potentially taking place is caused by the assumption that the collected data genuinely reflect the reality.

Similarly, the wrong perception of a data set as complete and logical may induce the intelligence analyst to stop searching for omissions. Again, the way in which data are graphically arranged by software visualization tools may reduce the analyst's ability to take into account all the relevant data and/or make him wrongly judging the importance of the various data available.

In LEILA, five macro-categories of technologies have been analysed: search and filtering, read and extraction, schematize, build case and search for relations. The identification of these macro-categories relates to the work carried out by Pirolli and Card, an interesting contribution to the theory of the intelligence cycle [19]. For each of these categories, the associated list of specific technologies and software tools is quite diversified.

3.2 Recobia

3.2.1 About RECOBIA

RECOBIA (REduction of COgnitive Biases in Intelligence Analysis) was an EC-funded project under the FP7 programme and lasted from February 2012 to January 2015. The aim of RECOBIA was to improve the quality of intelligence analysis by reducing the negative impact of cognitive biases upon intelligence analysis. To this end, the 9 partners of the consortium made an assessment of cognitive biases and assessed how these biases affected the practice of intelligence analysis. Building on this initial assessment, best practices to reduce the negative impact of cognitive biases have been defined in the domains of software tools, training of analysts and organisational issues.

The RECOBIA project consortium consisted of companies working in the field of intelligence analysis (CEIS, Hawk, Zanasi & Partners) and IT (Thales, Atos), research centres (CEA, University of Konstanz, Graz University of Technology) and psychologists specialised in cognitive biases.

In order to focus the research and development on the needs and requirements of professional analysts, their involvement was facilitated through the organisation of a series of workshops. During those workshops, the end-users were able to express their needs and requirements. On the other hand, the researchers and developers of the consortium received valuable input and guidance in order to identify and develop appropriate solutions.

RECOBIA had numerous findings, but those that are of interest for PYTHIA mainly focus on the relationship between cognitive biases and analysts, including RECOBIA's methodology and training programme. An overview of these findings is reported below.

3.2.2 RECOBIA's findings

The RECOBIA project has undertaken a detailed review of the traditional intelligence cycle, namely planning and direction, processing, collection, analysis and production, and dissemination. Each of these stages has been evaluated with reference to academic theory, the real world experience of European intelligence professionals, and partners' own experience as practitioners and consultants. Below a synthesis of the main findings is reported.

Admittedly, the purpose of the RECOBIA project is not to fix intelligence outright, but rather to alleviate those biases that can undermine the analytic process. To this end, the first step was to map those activities an "average" desk officer might undertake and have sought to identify those that are most vulnerable to bias.

Next, a series of workshops with European intelligence professionals were organised to gauge their understanding on the issue of cognitive bias, and to determine challenges they would like to see addressed in their workplace.

To many end-users the notion of cognitive biases and how it could negatively impact their daily work remains unclear or entirely unknown. Efforts are required to raise awareness and mitigation strategies to counter the negative impact of cognitive biases.

Structured methodologies could help surface bias and improve the quality of their analytic outputs. This is significant, as successive practitioners have urged the adoption of structured methodologies to mitigate the negative effects of bias.

RECOBIA's addressed also the double-edged sword of technology. While technology is essential to effective intelligence work, faith in its abilities is often misplaced, for well as mitigate bias, technology can also amplify it. Thus, for example, data mining technologies can encourage the intuitive fallacies that analysts operate with by allowing them to exaggerate anomalies that have little or no relevance, or to focus on those entities that are best understood, rather than those that are really important. In any event, the rubbish-in / rubbish-out predicament remains, as does the almost perpetual headache of identifying, implementing and operationalising new technologies to manage new sources and threats.

Biases are task specific: mitigating these biases requires identifying mapping the tasks involved and determining appropriate solutions. Furthermore, bias is not exclusive to the individual but can have a group dimension as well. Thus, for example, non-cognitive biases (such as cultural biases) can have a cognitive impact. As such, intelligence agencies should be cognisant of the many contextual factors, both individual and organisational that affect their work.

3.2.3 RECOBIA's methodology

From a huge amount of Cognitive Biases definition and Intelligence Activities, one of the main results of RECOBIA is the successful merge of the views of Psychologists and Intelligence consultants and analysts, in a shared model. These Cognitive Biases are often considered as errors as they show a non-rational decision-making process. As they are bound to the human cognition, the Cognitive Biases (CBs) are involved in any human mental activity including Intelligence activities.

Bringing together Psychologists, Intelligence consultants and analysts, and Computer Science or Knowledge Engineers, the RECOBIA project aims to assess the feasibility study of solutions to support the Intelligence Officers in their activities and to improve the Intelligence assessments by mitigating the CBs.

One of the aims of the RECOBIA project was to map CBs to the intelligence analysis process and identify corresponding reduction/remediation strategies to mitigate their impact. In order to identify strategies of this sort, it is notably important to be able to measure quantitatively the impact of the various cognitive biases identified during the work previously carried out by the project's partners.

Thereby, the project moved from a traditional Intelligence cycle approach to a user-centred approach in order to be able to slide from the Intelligence Officers technical tasks to cognitive tasks. Therefore, the aim to reduce the cognitive overload by filtering relevant activities, was reached by identifying the Key Intelligence Tasks and their link with Cognitive Biases.

Actually, a CB will exist to a greater or lesser degree in most judgments made by most of the group and even if CBs can affect an objective or rational (as following logical rules) Intelligence work, these heuristics also enable also good inferences. In the same way, when a cognitive bias is disposed of or impeded, the original CB can be moved, or another CB will be involved as the situation has changed.

One idea of reducing bias is then to render the bias explicit. The principle is to explain a CB or to show consequences of a CB to a user. The activity of formalizing concepts of a field, even for an expert of this field, is not natural, nor easy.

Ultimately, RECOBIA proposed a methodology that followed the four steps described below:

- From a list of thousands of Intelligence Activities, a list of 25 main intelligence activities have been identified;
- From these activities, Intelligence activities have been further defined as seven Key Intelligence Tasks – KITs;
- From a list of hundreds of cognitive biases, 77 sets clusters have been built;
- A coherent and adaptive model merging Cognitive Biases and Intelligence Activities has been built: the RECOBIA ontology.

Thanks to this methodology, the following main assets were defined and formally modelled:

- The KITs: Understanding/Interpreting the question, Planning and resources allocations, Selection of Sources, Selecting and interpreting information, Hypothesis and conclusions, Reporting, Request for clarification/verification;
- The RECOBIA ontology;

The fundamental linking of KITs and cognitive biases provides major step to potential RECOBIA success and real benefits for analysts. The ontology is a formal shared representation of data. This Knowledge Base can be processed:

- To infer links or appearance of Cognitive Biases;
- To present in a user friendly way the complex data of the RECOBIA project (navigate in the ontology as in a Web site);
- To model probability and severity parameters for risk assessment and apply rules of risk assessment on data;

- To enable the re-use of a structure validated by expert of Intelligence and Psychology when updating Intelligence or Cognitive data.

