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Chapter

The Perception of the Effectiveness of Vaccines between Myth and Reality

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Abstract

The perception of the risk of a vaccine and its effectiveness has always been the subject of study. The human mind, in fact, tends to underestimate the effectiveness of a vaccine and overestimate its risk. But where does this problem come from and how does the human being think when he is talking about a vaccine? In this chapter, I intend to review the main studies on the efficacy of the vaccine. I also intend to deepen the studies on the perception of risk to highlight what are the strategies of thought adopted by the human beings when they must reason on these issues.

Keywords: vaccine, thought psychology, cognitive bias, risk perception, efficacy and effectiveness vaccine

1. Introduction

Nowadays, the opportunity of getting vaccinated to lower the risk of contracting various diseases still tends to be seen by many people as an obligation that comes to undermines the rights of human beings rather than being an advantage. And yet, the history of humankind should have taught us that vaccines, far from being a dangerous tool to be demonised, are one of humankind's most important progresses. Today more than ever, after years of pandemic, we can only be aware of the fact that vaccines are the most important weapon people can use against viruses [1, 2].

Looking back over human history we can see a time when there were no vaccines. A time when people could not even imagine it could be possible to develop such a weapon to help people in the fight against disease. At that time the only weapon at the disposal of human beings was isolation. Once a person or a group of people had contracted an infectious, incurable or fatal disease, there was no other way of fighting it other than isolating people. That isolation, while protecting humankind from infection, did not however eradicate the disease and its spreading. Furthermore, isolation made it impossible to help the sick, left in this way to face their fateful destiny alone.

In 1796, however, a breakthrough was made in that sense by a British physician Edward Jenner. That year the world's population had to fight a terrible, lethal virus: smallpox. This caused an endemic disease to develop that soon became the leading cause of death in many geographical areas, including Europe. The British physician Jenner started with the consideration that once a person had contracted the virus, if

they were able to survive, they turned out to be immune to the disease. In the particular case of smallpox, the physician noted that milkmaids who had come into contact with bovine smallpox turned out to be immune to smallpox.

Starting with this consideration he thought of injecting bovine smallpox pus into a human being in the hope of thus making them immune to the disease. On 14 May 1796, the physician took material from a pustule on a bovine afflicted with smallpox and injected it into an 8-year-old boy. The reason for him choosing an 8-year-old boy as the subject of his test is unknown. However, today we can state that he made the right choice. Indeed, children are generally less vulnerable and this could have been advantageous since the test involved direct contact with the virus [3].

What happened on the days following the inoculation of the pus into the boy was something that appeared very similar to a miracle. The child, in fact, started developing the symptoms of the disease. After a few days, he recovered. Some months later, Jenner injected blood taken from another man afflicted with smallpox into the boy. The boy did not fall ill. No symptoms appeared. The boy had become immune to the disease. In 1796 Jenner had managed to chalk up the greatest point in the match against viruses. The history of smallpox confirms this. In 1979, in fact, the WHO declared smallpox to be permanently defeated and today it is no longer necessary to be vaccinated against smallpox (source: <https://www.epicentro.iss.it/>, website of the Italian National Health Institute). Going back over the essential stages that led to defeating the smallpox epidemic produces an authentic sense of relief. Indeed, the invention of vaccines permitted fighting the development of infection and slowing down the progression of epidemics.

In spite of this, in several countries so-called “anti-vax” movements are present and well-established. Furthermore, the recent COVID-19 epidemic led the world’s entire population to question the usefulness and importance of vaccines. And yet, there is a very strong emotion that accompanies every thought about vaccination: fear. Fear due to the feeling that inoculating foreign matter into our body, at a time of well-being, may lead to negative consequences. Fear in itself is an emotion that has developed for the survival of the species [4–26]. Without fear, human beings would be less attentive to difficulties and dangerous situations, they would be unable to develop strategies to overcome them and sometimes they would be unable to find helpful solutions for survival. However, at a historical time such as the one we have experienced, and are still experiencing, dominated by total uncertainty about the future, the risk is that fear may become a negative emotion that prevents distinguishing a subjective danger from the actual objective danger and fog the mind preventing it from seeing the real benefits of vaccination. This is why it is crucial, and urgent, to understand how the human mind thinks of the efficacy of a vaccine and, above all, what information the human mind uses when it has to choose between two different vaccines.

