How to reduce the likelihood of errors while presenting interesting ideas?

Abraham Meidan[1]

Abstract:

This paper suggests that skepticism is true: Statements cannot be justified in the epistemological sense of justification. Our beliefs are determined by a psychological process. When a statement reduces the strangeness of the empirical world, we tend to believe that the statement is true. This psychological theory of belief formation has implications in the philosophy of science and machine learning.

Keywords: Skepticism, Popper, Belief, Science, Machine Learning

INTRODUCTION

The current paper presents ideas I already published three times, once by myself and twice [1, 2] with Joseph Agassi, my Ph.D. adviser (with Ben-Ami Scharfstein), who was also a colleague and friend. Sadly, because Agassi passed away a year ago, he does not share in authoring this paper. I'm the legal heir of his intellectual property, which may indicate what he thought about me.

[1] Abraham Meidan is the legal heir of Joseph Agassi's intellectual property. He published two books with Agassi and he is the owner of a software company. His address: 160 West 66th Street Apt 48A, New York, NY 10023. Email: abraham@wizsoft.com, Abraham.meidan@gmail.com

Since a long time has passed since the publication of the previous books, I have slightly modified some ideas, which is the main reason for publishing a new paper on this subject.

The main ideas presented here and in the previous books are:

1. Statements cannot be justified in the epistemological sense of justification. Skepticism is true, and
2. Our beliefs are determined by a psychological process. When a statement reduces the strangeness of the empirical world, we tend to believe that the statement is true.

In my opinion these ideas are quite similar to those of David Hume [3]. However, this paper does not discuss who was the first to present them or and what is the right interpretation of Hume's ideas. If you think that Hume's ideas are quite different from those presented here, and no other philosopher has already presented them, I (and Agassi) are ready to be the first.

1. THE PROBLEM

The epistemological problem is one of the central problems discussed in the history of philosophy. Usually, it is presented under the following question: What can we know? This question, which was already discussed in ancient Greek philosophy, was one of the main topics in new Western philosophy (starting in the 17th century). Since the end of the 19th century, it has been discussed in the philosophy of science. Science is supposed to include what we know about the world, so the questions are: What is science? What is *actually* considered to be science, and what *should* be considered as science?

As stated, the epistemological problem is usually formulated by questions about knowledge. But then another question arises: What is the definition of knowledge? Apparently, knowledge is true belief. Namely, if one believes that proposition *p* is true, and if *p* is actually true, then one knows that *p*. But if one believes that *p* as a result of an arbitrary guess, then even if *p* is accidentally true, many will say that (since the belief rests on an arbitrary guess) one does not know that *p*. Some philosophers tried to overcome this criticism by modifying the definition of knowledge as follows: knowledge is *justified* true belief. But this new definition was criticized by cases where the belief that *p* is true was justified but the justification was not valid. This is called the Gettier problem. The discussion continues like many similar discussions about definition of familiar concepts. Philosophers disagree even on the definition of concepts like "table." I prefer to avoid discussions about the definitions of such concepts in general and the definition of knowledge in particular.

Instead of formulating the epistemological problem by questions about knowledge, one may consider the following formulation:

> How can we lower the likelihood of errors?

In contrast with the concept of knowledge, the concept of error is much more straightforward.

But this new formulation suffers from the following criticism: One can avoid errors by saying nothing or only tautologies. I, therefore, suggest modifying the formulation as follows:

> How can we lower the likelihood of errors while saying interesting things about the world?

This is the question that the current paper discusses.

The background of this question

The stimulus is the skeptical arguments. The skeptic asks: How do you know that the statement you present is true? How do you know that this statement is not false? Presumably, one can answer as follows: I know this statement is true since … and here another statement is presented, which justifies the first one. But then the skeptics keep asking: How do you know this second statement (that allegedly justifies the first statement) is true? And so on, endlessly. In other words, justification leads to an infinite regression; therefore, there are no justified statements.

One can describe the history of the discussions about the epistemological problem as attempts to find a good answer to the skeptics.

I (and Agassi) hold an opposite position. I belong to the small group of skeptics. I think that the skeptic is right. I think that statements cannot be justified.

2. THE SKEPTICAL POSITION

A terminological comment

Before continuing, I would like to refer to the various meanings of the concept of “skepticism.”