RECOBIA defined an ontology modelling the cognitive biases definition in intelligence and aiming at supporting the cognitive biases assessment for helping reducing them in intelligence activities.

The final ontology will be the basis for supporting mitigation of CBs. Finally, the project presented a decision support tool (Adaptive Decision Tool or ADT), a software tool that was designed as part of the RECOBIA project to provide the user with an interactive method of constructing.

3.2.4 RECOBIA's training programme

RECOBIA outlined the basic principles of a training programme that would be derived off the findings of the project. Most findings have been validated at one or multiple workshops with end-users for across the European Union and representing various intelligence services, including military intelligence, foreign intelligence, domestic intelligence, financial investigation units, LEAs, and others more.

The basic approach of the training programme would be:

1 To raise awareness of the course participants that cognitive biases pose a challenge to intelligence officers and that it is in the interest of every individual intelligence officer to know about them and know about strategies on hoy to mitigate them;
2 To introduce the participant into the underlying mechanisms of the cognitive biases, why they occur and why they are unavoidable, un-conscious and involuntary;
3 Finally, to introduce the participant to the mitigation strategies (why and how they work).

The training programme would be adapted and customised to the course participants, but some common features would be part of every training course on cognitive biases:

- The key intelligence tasks (KITs) that explain the activities of intelligence officers on the individual level. The KITs represent the activities that every employee of an intelligence service performs. Since they are generic from an intelligence and a psychological view, they are helpful to understand the occurrence of the cognitive biases in the context of the work of an intelligence officer.
- The experimental design approach to cognitive biases, namely that the occurrence of a cognitive bias is determined by the cognitive task that an intelligence analyst performs in a specific cognitive situation
- The underlying mechanism of the mitigation strategy that each solution consists of altering, influencing or changing the cognitive situation of the intelligence officer. Since the cognitive task has to stay the same if the intelligence officer has to achieve a certain objective, the only possibility is to change the cognitive situation.

Depending on the audience of the training course, whether it comprises of intelligence officers, intelligence trainers or managers, and the length of the training, the depth and comprehensiveness of the training would be determined.

The objective of the training programme would be to enable every intelligence officer to detect situations in which cognitive bias might occur and to able them to develop and apply mitigation strategies. This would lead to an increase in quality of the intelligence products of every intelligence service and might prevent the occurrence of intelligence failures that are due to un-mitigated cognitive biases.

4 Human factors

In this Section, a literature review on human factors-related errors during foresight activities are presented and described.

4.1 Kahneman's selection

Daniel Kahneman established a cognitive biases theory that common human errors arise from simple but efficient rules which are often used to form judgements and make decisions and are called heuristics. He was awarded the Nobel Memorial Prize in Economic Sciences in 2002.

4.1.1 System 1 vs. System 2

In his book "*Thinking, Fast and Slow*", (New York: Farrar, Straus and Giroux, 2011 [41]) D. Kahneman describes two systems of thinking that directly translate into our decisions. System 1 represents quick, emotional and intuitive way of thinking. It works automatically and quickly, usually with little effort and little sense of voluntary control. Slower operation, more deliberative and more logical thinking are the main features of System 2, which primarily focuses on the mental effort that is worth of it.

The biggest mistake we can commit and usually commit, is that we believe that we use logical, conscious and rational System 2 and our choices based on deep and thoughtful analysis. However, our decisions are, in fact, made by System 1. Its careless impressions and feelings are the main source of clear choices for System 2. System 1 constantly creates suggestions – feelings, intentions, impressions, intuitions etc., which can be approved by System 2 and then turn into beliefs and voluntary activities. Usually everything runs smoothly, and System 2 accepts an idea of System 1 with or even without a slight modification. Usually, people believe their impressions, what is correct in most cases. System 2 is activated for more detailed analysing of problems only when System 1 encounters difficulties and cannot propose simple answer. System 2 has also the feature of continuous monitoring of one's own behaviour.

On the other hand, System 2 also takes control over System 1 in certain situations, what is connected with a control of attention. System 1 unintentionally focuses on loud sound, what at once switches on intentional attention of System 2. Attention can be transferred from the unwanted goal, mainly by focusing on another target. Various activities of System 2 have one thing in common: they need attention and are easily disturbed when attention is distracted by other purposes.

These two systems differ significantly in judgement process. System 1 constantly monitors what is happening inside and outside the mind; diversity of the situation is evaluated. Emotional and intuitive reactions are well correlated with mean values and comparisons but are hardly correlated with numbers and statistics. System 1 performs comparisons and evaluations with ease. However, in statistical and computational reasoning it causes systematic errors, which renders these judgements doubtful. On the contrary to System 1, when System 2 receives the query, it focuses the attention and send the query to the memory for answers.

In conclusion, usually System 1 rules thinking and doing of our System 2. System 2 is activated only when difficulties appear and then takes control. This arrangement of work between both systems is very productive and yields relatively high performance at low effort. This setup usually works correctly, because System 1 provides fast and quite good model of situations, which have similar circumstances to previous ones, its short-term forecasts are also accurate, and its responses to challenges are fast and generally right. When it comes to drawbacks, System 1 is prone to biases and features some systematic errors. Moreover, it goes shortcuts and has a small concept of logic and statistics. Limitations of intuitive thinking of System 1 are often difficult to avoid due to the fact that it works automatically and has no stop button. System 2 may not know about an error and therefore the biases cannot be prevented but can be minimized by increasing the effort of System 2.

4.1.2 Laziness

When it comes to attention and effort issues, one can consider the "**law of the least effort**", which is very general rule of human actions and also refers to cognitive effort. People will tend to the least demanding activities, if there are several ways to achieve the same goal. Since mental effort is a cost and laziness is inherent part of our nature, people's activities are motivated by a balance of benefits and costs. Let's compare these two systems. Only System 2 is able to obey rules, compare things with similar properties, and select right variants. On the contrary, System 1 does not have these options. It focuses on simple relationships regarding one issue and not several at a time. It was proved, that transition from one task to another requires effort, especially when time is an issue and people avoid mental overload by dividing tasks into many simple steps.

People prefer System 1, because they are generally lazy and rely on feelings, impressions, and intuitions. If we are convinced that the conclusion is correct, we will probably also trust arguments and evidences that advocate it, even if they are wrong. We can accept a probable answer at first glance, but an incorrect answer that comes easy to mind is a serious temptation for us. Intellectual hard-workers are more committed, rational thinking, vigilant, intellectually active, less willing to satisfy the superficial response and more critical to their intuition.

Violation of what we consider to be normal is registered by us with high speed and subtlety. We can detect anomalies due to the fact that we assign standards to a large number of categories. System 1 is perfect in finding a coherent, causal history that combines pieces of knowledge at your disposal, sometimes it does it incorrectly.

"*Jumping to conclusions is efficient if the conclusions are likely to be correct and the costs of an occasional mistake acceptable and if the jump save much time and effort*" [41]. On the other hand, this operation can be hazardous, especially when we can lose a lot and time to collect information is limited. System 2 should be engaged, when the probability that intuition will fail is high and the resultant fault is costly. During jumping to conclusions usually System 1 decides about the final result and only it shows the possibilities. He does not follow alternatives and may not even know about them. Therefore, only System 2 focuses on uncertainties and doubts, because it can bear in mind various sometime incoherent alternatives.