2. Relative and absolute risk reduction

The concept of vaccine efficacy (VE) is regularly used in medical statistics. In order to understand it you need to know not only two fundamental concepts but also above all the difference between them. These concepts are relative risk reduction (RRR) and absolute risk reduction (ARR). Indeed, the formula to calculate vaccine efficacy is the following: $VE = (1 - RR) \times 100$ where RR is the value of relative risk reduction, that is the reduction in the risk of infection between the vaccinated population and the non-vaccinated population of a specific group of subjects in a trial [26–28].

Let us look at an example taken from reality to better understand what we are talking about. As the starting point, let us take the two articles presenting the vaccine efficacy data related to the vaccine for COVID-19 developed by Pfizer [29] and that related to the vaccine for COVID-19 developed by Moderna [30] when we were at the height of the pandemic. In that same year, we all discussed specific data reported by the media, that is a rate of vaccine efficacy of 95% for the Pfizer vaccine. How was this number arrived at, which from merely a media and communicative perspective had a very strong impact?

The calculation to arrive at this figure is the following. The starting point was the total number of subjects who took part in the Pfizer vaccine trial, that is 34,922 persons. Of these, 17,411 were subjected to the vaccine and 17,511 received the placebo. Only 8 people in the vaccinated group got infected while 162 in the non-vaccinated group got infected. The estimate of the probability of getting infected for the group of vaccinated subjects was therefore calculated through the ratio $8/17411$ that is 0.046. In the group of non-vaccinated subjects, instead, this estimate is given by the ratio $162/17511$ that is 0.925. Given these two probability estimates, the vaccine efficacy is generally calculated by using the ratio. In this case, therefore, $0.046/0.925 = 0.05$. This figure given as a percentage has become that 5% in the reduction of the probability of getting infected from which derives the 95% communicated to the media [11, 12].

In itself, the figure of 95% would therefore be the correct number to be communicated to the general public. The basic problem is that a probability of this type, given as a percentage, was misunderstood by the world's population. For what reason? Because when our mind is faced with a figure of 95% of vaccine efficacy it intuitively interprets it in terms of frequency. That is, in this specific case, if the Pfizer vaccine has an estimated efficacy of 95% it means that of 100 persons exposed to the virus, only 5 will contract it. But this certainty is, in actual fact, misleading.

Let us go back over the calculation that led to the figure of 95%. That which has been calculated is what in medical statistics is defined as RRR, a proportional reduction in relative risk, in other words, an estimate based solely on the population that took part in the trial and not the world's population. This specification, far from being superfluous, is fundamental when it is necessary to choose a vaccine. Indeed, the absolute risk reduction, therefore that measurement that allows us to quantify the difference between the risk of disease between vaccinated and non-vaccinated subjects in absolute terms is much smaller. In the case of the Pfizer vaccine, the absolute risk reduction is given by the difference between the probability of getting infected between the two groups, of vaccinated and non-vaccinated subjects: $0.925 - 0.046 = 0.879$. The value of 0.879 is much lower than the 95% of efficacy communicated by all the media. Therefore, we tend to consider 95% as an absolute risk reduction while the figure is actually lower.

3. Misunderstandings about the vaccine efficacy figure

The inability to comprehend the concept of vaccine efficacy just like the lack of knowledge of the two concepts, relative risk reduction and absolute risk reduction, has repercussions on the daily life of the world's population. To understand what we are talking about, let us start by analysing a tangible case: the recent COVID-19 pandemic. The decision to talk about this case is due to the fact that it is the most recent pandemic condition that people have had to face. Furthermore, the emergency led the world's entire population to reflect about vaccines.