When persons are classified as climate-change skeptics usually this means that they claim that: (1) it is doubtful that there is climate change, or it is doubtful that climate change is the result of human activity. (2) Therefore, we should not change our current behavior. This meaning of “skepticism” is not relevant to skepticism in epistemology. The skeptic agrees that statements like “the world is becoming warmer” or “climate change is the result of human activity” are not certain and therefore doubtful, but does not claim that this doubt leads to the conclusion that we should not change our behavior. As I suggest later, it is reasonable to claim that: (1) the statements “the world is becoming warmer” and “climate change is the result of human activity” are not certain, and (2) the world is becoming warmer, and this climate change results from human activity. The concept of skepticism in this paper refers just to the epistemological status of statements, and implies no conclusions as to what we should do. I’ll return to this point shortly.

Another ordinary meaning of the concept of skepticism presents it as an *attitude*. For example, the first definition of skepticism in Merriam Webster dictionary is:

> An attitude of doubt or a disposition to incredulity, either in general or toward a particular object

But in this paper, skepticism refers to statements that are entities out of space and time (so-called platonic entities) and does not refer to a psychological attitude.

The meaning used in this paper is the one common in classical epistemological literature.

What do skeptics claim, and what do they not claim?

(1) The skeptics present a generalization. They do not limit themselves to the trivial position according to which *there are* doubtful statements. They present the generalization: *All* statements are doubtful.

(2) During the history of epistemology, some philosophers presented skeptical positions limited to a specific field. For example, skepticism regarding science claims that all scientific theories are doubtful (and does not refer to non-scientific statements). The skeptical position presented in this paper is not limited. I claim that *all* statements are doubtful.

(3) Contrary to some popular ideas, skeptics do not contradict themselves. Indeed, skeptics claim that all statements are doubtful; therefore the skeptical position itself is doubtful too. But the skeptics do not claim that every statement is *false*. If every statement is false, then this statement (that every statement is false) is also false. And this leads to the well-known liar paradox that was presented already in old Greek (The statement “this statement is false” cannot be false and cannot be true. The assumption that it is true implies that it is false, and vice versa: The assumption that it is false implies that it is true). But as stated, skeptics do not say that every statement is false; therefore, skepticism does not imply the liar paradox.

(4) Skeptics (as presented in this paper) do not just claim that “no statement is certain.” They also claim that “every statement is neither certain nor plausible, corroborated or justified (in the epistemological meaning of these terms).” The history of skepticism includes the following stages: Many skeptics claimed “no statement is certain,” presenting the argument mentioned above (A statement is certain only if it is justified, but the justification holds only if it is too justified, and so

on endlessly). The answer to this argument was: We may assume that no statement is certain, however, there are plausible statements, and a plausible (or justified or corroborated) statement is more plausible than its negation and therefore to be preferred. The skepticism presented in this paper claims that every statement is not just not certain but also not more plausible (or justified or corroborated) than its negation.

(5) Skepticism (as presented here) refers only to the epistemological status of statements. The skeptic does not claim "I don't believe that the world is getting warmer," but rather "The statement that the world is getting warmer is doubtful (like any other statement)." The skeptic can consistently claim: "I am convinced that the world is getting warmer," (in other words, "I'll be surprised if it turns out that the world is not getting warmer"), but the statement "The world is getting warmer" is doubtful. To repeat, the skeptics do not refer to the mental aspects. They do not refer to what people believe and do not refer to degrees of belief.

The last paragraph is relevant for a popular argument against skepticism: If every statement is doubtful, it follows that the statement "Jumping from a high-floor window is dangerous" is not more plausible than its negation (i.e., such jumping is not dangerous). Therefore, we may ask the skeptic: "Why don't you jump from the window?" But following the above distinction the skeptic answers this argument accordingly: The statement "Jumping from a window in a high-floor is dangerous" is indeed doubtful, but I believe that jumping from a high-floor window is dangerous, and this is why I don't jump. As mentioned, skepticism refers just to the epistemological status of statements; it does not refer to beliefs.