4.1.3 Biases

It is commonly known, that **the law of small numbers** is kind of judgemental bias (or error) which happens when features of a sample population is estimated from a small number of observations or data points. However, only a large number of observations provides more precise result. As it was said, way of thinking of System 1 is inherently unpredictable and intuitive. It looks for consistency, so even a small number of observations is considered as appropriate clarification. It is hard to believe that many aspects of our life are random, and we try to find a reasonable statistical explanation. Therefore, underestimation of this law leads to a general systematic error.

Another cognitive error of our judgement is called the **availability bias**. It is a kind of mental shortcut we make during evaluation of a specific decision or issue. Something that can be retrieved from our memory is more significant than other issues which are not as readily recovered. Events that particularly attract attention are easy recovered from memory. An unpleasant event temporarily increases the availability of a given category in the brain. Personal experiences are easier recovered than incidents that happen to other persons or are statistically reported. For this reason, stories, images and clear examples are effective communication tools. Basing on this large set of availability biases requires some effort, but often results in success. Consciousness of availability biases can contribute to success in team projects and relations. Common issue in joint team works, is that many members of this team feel that they work harder than others, more than their fair share, and others are not grateful enough for their contributions. It is another bias in team work – majority of people think that their contribution is above average.

Our expectations regarding the probability of events, especially thanks to the media, are deformed by the spread and emotional intensity of information to which we are subjected. This causes that our image of the world is not a copy of reality. Humans are mostly driven by emotions rather than reason. They easily focus on not important details; it is hard to distinguish between low and very low probability that something can happen. The cognitive bias, when we either ignore a small risk or give it too much rank, what distorts our judgements, is called **probability neglect**.

Next cognitive bias is an **anchor effect** that describes process of making decisions by humans. We have a tendency to stick too much to the first piece of information (anchor), when we estimate value for an unknown quantity. Next, we based on this first information and our subsequent judgements are made by adjusting away from that anchor. As a result, a bias connected with assessment of further information through the anchor prism is observed. One can defend against the anchor effect by gradually estimating an unknown quantity, whether it is too high or too low, and thus mentally move away from the anchor. This correction often finishes too early, because we are not sure to go further or not, what is a failure of the lazy System 1. Anchoring also occurs as a suggestion-based effect. The method to overcome the anchor is to switch on System 2 and reject the anchor by making and argument.

Representativeness is a simplified method of reasoning, which based on making classification on the basis of the partial similarities to something typical, characteristic, representative, which we already know, to our typical stereotype image. If humans are requested to determine probability, they usually replace probability by representativeness, don't take into account other important information. Moreover, it is common not to consider quality of information in preparing probability estimations. Sometimes, assessment using representative stereotypes is appropriate and gives a solid estimate. In other cases, stereotypes give wrong results, or the estimates are problematic, because of neglect of the base rate. Our minds are prone to lowering the quality of data, so a thoughtful and controlled operation of System 2 is required.

Taking into account stereotypes and representativeness from System 1 point of view, the more precise and concrete description, the more likely it is true. In reality, if an event is described with higher precision, probability that the event occurs is lower. On the other hand, the more general description results in higher likelihood. Therefore, logical and rational System 2 should remember about laws of probability.

The quality of the data is not very important for intuitive forecasts. Anticipating the future, one should always distinguish present evidence from its potential to well indicate future events. Uncertainty should be considered as a key element. We need System 2 to assess if our intuitive forecasts make sense after taking into account the predictive value of current evidence for future events. To forecast the future with higher probability, we should consider common factors between the evidence we got and the potential future state that we are trying to predict. This solution helps to assess how important your data is for the future state.

When we overestimate our ability to interpret and forecast precisely the output after analysis of a collection of data, it is another cognitive bias - **illusion of validity**. Quite often we don't care about quantity and quality of evidence and data we have, because the resultant story, even if it's wrong, is consistent and show a logical pattern. Therefore, we shouldn't trust information and opinions that seem to be coherent and easy to cognitively analysed. We need to focus on the quantity and quality of the actual evidence supporting this information and opinions and access probability that they show reality.

Narrative fallacy describes a phenomenon that untrue stories from the past create our perception of the world and visions of the future. It results from constant human trials to understand the world. We believe in illusion that we have comprehended the past factors that creates the future, and hence we can predict or even control the future. This mechanism causes that we feel more comfortable and level of our restlessness is lower in comparison to situation of full exposure to unpredictability and complexity of the world.

People have tendency to underestimate time and resources needed to finish a future task. This phenomenon is called **planning fallacy**. The following algorithm was prepared to deal with this problem. It is advised to find a reference set and use statistics of this reference to prepare a prediction, which can be further modified using your specific information.

When it comes to predicting results, it was proved, that statistics and formulas are more reliable than even well-prepared humans. Majority of top level forecasters and experts try to be smart, they think in non-standard way, and sometimes they analyse sophisticated sets of factors and agents. Complexity of thinking can be sometimes desirable in strange cases, but usually it decreases the validity. Except for cases that are strange, simple combinations of functions gives better results. Moreover, in comparison to algorithms, **experts' judgements are prone to human erratic and incoherent thinking** in case of complicated data.

Can we trust **expert intuition**? Useful and reliable intuition of forecasters is rather rare. Two main factors can increase probability of correct predictions: regularity of an environment to be forecasted and long period to study these irregularities. We can only rely on predictions prepared in such conditions but doubt about the correctness of predictions done for other environments.

Some people are inherently optimistic and think that they are lesser exposed to negative situations or events than others – this is **optimism bias**. For them, goals are more feasible than likely. Therefore, they believe that are more skilful in predicting the future, which results in overconfidence. Moreover, we have a tendency to consider only our own plans and abilities and we are not interested in other people skills, goals and aspirations. This phenomenon is called **competition neglect**.

4.2 Other categories

4.2.1 Unpredictable Interactions

Unpredictable interactions between various phenomena do not allow us to determine the extent of the correct forecast or forecast of the system status, qualitatively or quantitatively. The unpredictability of interaction is dictated by the randomness of events, behaviours and the effects of actions. Additionally, we may not be able to predict technology development by constraints imposed on us by such factors as lack of information, excessive complexity of information and human factors. "Randomness is the lack of pattern or predictability in events" [Oxford English Dictionary]. The random sequence of events has no logical order and is not compatible with a pattern or combination understood by humans. This makes it difficult to predict whether a given project or the technical solution will be accepted by the target receiving group or whether the tendency of development and interests will be maintained. The consequence may be the lack of a decision or no market introduction of the solution because it involves too much risk of unpredictability and it involves too high costs and work and time expenditure. On the other hand, the introduction of a solution whose effects we cannot predict can cause a great danger to people.

In cybernetic terms, the complexity of the object associated with unpredictable is dependent on the observer's ignorance, i.e. on the amount of information that he / she is he has about this object. If the observer has a large amount of information about the observation object, this object exhibits a low level of complexity. Therefore, the complexity of the object depends on the observer, but it is the subjective nature of the complexity.