People regularly hear talk about vaccine efficacy in the media, and the media tends to give numbers as a percentage. And yet, given the delicate nature of the choice to be made, the information about a vaccine should be gathered by interviewing doctors, especially general practitioners. These doctors are indeed those assigned by the government system to be intermediaries between the pharmaceutical companies, governments, and the general public in a medical setting. However, at least in the case of the COVID-19 vaccine, the information was mostly collected through media channels and spread over social networks. This meant that in terms of vaccine efficacy the world's population encountered a single value, given as a percentage, for each vaccine. This value, as we have seen, expresses an efficacy based on a relative risk reduction, that is a reduction in risk proportional to the sample that took part in the trial. The problem is that this index of efficacy is intuitively and erroneously interpreted by the general population as an index of absolute risk reduction. And this is because of the very operation of our mind.

In 2021 two different types of vaccine, developed by different pharmaceutical companies, were chiefly distributed in Europe. In countries where both vaccines were distributed to the population, controversies arose immediately. For example, in Italy, the two vaccines available in early 2021 were the one developed by Pfizer in partnership with BioNtech (trade name: Cominarty) and the one developed by AstraZeneca (trade name: Vaxzevria). The former is of American and German origin, the latter is of British origin born from the partnership between Oxford University and the pharmaceutical company. Controversies about vaccines in Italy are clearly nothing new. And yet, in this case, the controversy had a very peculiar nature since it started not from the general population but from a group of doctors. In February 2021, in fact, a group of doctors in Rome stated they did not want to accept the vaccination reserved for them with the vaccine developed by Astrazeneca. This one proved to have a much lower declared efficacy than the one developed by the Pfizer pharmaceutical company, administered to their senior colleagues. From then on, we witnessed a succession of fear, scepticism and rejection of the Astrazeneca vaccine. These emotions were also fed by additional communications about the side effects of this vaccine and by suspensions then followed by the authorisation for its administration by EMA. The controversy that fed the debates about vaccine efficacy not only in Italy but also in the rest of Europe was due to the apparent existence of first-class vaccines (such as Pfizer, BioNtech or Moderna) whose declared efficacy was around 95% and second-class vaccines (such as Astrazeneca or Janssen of the Johnson & Johnson group) whose efficacy was around 65–70% [31].

Now, when someone reads that there are two vaccines whose efficacy is 95% in one case and 65% in the other, they immediately think that one vaccine is able to create a greater immunity barrier than the other. Interpreted in this way, however, the figure would seem to have been obtained from a mere difference in efficacy of the two vaccines, which in actual fact is not correct. The problem at the origin of the misunderstanding however is difficult to solve since it depends on the way our mind reasons. Faced with a vaccine efficacy of 95% we think that what they are communicating is a figure that tells us that given 100 people subjected to the vaccine only 5 will fall ill; or, to put a more positive spin on it, given 100 people exposed to the virus 95 will be immune.

4. Human reasoning in the presence of efficacy expressed as a percentage

Several studies [4–24, 26–28, 32–34] have demonstrated that the human mind finds difficulty in interpreting medical statistics relating to vaccine efficacy.