One can continue the attack on skepticism as follows: If the statement "jumping from a high-floor window is dangerous" is not more plausible than its negation, then why did you choose to believe that this statement is true (and didn't choose to believe that its negation is true)? This anti-skepticism argument assumes that we choose our beliefs. It is the assumption that we select our beliefs just as we select products in the supermarket. We compare prices and other features and select the product to place in the basket. But as Hume [3] and others already claimed, this assumption is not true. We do not select our beliefs similarly to selecting products in the supermarket. Our beliefs are determined through psychological processes, and our control of these processes is quite limited. We cannot choose to believe that jumping from a high-floor window is *not* dangerous. We will discuss the question, what is the psychological process that determines our beliefs, later in this paper.

Skepticism vs. psychologism

Another possible criticism of the skeptical position presented here is that it implies psychologism. Psychologism is the position according to which certainty and plausibility, in the epistemological sense of these concepts, rest on psychological processes. Many philosophers criticized this position. Gottlob Frege [4] is one of the well-known critics of this view.

But the skeptical position presented here does *not* imply psychologism. Contrary to psychologism, I claim that psychological processes do not determine the epistemological status of statements. My position that all statements are doubtful rests on epistemological arguments (some already presented, and additional ones will be presented shortly). The psychological processes merely determine our feeling of certainty or plausibility, not the epistemological status of the statements.

3. ARGUMENTS FOR SKEPTICISM

I have already presented one argument for skepticism (justification leads to infinite regression). I will present some additional arguments below.

Philosophers distinguish between statements in logic and mathematics on the one hand and statements about the empirical world on the other. Most discussions about the epistemological problem refer to the epistemological status of statements about the empirical world. I'll discuss this issue first, then return to the epistemological status of statements in logic and mathematics.

When discussing statements about the empirical world, philosophers distinguish between statements that present facts and those that present theories. Theories are generalizations, and generalizations are required for explanations and predictions. For example (to give a trite example in the philosophy of science literature), the generalization is “All ravens are black.” The fact or observation is “This object is a raven.” And the prediction is “This object is black”.

The skeptic claims that both type of statements, those that refer to facts and those that refer to generalizations or theories, are doubtful. I’ll start by presenting the skeptical arguments concerning generalizations.

Allegedly one can conclude that a given generalization is true based on many observations. This is called induction. Following the observations of many black ravens, and no counter examples (no non-black ravens), one may conclude: The generalization “All ravens are black” is certain or at least more plausible than its negation (there are non-black ravens).

Not so. In the 18th century, Hume [3] claimed that induction does not logically imply certainty. The fact that the sun has risen every day does not logically imply that it will continue to rise tomorrow and in the next days. We can add to Hume’s argument that according to accepted theories nowadays, the sun will not rise within a few billions of years. Obviously, the statement “The sun will rise tomorrow” did not refer just to the exact day when Hume presented it, but rather to the tomorrows of the next days, meaning “the sun will rise every day.” One may try to avoid this criticism by saying that the statement “The sun will rise tomorrow” refers only to the period when the sun exists and our planet goes around it. But under this formulation the statement “The sun will rise tomorrow” turns to be a logical tautology and, therefore not a scientific theory.

Another well-known example of a theory that was supported by an enormous number of observations and was empirically refuted is Newton's mechanics. It was positively tested in countless experiments and observations, but empirical discoveries following Einstein’s relativity and quantum mechanics theories refuted Newton's theory.

Some philosophers of science and scientists try to defend Newton. They claim that the discoveries that supported Einstein’s theory and quantum mechanics did not refute Newton’s theory but just pointed at more accurate theories. This is a needless sophistry. The position according to which Newton’s theory was refuted does not defame Newton. Everybody (skeptics included) agrees that Newton's theory is one of the most successful and glorious theories in the history of science, which continues to be useful when engineers design, for example, cars and bridges. (The reason is that Newton's theory is much simpler to use than Einstein's, and that the differences between the predictions of these two theories regarding the practical use of cars and bridges are negligible).

As I mentioned in above (section #2), Hume's idea that induction cannot logically imply certainty was followed by a new anti-skeptical position: Indeed, induction does not entail certainty, but it can raise the plausibility of generalizations. This is the current popular view among philosophers of science. They claim that the theory "All ravens are black" is not certain, but since many observations supported it, and no counter-observation refuted it, it is more plausible than its negation.