After the Second World War, decisions to highlight manned bombers instead of missiles did not predict potential interactions of more compact and stronger atomic weapons, increased reliability and reduced semiconductor devices compared to traditional electrical systems, the ability to guide and control computers by people's mind and the impact of new materials. We are not able to predict how interactions in biological studies of cellular and molecular coding will interact with studies with very high polymer content. The molecules of the polymer produce synthetic molecules that have many features of living organisms. In such advanced areas of technology one can only predict that there is a high probability of intense interactions. However, it is expected that they will increase the significance of both areas, and not contribute to the fall of one of them [20]. In the applied fields of technology, it is done by analyzing how the advances in technologies of individual components can affect the overall performance of a complex system. One encounters a barrier connected with human factors - technologies support and compete, and the impact is so big that no specialist can handle it with the whole -he can only specify the range.

Perrow C. [21] analysis of system disasters. He notes that some industries are more subject to accidents - equipment, procedures, people can interact, particularly unexpectedly. Accidents cause multiple and unexpected interactions of malfunctioning parts, improper procedures developed by people and unforeseen actions. An example of a plane crash of manned aircraft. We can only prevent them when you understand the special features of high-risk systems, avoid blaming the wrong parts of the system, and refrain from technical solutions that only serve to make the system riskier.

In the study of human-computer interaction, predictability allows to determine the consequences of the user's action on the state of the system. An example are computer vision algorithms for collision-avoidance software in self-driving cars. Scientific research of various institutions, including NVIDIA Corporation, [22] Princeton University, [23] teach computers to predict successive road scenarios based on visual information from the environment about current and previous states. Groups of people [24] show a dislike for such cars and they bother them especially in self-learning - they attack them by intentionally throwing themselves on the mask. The unpredictability of the interaction of the human factor may lead to stop the development of such a technology or to a significant extent delay its introduction.

4.2.2 Denial

Denial is a defense mechanism postulated by psychoanalyst Sigmund Freud. Usually, denial manifests in a scenario in which someone is faced with a fact or information too uncomfortable to accept: instead of recognizing it as valid, the subject rejects it instead, despite what may be overwhelming evidence [25].

A cognitive bias that is very similar to denial is confirmation bias. While denial is "an assertion that something said or believed is false", confirmation bias is "a tendency for people to prefer information that confirms their preconceptions or hypotheses, independently of whether they are true".

Often, denial episodes are caused by cultural or religious beliefs, but sometimes they are backed up with the argument of habits ("It has always been done this way"). These beliefs are often the most difficult to counter in an argument, because denial of the given problem, and any form of cognitive dissonance will back up the cultural position. Cultures are especially difficult to criticise, because the culture is what shapes each individual, its decisions and its beliefs.

An example of denial related to the forecasting world could be global warming. Climate scientists are almost unanimously convinced of its reality and have published thousands of publications related to this phenomenon. Despite that, only around half of Americans believe that man-made global warming is happening (a quarter didn't believe that any warming was happening at all).

There are obviously complex reasons for this discrepancy. There are powerful vested interests who are very keen to play down the evidence for climate change for the sake of profit - most notably global energy corporations, and politicians who are associated with them. There may be religious reasons too - to strongly religious people, the idea that human actions are seriously damaging their planet might seem to contradict their notion of an all-powerful God who is directing events on the Earth ("If God is so powerful, why is He allowing this to happen?"). The very unanimity of scientific opinion on climate change also attracts suspicion from people who are prone to seeing conspiracies. They feel that they are somehow being duped by the scientists, that it is part of some kind of global agenda to make us feel anxious and powerless.

However, there may be also psychological reasons for climate change denial. One issue is how abstract global warming is an issue. Human awareness tends to be quite narrow and focused on everyday immediate concerns. Climate change isn't visible and immediate, not part of everyday world, and so most people don't pay attention to it.

But more importantly, human beings are frequently reluctant to accept uncomfortable facts. The theory of cognitive dissonance describes the unease which comes when reality conflicts with someone's beliefs, and how he often tries to ignore or distort evidence, so that he can maintain his beliefs. People try to deal with cognitive dissonance created by global warming by ignoring it completely or attributing it to a conspiracy.

A similar way in which someone deals with difficult situations is through "positive illusions" or self-deception. To avoid confronting uncomfortable realities, people engage in self-deception, convincing themselves that everything isn't as bad as it seems. This is such a grave threat that it is not surprising that many people refuse to accept it.

4.2.3 Inadequate Data

Previous case studies in this paper have pointed to a lack of data as being instrumental in making flawed or inaccurate technology foresight predictions. This may appear relatively straightforward – not enough information is available to make a sound judgement. But is the analyst aware of this? Can it simply be put down to a lack of resources (for example limited collection functions, limited information acquisition budget) and do we fully understand what this lack of resources means for our predictions? Results in this context should be provided with necessary caveats (e.g this prediction is based only on English language sources) but this is difficult when those limitations are not known or appreciated.

Inadequate data does not only refer to a lack of available data. It may also refer to the viability of the data, its reliability, its veracity, its cost, its format (not being easily assimilated into an information system for example), its relevance, provenance and how up to date it is. Organisations must make strategic information decisions that inevitably preclude their ability to have adequate data all the time, on budget and in a format that is compatible with their in-house information system.

Another question is how data may be adequate for one purpose but not for another. We are used to seeing polls for Government elections based on a relatively small data set. This is adequate for that purpose but would not be adequate for determining the outcome of an election.

Specifically, on the challenges that Intelligence Agencies face, and using the results from RECOBIA's D3.1 (Psychological Factor Survey) we should mention the following points that relate to cognitive biases and the information collection process and how these limitations can impact our ability to perform accurate technology foresight:

- There are other cognitive biases that affect the data collection process. For instance, the planning fallacy occurs when the predicted completion time for a task is far more optimistic than the time needed to actually complete it. See: Buehler, et al. (2002), p.250

- The collection phase of the intelligence cycle is especially vulnerable to this kind of fallacy as the time needed to identify and exploit a source can be difficult to estimate. Similarly, it is not unusual for the collection effort to stumble. For example, a promising source may turn out to be useless, or the collector may lack the knowledge or experience necessary to find the information requested by the customer. Consequently, they are obliged to revisit and revise their collection plan and look for alternative solutions

- Another cognitive bias is the "swarm ball" bias. As defined by Lowenthal, the "swarm ball" bias relates to the tendency of collectors or collection agencies to generate information on high-value issues that are deemed important, regardless of whether or not they are able to generate anything useful or can employ the appropriate collection methodologies. Lowenthal (2006), p. 73

- Invariably, the primary impetus of this behaviour is the need to secure one's future budget. The problem can be overcome by matching intelligence priorities with the resources and capabilities of the different collection agencies

- This can be reinforced by an experiential limitation bias. This argues that collection habits are the consequence of collector's prior experience, as well as the reluctance to employ new or unfamiliar approaches to the work. Consequently, collectors are likely to ignore new methods or sources simply because they are not consistent with previous experience or with the modus operandi of their organisation