This difficulty is part of the many traps of our thinking that lead us to make mistakes when we have to take decisions or when we need to calculate the probability that an event may occur [30]. These traps are such for all human beings and are part of the very workings of our reasoning. For example, Daniel Kahneman, Nobel Prize winner for economic sciences in 2002, famous for the study of these traps, performed an interesting test. He presented a riddle that throughout history has managed to drive thousands of students of the finest American universities crazy. The riddle at issue is the following: *A baseball bat and a ball cost 1 dollar and 10 cents. The bat costs one dollar more than the ball, how much does the ball cost?* In this case, the answer that comes naturally is 10 cents. However, let us try doing the maths. If the ball cost 10 cents, the price of the baseball bat plus the ball would be 1 dollar and 10 plus 10 cents, that is one dollar and 20. Here then our intuitive, fast thinking leads us in the wrong direction. Another pioneer in studies into the psychology of reasoning, as well as a psychologist who conducted one of the first and most important investigations into the psychology of reasoning is Peter Wason (1924–2003). In 1966, he managed to devise a riddle capable of revealing the fallacy of deductive reasoning. In actual fact what Wason managed to discover with his experiment was not entirely new. Indeed, Aristotle had talked about the problem of deductive reasoning when he introduced what was called *affirmation of the consequent*, that is:

*If A then B
B
Therefore: A*

This method of reasoning is quite common in human beings and the fact that it had been isolated already in antiquity simply means that it is a matter of a way of reasoning that has always been based on the manner of thinking of human beings. And yet, Wason's research stands out for two factors. The first is that his experiment has been replicated a great many times and always gives the same result. The second is that one of the variants of the experiment presented by Wason demonstrates that this type of fallacious deductive reasoning is affected by the context. Therefore, depending on the contextual information within which the deductive reasoning has to be carried on, this may or may not lead us to error.

The traps of our reasoning are many, but the merit of the psychology of reasoning is of having discovered and explained many of them. In fact, the only chance the human being has of not falling into these traps is the fact of knowing them. One of these, when talking about vaccination, is the one that leads us to remain anchored to a concept of disease that prevents us from bearing in mind all the variables in the very concept of efficacy. It has, in fact, been demonstrated that when the human mind has to reason in terms of vaccines and vaccine efficacy it tends to take no account whatsoever of the factor related to the control population, that is the subjects who are administered a placebo. Faced with information containing data related to sick people and vaccinated or non-vaccinated healthy people, the information that will be taken into consideration will concern the number of vaccinated sick people, the number of vaccinated people or non-vaccinated sick people. However, the control group is not taken into consideration. This means that intuitively when our mind hears talk about vaccine efficacy it thinks it is a matter of efficacy in terms of an absolute risk reduction, that is the reduction in the risk of falling ill if you get vaccinated. However, since the figure presented by the media concerns the relative risk reduction one then runs into a basic misunderstanding leading to overestimate the efficacy and not seeing its

immediate application. Furthermore, other studies, conducted into the perception of the efficacy of vaccines for COVID-19, have demonstrated that people tend to identify the figure of vaccine efficacy with the rate of non-mortality among vaccinated people. This is clearly incorrect and over the long term can lead to overestimating efficacy itself [2]. This type of problem in the methods of reasoning has necessarily affected the choice of vaccine and as a result people's daily lives.

5. Repercussions of the mechanisms of reasoning on vaccine choice

We have seen how in Italy in 2021 there was great controversy surrounding the first two vaccines that were distributed: Pfizer and Astrazeneca. This controversy, far from being solely Italian, presented itself in other European countries and in Canada. There were plenty of repercussions and EMA, just like several countries such as Canada for example, opted for an albeit temporary suspension of Astrazeneca. This suspension was requested solely due to an issue concerning the side effects of the vaccine. And yet, if we ask the person in the street about this matter, we will hear that the Astrazeneca vaccine was withdrawn because it was not as effective as the others. From this perspective we can state that the reasoning intuitively conducted by the human mind regarding the concept of vaccine efficacy led to an incorrect interpretation of the figure. In fact, that 65% of efficacy compared to the 95% of Pfizer remained fixed in people's minds. And through an anchoring bias, it meant that the whole history of the Astrazeneca vaccine remained tied to the concept of a vaccine that failed to provide sufficient coverage. This misunderstanding was the reason that triggered the many controversies that broke out in 2021. Moreover, it led many people to refuse the vaccine, or not get the booster, thereby slowing down the process of coming out of the pandemic. In a recent study, the misunderstandings and false myths about vaccines are mostly attributed to an incorrect conception of the concept of risk reduction. This concept is at the base of the related concept of vaccine efficacy. Indeed, the latter is indicated as a relative risk reduction. This has the disadvantage of only considering the subjects who took part in the trial, it is however understood as a figure regarding coverage on the basis of sick people in the world's entire population. The media, moreover, generally publish the figure related to relative risk reduction.