The meaning of "plausibility" is supposedly close to the meaning of "probability." Probability refers to future *events*. Probability ranges between 1 (the event will certainly happen) and 0 (certainly, the event will not happen). Plausibility refers to the epistemological status of *statements*, and like probability, plausibility ranges between 0 and 1. When the plausibility level is 1, the statement is certain, when the plausibility level is 0, the statement is certainly false. A statement is plausible if its plausibility is higher than the plausibility of its negation. The theory "All ravens are black" is not an event, and therefore we cannot assign probability to this theory. But according to the accepted view among philosophers of science, we can assign plausibility to this theory. Since we have observed many black ravens and have not observed any non-black ravens, the plausibility of this theory is higher than the plausibility of its negation.

But there is an important difference between probability and plausibility. One accepted interpretations of probability is relative frequency. The probability that a fair coin will fall on the tail side is 0.5, since if we throw the coin many times the frequency of falling on the tail side approaches 50%. (This interpretation can be applied when probability is assigned to a single event, such as the probability that it will rain tomorrow. The meaning of the statement "The probability that it will rain tomorrow is 0.8" is: In 80% of the possible worlds where the laws of nature hold, and the facts are as the facts about our current world, it will rain tomorrow). But we cannot assign a relative frequency to theories. It makes no sense to say that a theory is true in 90% of cases (that the frequency of its being true is 90%). If a theory is not true even in one case, then it is refuted, and the plausibility of a refuted theory is 0.

The paradoxes of induction

During the 20th century several philosophers of science discussed several arguments that raised difficulties against the idea that induction can imply high plausibility of empirical theories. These are known as “the paradoxes of induction.” I’ll briefly review these so-called paradoxes below.

Goodman’s paradox [5]

Consider the following four theories:

1. All emeralds are green
2. All emeralds are blue
3. All emeralds are grue (green before the year 2100 and blue after that)
4. All emeralds are bleen (blue before the year 2100 and green after that)

All emeralds that have been observed till now were green. These observations refute theories (2) and (4) but corroborate both (1) and (4).

Everybody agrees that theory (3) is absurd, but the induction theory fails to explain why. Allegedly one may answer that theory (1) should be preferred over theory (3) since (1) is simpler than (3) since the feature “grue” rests on the features “green” and “blue.” But contrary to this answer, one can construct the features “green” and “blue” from “grue” and “bleen.” For example, green is bleen till year 2100 and grue after that.

Hempel’s paradox of corroboration [6]

The theory

5. All ravens are black

is logically identical to the theory

6. Everything, if it is a raven, then it is black

And according to the induction theory, we can corroborate this theory by pointing at observations of things that are both raven and black.

Similarly, the theory

7. All the non-black are non-ravens

is logically identical to the theory

8. Everything, if it is non-black, then it is non-raven

And according to the induction theory, we can corroborate statement (8) by pointing at observations of things that are both non-black and non-raven, for example, white shoes.

But all the theories mentioned above are logically identical. Statements (6) and (8) are equivalent following first-order predicate calculus.

It follows that observations of white shoes corroborate the theory “all ravens are black,” which is obviously absurd.

Several philosophers tried to save the induction theory by claiming that the existence of white shoes corroborates the theory “all ravens are black,” since it decreases the number of things that may refute this theory (if the shoes had been ravens, such observations would refute the theory). But this argument assumes that the number of things in the universe is limited, while the theory “all ravens are black” refers to an unlimited number of things (all ravens that were till now and will be from now on are black).

Both Goodman and Hempel held logical positivism, the position that empirical observation can corroborate theories by induction, and both tried to solve the paradoxes they presented. Because the debates about these paradoxes in the philosophy of science literature are discussed voluminously, I will not review them here. Being aware of these discussions, I can say that I am not aware of good answers that resolve these so-called paradoxes and save the theory of induction.

It is self-evident that as a skeptic I don’t view these arguments as paradoxes. As a skeptic I view them as additional arguments for skepticism.

Ad hoc theories

There are additional arguments against the idea that induction can corroborate empirical theories. One argument refers to *ad hoc* theories.