- The validation of sources remains one of the thorniest challenges in intelligence collection, and one that continues to grow in complexity. See: Omand (2010), p.146

- For example, HUMINT collection can be undermined by the lack of direct access to the source. The most notorious example of this is Curveball, the Iraqi defector who provided the German intelligence service, the BND, with information on Iraq's WMD capabilities. This information was passed on to the US intelligence community and used to justify the toppling of Saddam Hussein. However, the US was never given direct access to the source and so was unable to engage in face-to-face validation. With regard to OSINT, collectors and analysts alike are finding it increasingly difficult to separate fact from fiction. Open sources are increasingly susceptible to denial, deception and manipulation and so must be handled with particular care. However, most validation guidelines are bound to the printed word and do not provide adequate advice in how to evaluate the validity of an image, video, satellite photo or social media feed. This process is only likely to get worse

- Further cognitive biases can emerge through what is known as "The curse of knowledge (or déformation professionnelle)". Collectors may be unable to communicate with non-collectors who lack expert knowledge on collection systems and approaches. Consequently, their ability to improve the collection process may be constrained by their inability to communicate effectively, to accommodate opposing views, or to transcend the limitations of their learning

- This type of bias can also be found in Language-related collection challenges. The process of collection is invariably dependent on the language capabilities of the collector. The more adept the collector is in a foreign language, the likelier they are to find, process, analyse and communicate relevant information, as well as structure additional collection activities in light of previously acquired knowledge. Lowenthal (2006), p. 92

- In light of this challenge, local native speakers may appear to be the best recruitment targets. However, serious challenges arise in relation to their employment. For example, security restrictions may deny them the necessary clearances. Moreover, while their foreign language skills may be outstanding, their ability to translate terms into a local language terms may be unsatisfactory. Lowenthal (2006), p. 92

- For OSINT users, there are substantial language biases in favour of English, which still dominates the internet, as there are more documents posted in English. This can introduce a number of cultural as well as information biases. Unless corrected, it leads data collectors to systematically under estimate the importance of foreign (non-English) language sources, which contain differences in perception.

4.2.4 Information Overload

Information overload is one of human factors-related errors during foresight activities. Generally, information overload means too much information which causes a problem in effective understanding of an issue or making decisions. It was defined by Speier et al.[28] as "Information overload occurs when the amount of input to a system exceeds its processing capacity. Decision makers have fairly limited cognitive processing capacity. Consequently, when information overload occurs, it is likely that a reduction in decision quality will occur." Finally, it results in either delay in making decisions or making the wrong decisions.

A primary source of information overload results from increase in number of information channels like radio, television, print media, websites, e-mail, mobile phones, RSS feeds, social media etc. A lot of new, often conflicting, contradictory, old, or inaccurate information is constantly created, duplicating and sharing, especially online. There is also increasing volume of available historical data. On the other hand, there is a lack of methodologies for quick processing, comparing and evaluation of information sources. We also suffer from deficiency in clear structure in groups of information and poor clues as to the relationships between those groups.

Thanks to search engines we can find required information on line in seconds. However, due to lack of supervision we have to cross-check the obtained date before decision-making, which takes up more time and causes confusion. Information overload can cause, that people ignore or underestimate low priority issues and fail to identify emerging threats or do it too late. Forecasters can receive too much information, while on the other hand, they don't get enough of the right information.

Most of the current methodologies for technology forecasting are performed by human beings and therefore are vulnerable to human limitations including information overload. Specialists, experts and other people involved in the forecasting like to keep up with the constant stream of new data and often exceed an optimum amount of the proper information, which enables the most-considered judgements. This illusory temptation to constantly gather information can lead to ineffective thinking and perhaps failing to spot the obvious issues.

Trend analysis methodologies create predictions basing on quantitative historical data. Forecaster have to take care to use information from reliable sources. Some sources, especially Internet-based, can be accidentally altered or intentionally manipulated what can lead to incorrect forecasting results and economical failures.

How to cope with information overload? There are two main strategies prosed by Savolainen [30] – withdrawal and filtering [29]. The first strategy operates at the level of information source and suggests limiting number of information sources to a minimum by selecting only reliable sources. Filtering works at the level of information content and assumes systematic attempts to get rid of insignificant information from the selected sources, e.g. by removing the emails based on the subject or the sender. Eventually, it is also assumed that a combination of these strategies, depending on the situation, gives the best results in protecting oneself from the flood of information.

And finally, some advice given by A. Gross [31], experienced forecaster: “Forecast with care, adopt the idea of crowd-sourcing or the wisdom of experts; believe no-one, consider every-one. Welcome information overload, but then quickly reduce quantity, upgrade quality.”

4.2.5 Post-storm Neurosis

This bias involves people who have been subjected to extreme events, referring to: "danger of overreacting to circumstances having just had a severe event" [34]. Clearly the problem can convene any type of forecast, not only those related to the weather, for example following an unexpected earthquake and sudden predictions of more powerful earthquakes are often followed, these forecasts often have no scientific basis (the scientific community is very sceptical that earthquakes can be predicted) or using statistical data as a method and a comparison with unrelated historical events. The examples can also concern technological forecasts, let's think, for example, of the famous millennium bug. Previous bugs had led many people to catastrophically interpret what would be a localized and limited problem for many experts. For this reason, many forecasters were very pessimistic about the millennium bug and people had given even more weight to these forecasts. There are stories of those who took refuge in remote and deserted places for fear.

4.2.6 Groupthink

The social nature of humans stipulates that everybody wants to belong to a group of people. This rule is essential for the human society and for intelligence services as well. However, if belonging to the group becomes more important to the intelligence officer than coming to the right conclusions, the distorted rule can lead to over-conformism, which is also known as group thinking. As Janis notes, this is “a mode of thinking that people engage in when they are deeply involved in a cohesive in-group” [35]. In such circumstances, group members stick to common assumptions and views that are never questioned and challenged. Consequently, the desire to remain friendly and avoid conflict invariably results in dismissing or ignoring novel assumptions, hypotheses or opinions, resulting in poor analytical rigour.

This process is often un-conscious and can, therefore, not be controlled. The affected group fails to consider views and approaches which are alternative to the mainstream reasoning that universally shapes attitudes of its members. Some intelligence services attempted to institutionalise dis-conformism to prevent group thinking by creating red teams (independent groups that challenge an organization to improve its effectiveness by assuming an adversarial role or point of view). Compartmentalization and secrecy can increase the likelihood of groupthink.

Davies substitutes “groupthink” with three related phenomena: “tribal think”, “boss think”, and “no think” [36].

- “Boss think” occurs when “the more senior practitioners who have worked complex substantive issues the longest [...] act as if they "own" the paradigm through which inconclusive evidence is assessed”.
- “Tribal think” occurs when novel interpretations and judgments are rejected because they do not agree with the main line of reasoning that cost a group a significant amount of time and effort to develop.
- “No think” refers to “a psychological barrier to sound analysis, ... the analyst’s conscious or unmotivated resistance to changing an "agreed-on" assumption or estimative judgment that took hours, if not days, of overcoming tribal think to reach”.