A recent study demonstrates that human reasoning is such as to chiefly conceive the concept of relative risk reduction. Hence, therefore, the proliferation of misunderstandings about the usefulness or lack of one vaccine rather than another or of any vaccine in general. An even more important problem is that in order to choose a vaccine the general population bases itself on what the media publish and on the opinion of the general practitioners. This category of doctors, however, does not seem to be exempt from implementing the common strategies of reasoning that lead to misunderstanding the concept of efficacy. More than the general practitioners it seems that the oncologists, mostly called on to decide in the case of pharmacological therapies and surgery, are facilitated in correctly interpreting the data related to vaccine efficacy. However, they too are only able to interpret it correctly if a greater amount of information is presented.

The concept of efficacy, moreover, is only conceivable within the broader medical statistics founded by Greenwood and his successors [33]. Moreover, studies into vaccine availability, already in the last century, have highlighted how the manner of presenting the data affects their interpretation [35]. And in a historical context such as the current one a manner of presenting data that is not very clear can become very dangerous.

6. Conclusions

Several studies have highlighted that approximately 66% of the world's population uses the internet. These users spend many hours a day on the web [36]. It is clear that the twenty-first century has been marked by the development of digital technology. However, it is necessary to bear in mind that the development of digital technologies, just as their understanding by most of the world's population, underwent a drastic change as regards speed starting in 2020. The pandemic that marked human history brought about an acceleration in the development of digital technology, on the one hand, and in its use, on the other hand. What was a privilege just for some generations has become a worldwide means of communication for everyone. Very small children just like the elderly have learned what the web is, what digital registration is and what a cloud is, but above all what digital communication is. Today, information about vaccine efficacy comes not only from accredited means of communication but also above all from social media. It means our devices keep us constantly connected with all the other human beings, and unfortunately, give everyone a voice on sensitive subjects such as the choice of a vaccine.

So, therefore, it becomes increasingly more urgent to be able to understand what the themes, concepts and notions are on which our mind can lead our reasoning astray. Vaccine efficacy is one of these themes. It is necessary to be able to provide information as correct as possible explaining to the general public what the above-mentioned 95% of efficacy of the Pfizer vaccine means. To do that I believe it is desirable, since we are talking about vaccine efficacy, to explain that the efficacy of a vaccine corresponds to the extent of the relative risk reduction. That is the risk reduction calculated solely on the population that took part in the trial. This figure is a ratio between the two possibilities of risk reduction, that of the vaccinated subjects and that of the non-vaccinated subjects. We cannot then think in terms of frequency that 95% of efficacy corresponds to a probability that of 100 persons 95 turn out to be immune to the virus. Furthermore, it is important to clarify that the figure on the efficacy of the vaccine does not take account of the variables that were not able to be calculated in the trial. Among these, for example, the length of time for which the vaccine is able to remain active or the exposure to the risk of infection of the population. The latter variable is indeed subject to change depending on the areas and persons involved.

Today the pandemic is over, but our way of reasoning in terms of vaccine efficacy still remains the same. This is why it has become important and urgent to manage to implement more precise and accurate communication. Furthermore, it becomes important to permit general practitioners, called upon to provide help in making decisions about vaccines, to understand what information is actually useful to this end. From this perspective, while the development of the vaccines COVID-19 permitted considerable progress, it seems instead that at the level of communication and understanding of vaccines, the general public has still remained very far behind.

Conflict of interest

“The authors declare no conflict of interest.”

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