If available resources permit, the problem of groupthink can be addressed through competitive analysis, with multiple units and agencies working on the same analytic problem [37]. However, as an example of failed intelligence surrounding Iraqi WMD shows, competitive analysis cannot be trusted to yield multiple perspectives.

Quoting from the *Report On The US. Intelligence Community’s Prewar Intelligence Assessments On Iraq*, “the Intelligence Community suffered from a collective presumption that Iraq had an active and growing weapons of mass destruction (WMD) program. This “group think” dynamic led Intelligence Community analysts to both interpret ambiguous evidence as conclusively indicative of a WMD program as well as to ignore or minimize evidence that Iraq did not have an active and expanding program [38].”

4.2.7 “False Analogy” Syndrome

In an analogy, two objects (or events) are shown to be similar. Then it is argued that since one of the two objects has a certain property, so also the other object must have it. A false analogy happens when the two objects are different in a way which affects whether they both have the selected property. In this case, the two objects are substantially different, and the same conclusions cannot logically be drawn.

Sometimes these differences are outright ignored by the person presenting the fallacy; other times, they may not be aware of the differences. The fallacy occurs, and is common, because real-world parallels are always limited; the differences between things can often be overshadowed by their similarities [39].

A first example of false analogy could be a statement from the conservative guru Glenn Beck, right after the massacre of 77 young people at a Norwegian Socialist Party youth convention carried out by Anders Behring Breivik in 2011: “The Norwegian Socialist Party has a Youth wing. The Nazis had their Hitler Youth. Sounds to me like the Norwegian Socialists are indoctrinating their young people just like Hitler [40].”

Another example is the following. DNA is a code, a code requires an intelligence, therefore, DNA comes from an intelligence. The problem with this is that the idea of DNA "encoding" the information is purely an analogy, since the DNA precedes the information rather than vice versa.

Because of the prevalence of false analogies, metaphors and actual analogies are much less useful in making arguments. To tackle this kind of cognitive bias, one should identify the two objects or events being compared and the property which both are said to possess and show that the two objects are different in a way which will affect whether they both have that property.

4.2.8 Halo Effect

The halo effect is a cognitive bias. It is the tendency for a person's positive or negative traits to 'spill over' from one area of their personality to another in others' perceptions of them (it is linked to the physical attractiveness stereotype).

In cognitive psychology, the situation or cognitive context for the halo effect is when a prior or previous global judgment has been produced about a person. Our cognitive task (or goal) is to make a judgment about the specific independent characteristics of a person, and the halo effect means we are less rational when we perform this task.

The effect of the halo effect is twofold: an assimilation of the specific judgments to our global impression; an over estimation of the correlation between the independent characteristics of a person.

To highlight this cognitive bias in practical terms, it is insightful to mention here the work done as part of the RECOBIA project. During a workshop session, two different documents, each with a picture of a different man and five questions were distributed to different participants. What was expected is that a first global impression of an object would influence the subsequent judgments or evaluations of that same object on more specifics dimensions or characteristics. The two fictive persons were highly differentiated on a broad dimension that is attractiveness. The pictures were combined with a set of questions, such as 'would you like to work with this person?', 'Do you think this person is reliable?' etc. The two variables were attractiveness and induced effect. The objectively more attractive person received more favourable judgments than the objectively unattractive one. These results demonstrate the Halo effect.

5 Stakeholder's questionnaire

To further investigate the area of forecasting errors, an online questionnaire was arranged by the consortium members using Google Forms and circulated within the PYTHIA's Stakeholders Group in the period July – August 2018. This questionnaire had the purpose to collect experience directly from practitioners and experts from various domains. All the questions are presented in section 5.1, answers are shown in section 5.2, while in section 5.35.2 an analysis is provided about the collected answers.

5.1 The questionnaire

The aim of the questionnaire was to get the experts to reflect upon the topic of errors in the field of technology predictions, taking advantage from their direct experience. The survey started with considerations regarding privacy issues: it was stated that information provided in the questionnaire would have been stored anonymously and deleted after the completion of D2.2. Moreover, it was assured that data from the questionnaire would have not been shared with any third parties outside the PYTHIA consortium and that the Stakeholders Management Committee (SMC) of the PYTHIA project, chaired by Zanasi & Partners, would have guaranteed the compliance with privacy and data protection regulations. A general introduction followed, with the purpose to frame the problem. Then five main questions were presented, each one divided in more specific sub-questions. The full questionnaire is reported below.

Are you aware - or have been part of – technology prediction activities that proved to be inexact? "Technology prediction", in this context, refers either to forecast or foresight activities related to a technology development. In our interpretation, the difference between the two concepts is that "forecasting" usually refers to predicting the likely outcome of a certain event based on the knowledge currently available, while "foresight" refers to predicting different, possible, alternative scenarios. Although it is often not a simple task to determine whether a prediction is correct or not, what we are interested in collecting here are information about those experiences that, according to your judgement, ended up with a "wrong" result.

Please describe each of those experiences by replying to the following questions:

A) Prediction activity

1) What was the aim of the prediction activity?
2) What technology areas were involved?
3) What forecasting methodology/-ies was/were used?

B) Forecast errors / forecast results

4) How it has been discovered that the prediction was wrong?
5) What the "correct" outcome of the prediction should have been?

C) Details of errors

6) Have errors been made during the prediction activity?
7) What kind of errors?
8) Would you consider some of those errors been the consequence of mistakes/flaws in reasoning, happened either at the conscious or unconscious level?

D) Consequences

9) What consequences those errors produced?

E) Next forecasts

10) In successive predictions, have precautions been taken to avoid repeating those kinds of errors?
11) If YES in 10: Have those precautions proved to be effective?

Questionnaire PYTHIA

The information provided through this questionnaire will be stored anonymously.
The PYTHIA consortium will securely store this data until submission of deliverable D2.2 (scheduled for the end of September 2018).
The collected data will be deleted immediately afterwards.
The data from this questionnaire will never be shared with any third parties outside the PYTHIA consortium.
The Stakeholders Management Committee (SMC) of the PYTHIA project, chaired by Zanasi & Partners, guarantees the compliance with privacy and data protection regulations.

If you have any question, please contact Mr. Graziano Giorgi at: graziano.giorgi@zanasi-alessandro.eu

*Required

Predictive methodologY for TecHnology Intelligence Analysis

PYTHIA

Are you aware - or have been part of – technology prediction activities that proved to be inexact?"Technology prediction", in this context, refers either to forecast or foresight activities related to a technology development. In our interpretation, the difference between the two concepts is that "forecasting" usually refers to predicting the likely outcome of a certain event based on the knowledge currently available, while "foresight" refers to predicting different, possible, alternative scenarios.Although it is often not a simple task to determine whether a prediction is correct or not, what we are interested in collecting here are information about those experiences that, according to your judgement, ended up with a "wrong" result.

Figure 1: The questionnaire's introduction on Google Form

5.2 Results

Until August 15th, a total of 9 responses have been collected.

It is thought, that relatively low number of stakeholders involved in the questionnaire resulted from the fact, that the stakeholders were generally reluctant to describe their failures in technology forecasting. Although the questions were prepared in a general way, each description could potentially reveal some sensitive facts and undermine reputation of a company.

Authors are aware, that representativeness of the analysis performed on the basis of nine answers could be thought as limited, however, some general conclusions seem to be drawn correctly.

For each question, the more significant answers are reported below.

A) Prediction activity

1) What was the aim of the prediction activity?

The collected answers show very different aims. Some of them are:

- to reason on the future, looking for strategic advantages;
- to provide new and efficient debris removal solutions;
- to start a research and development on new brunch of applications within the scope of the interest of a company;
- to perform an intelligence foresight analysis about a major current affairs crisis for policy-makers;
- to forecast the total number of shelters needed for flood victims in a specific area.

2) What technology areas were involved?

Technology areas are quite different one with each other too. Some of the covered topics are:

- unmanned vehicles and drones;
- cyber defense situational awareness and crawling;
- data/text mining;
- lasers;
- mathematical algorithms applied to economic, social and political systems;
- earth observation based technology.

3) What forecasting methodology/-ies was/were used?

The main methodologies reported are:

- IT platforms for technology monitoring, technology watch, technology alerts, technology assessment;
- scenario building;
- technical studies and simulations;
- analytical network process;
- desktop analytical techniques such as analysis of competing hypotheses (ACH);
- analysis of new technology reports from newspapers;
- trend extrapolation method.

B) Forecast errors / forecast results

4) How it has been discovered that the prediction was wrong?

Respondents realized that there were imperfections in their forecasts in the following ways:

- only at the end of the prediction process;
- comparing estimated data with real ones;
- while using IT tools, discrepancies emerged and forecasters realised that a tool alone cannot make predictions accurately;
- comparing outputs with the opinion of forecasting experts.

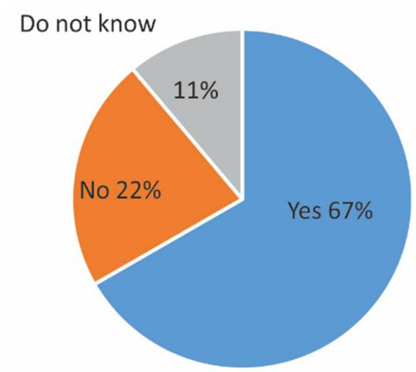
5) What the "correct" outcome of the prediction should have been?

This question did not provide simple answers. Some experts complained about how "blurry" the estimated scenarios were: this fact hindered decision-making and more realistic and defined views would have been preferred. Other respondents explained that predictions were incomplete and should have considered a longer time window. Finally, other experts reported numerical differences between forecasts and the real outcome, up to a quarter of the estimated value.

C) Details of errors

6) Have errors been made during the prediction activity?

Six respondents out of nine answered "Yes" (67%), two respondents answer "No" (22%) and one person stated that he did not know. According to these data, two predictions out of three contained errors.



7) What kind of errors?

The most common answers are:

- inaccurate sources selection and validation;
- methodological errors;
- only the technical aspects were considered;
- cognitive errors, such as:
  - misinterpretation of the significance of data;
  - misattribution of causal relationships between data;
  - biases such as conformation bias;
- too much trust in IT tools (assumption that "the forecasting software knows best").

8) Would you consider some of those errors been the consequence of mistakes/flaws in reasoning, happened either at the conscious or unconscious level?

As emerged in the previous answers, several errors were due to unconscious issues.

D) Consequences

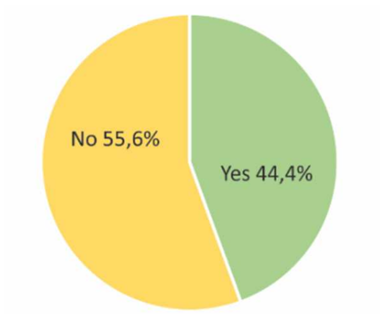
9) What consequences those errors produced?

The most common answer are:

- loss of strategic superiority and reputation damages;
- delayed development of such technology;
- some diseases were transmitted more quickly than expected;
- chance for being among first suppliers of drone application developers was lost;
- stopping real tests.

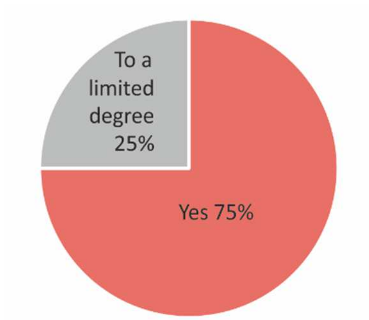
10) In successive predictions, have precautions been taken to avoid repeating those kinds of errors?

Five respondents out of nine answered “No” (55,6%), four respondents answered “Yes” (44,4%).



11) If YES in 10: Have those precautions proved to be effective?

Most common answer is “Yes” (75%). In 25% cases, experts answered “To a limited degree”, explaining that they are not sure about how to effectively remove cognitive errors.



E) OTHERS

12) Do you know other use cases?

All respondents answered “No”.

5.3 Analysis

As the questionnaire showed, technology predictions could be useful in several areas and applied to very different problems: from robotics to text mining, from mathematical algorithms to earth observation technologies.

Almost every methodology reported by the experts has been already analysed in PYTHIA in the deliverable D3.1 (“Review of the current methodologies for defence and security technology forecasting”), except for Analysis of Competing Hypotheses (ACH). This methodology is used to overcome cognitive biases by taking into account multiple possible hypothesis and organising them in an ordered matrix structure, providing lists of arguments (for and against) each one of them. ACH, however, is quite time-consuming and for large and complex project could be not affordable. Even though D3.1 has already presented several methodologies with similar aims, ACH should be taken into account in the next steps of WP2 and represents a precious input from the PYTHIA’s Stakeholders Group.

What emerged from the questionnaire is that the experts have happened to face prediction failures or errors, leading to quite serious consequences reported to be: loss of strategic superiority, reputation damages and delayed development. The most predominant causes appear to be methodological and cognitive errors, suggesting that powerful tools and renown predictive methods are often insufficient for delivering satisfactorily results, if the analyst is not supported by a solid methodology and cognitive issues’ awareness.

Finally, in question 11 emerged that some experts were unsure about how to remove cognitive errors by their forecasting process. This underlines the need for recommendations and best practices in order to tackle cognitive pitfalls: PYTHIA dedicates tasks T2.3 and T2.4 to this exact purpose.

6 Conclusions

In this document the subject of failures of the technology forecast was undertaken. From the presented past cases, it is clear that judgments or any attempts to quantify or measure risk and possibilities of failed forecast is not an easy task. Each case is different and individual, placed in various situations, in local or global background etc.

In selected cases, we presented the variety of reasons for technology to fail when its success was optimistically predicted. Many errors are strictly technically related, and some of them could be avoided by additional quality control or modeling and simulations. Unfortunately, in cases from everyday life many reasons are human related. They can range from simple negligence at manufacturing level through lack of vision and ideas for the technology ending with cases of personal prejudgment.

Projects related to PYTHIA, like LEILA or RECOBIA, that aimed to provide innovative learning methodology and to improve the quality of intelligence analysis, show that investing and educating skilled and experienced personnel is one of the best way to improve forecast accuracy and to reduce possibility of potential fail.

The prepared questionnaire proved usefulness of the forecasting methodologies to various issues starting from text mining, through mathematical algorithms up to lasers and unmanned vehicles and drones. However, the questionnaire also revealed that only one third of the predictions have been errorless. The responders pointed out different kinds of errors, including inaccurate sources selection and validation as well methodological and cognitive errors. This proves that a solid methodology must be combined with a powerful tool to reach satisfactorily results, because errors in forecasting can lead to serious consequences including loss of strategic superiority, reputation damages, delayed development of a technology and lost chances for business.

The Stakeholders Group in their forecasting activities used the methodology called Analysis of Competing Hypotheses (ACH), which is quite time-consuming and complex. ACH was not described in the deliverable D3.1 and therefore will be analysed in the further works in WP2.

It can be also concluded from the questionnaire that some experts are not sure about how to effectively remove cognitive errors from their forecasting activities. It clearly shows the strong need for improvement of accuracy of technology foresights, what by done by recommendations of successful forecasters and best practices for avoiding cognitive pitfalls. These issues will be considered by PYTHIA consortium in tasks T2.3 and T2.4.

7 References

[1] Jim Winchester, "The World's Worst Aircraft", 2005.

[2] “Huge Soviet Plane Crashes, Killing 14”. New York Times. November 23, 1933.

[3] Howard Mingos, ed. “The Aircraft Year Book for 1935”, New York: Aeronautical Chamber of Commerce of America, Inc., 1935. 248.

[4] F. Robert Van der Linden, Victor J Seely, “The Boeing 247: The First Modern Airliner”.

[5] "De Forest Says Space Travel Is Impossible", Lewiston Morning Tribune, February 25, 1957.

[6] “Rutherford cools atom energy hope”. The New York Times, September 12, 1933

[7] Brian Van DeMark , “Pandora's Keepers: Nine Men and the Atomic Bomb”.

[8] G. Baura, Engineering Ethics: Chapter 3: 1978: Ford Pinto Recall, Elsevier, 2006

[9] Technical Assessment of Toyota Electronic Throttle Control (ETC) Systems, National Highway Traffic Safety Administration, February 2018.

[10] T. Irvine, “Tacoma Narrows Bridge Failure Revision A”, 16 April 2003, http://www.vibrationdata.com/Tacoma.htm

[11] Heuer, R.J., “The Psychology of Intelligence Analysis”, Washington DC: Center for the Study of Intelligence, Central Intelligence Agency, 1999.

[12] Coxall, M. & Caswell, G. “Human Manipulation: A Handbook”, Spain: Cornelio Books.

[13] John Read, “From Alchemy to Chemistry”, Courier Corporation, 2013, ISBN 0486170845, 9780486170848

[14] Wason, P.C., “On the Failure to Eliminate Hypotheses in a Conceptual Task”, Quarterly Journal of Experimental Psychology, 12 (3), 129-140, 1960.

[15] A. Tversky, D. Kahneman, 1973 “Availability: A Heuristic for Judging Frequency and Probability. Cognitive Psychology”, 5, 207-232, 1973.

[16] https://www.sciencehistory.org/distillations/magazine/the-secrets-of-alchemy

[17] Ibidem

[18] Ibidem

[19] P. Pirolli, S. Card,“The Sense making Process and Leverage Points for Analyst Technology as Identified Through Cognitive Task Analysis”, Proceedings of International Conference on Intelligence Analysis. Retrieved on 21/07/2014, 2005; from: http://vadl.cc.gatech.edu/documents/2 card-sensemaking.pdf

[20] James Brian Quinn, "Decision making Technological Forecasting", Harvard Business Review, From the March 1967 Issue

[21] Perrow C. “Normal accidents—living with high-risk technologies” New York: Basic Books, Updated Edition, Princeton University Press, 1999

[22] "The AI Car Computer for Autonomous Driving". NVIDIA. Retrieved 27 September 2017,

[23] Chen, Chenyi. "Deep Learning for Self -driving Car" (PDF). Princeton University. Retrieved 27 September 2017.

[24] Rage against the machine: self-driving cars attacked by angry Californians, The Guardian, 06.03.2018, https://www.theguardian.com/technology/2018/mar/06/california-self-driving-cars-attacked

[25] Niolon, Richard, "Defenses". psychpage.com, (April 8, 2011).

[26] https://gigaom.com/2012/08/27/how-iridium-took-a-chance-on-spacex-and-won/

[27] https://www.economist.com/books-and-arts/2016/06/30/highs-and-lows

[28] Speier, Cheri; Valacich, Joseph; Vessey, Iris, "The Influence of Task Interruption on Individual Decision Making: An Information Overload Perspective". Decision Sciences. 30, 1999.

[29] https://www.interaction-design.org/literature/article/information-overload-why-it-matters-and-how-to-combat-it

[30] Savolainen R. “Filtering and withdrawing: strategies for coping with information overload in everyday contexts”, J Inf Sci 33(5): 611–621, 2007.

[31] Andrew C. Gross, “Analysing and forecasting global business markets: Reflections and recommendations,” Social and Management Sciences, 21/1 (2013).

[32] https://www.theguardian.com/environment/2012/oct/15/fukushima-disaster-avoided-nuclear-plant

[33] Severinghaus, J.P., Wallace, S.B., William, F.D., MacCallum, T., Whalen, M., “Oxygen loss in biosphere 2”, Eos 75, 33–37, 1994.

[34] Martin V Young , “The Human Element in Forecasting - a Personal Viewpoint”, The European Forecasters : 33 – 39

[35] I. Janis, ”Victims of Groupthink”, Houghton Mifflin, Boston, 1972.

[36] J. Davis, “Why Bad Things Happen to Good Analysts”, in RZ George & JB Bruce (eds.), “Analyzing Intelligence: Origins, Obstacles, and Innovations”, Georgetown University Press, Washington, D.C., pp. 157-170, 2008.

[37] M. Lowenthal, “Intelligence: From Secrets to Policy”, CQ Press, Washington, D.C 2006.

[38] Report On The US. Intelligence Community’s Prewar Intelligence Assessments On Iraq. Ordered reported on July 7,2004

[39] Cederblom, J., and Paulsen, D., 2000, “Critical Reasoning, Cengage Learning”.

[40] https://www.telegraph.co.uk/news/worldnews/europe/norway/8660986/Norway-shooting-Glenn-Beck-compares-dead-teenagers-to-Hitler-youth.html

[41] “*Thinking, Fast and Slow*”, New York: Farrar, Straus and Giroux, 2011.

[42] https://www.cio.com.au/article/420036/what_went_wrong_hubble_space_telescope_what_managers_can_learn_from_it_/

[43] https://spaceflightnow.com/2015/04/23/fixing-hubbles-blurry-vision/