Suppose one observed several black dogs and presented the following theory:

9. All dogs are black

Later someone points at an observation that refutes this theory, for example, a particular dog, D1, that is white. Following this counter-example one modifies the theory as follows:

10. All dogs are black except for the dog D1

One can continue in this way and modify the theory whenever a counter-example is observed. Such a continually modified theory is called an *ad hoc* theory.

Everybody agrees that such ad hoc theories are not serious. But the induction theory fails to explain why. When one considers the relation between the statement presenting the theory and the statements presenting the observations, then according to the induction theory, the ad hoc theory is corroborated. Many observations support the theory and none refute it.

Allegedly one can alter the induction theory as follows: We can corroborate empirical theories by induction, except in cases where we modify the theory ad hoc. But (1) according to the induction theory, such a modification is arbitrary and somewhat ad hoc. And (2) there are cases in the history of science where scientists accepted ad hoc modifications as valid modifications. For example, the theory “all bodies expand when they become warmer” was modified when it was discovered that water behaves differently around freezing temperature.

Popper and Agassi [7]

An additional argument was presented by Popper and his student Agassi. Contrary to Goodman and Hempel, Popper and Agassi rejected the idea that theories can be corroborated by induction. Consider the following theory:

11. Newton’s mechanical theory or Einstein’s relativity theory is true

And assume that this theory is presented after 1905 (when Einstein’s theory was published) and prior to 1918 (when Newton’s theory was empirically refuted). In this period, many observations supported each of these two theories, and none clearly refuted them. Therefore, if observations can inductively corroborate theories, in this period both statements:

12. Newton’s theory is true
13. Einstein’s theory is true

were highly corroborated, higher than 0.5. Now, if corroboration behaves mathematically like probability, then the corroboration of the statement (11) is equal to the sum of the corroborations of the two statements (12) and (13), minus the corroboration of the statement:

14. Both Newton’s theory and Einstein’s theory are true

But since Newton’s theory and Einstein’s theory are inconsistent, the corroboration of (14) is 0. Therefore, the corroboration of (11) is higher than 1, which is absurd.

We will return to Bayesian epistemology later.

Simplicity

The final argument I will present here refers to the concept of simplicity. When there are several observations related to, say, two continuous features, an infinite number of functions can explain all the observations. But we tend to accept the simplest function. For example, suppose all the observations can be explained by a linear function that relates between the two features. In that case, we tend to accept this function as the theory that explains the observations, even though there are infinite wave-like functions that meet all the points (the observations). The induction theory fails to explain why we tend to accept the simplest function.

There are additional arguments against the induction theory, but I believe the above arguments are sufficient. I will return to these arguments later.

4. FALLIBILISM

Another answer to the question, what can we learn from observations, was presented by fallibilism. This is the idea according to which observations cannot justify theories, but we can use observations to refute theories, and in this way, we can learn that the refuted theories are not true. Observations of many black ravens do not justify the theory "all ravens are black," but if we discover some non-black ravens, we will know that this theory is false, then may proceed to look for better theories that explain all the observations including those refuting the old theory. Charles Sanders Peirce [8] and Karl Popper [9] are well-known representatives of this position.

The skeptic may answer that since the observations are not certain, the refutations are not certain either. (We will discuss skepticism in regard to facts later). Additional criticism of fallibilism is raised by the so-called Quine-Duhem argument (Willard Van Orman Quine [9] and Pierre Maurice Marie Duhem [10]): Consider testing an astronomical theory about stars and suppose we find some observation that allegedly refutes the theory. The refutation is not of the theory itself but rather of the theory under discussion and the theory of the telescope. Therefore, we cannot know which theory – the astronomical theory under discussion or the theory of the telescope (or both) – is false.

Another criticism of the idea that science proceeds just by raising theories and testing them to find refutations is as follows: This method fails to determine which (not yet refuted) theories are reasonable, and which are nonsense; which theories it makes sense to test, and which theories are not worth the effort of testing. Popper claims that we should prefer as basis for action the best-tested theory [12]. But this suggestion is refuted by the above-mentioned Goodman paradox: The two theories “all emeralds are green” and “all emeralds are grue” successfully pass exactly the same tests. And clearly, many other empirical generalizations are not (yet) refuted, but still no one will invest time to test them.

This criticism is mainly relevant to technology. When debating technological questions, we often have to select one theory among several. For example, when physicians debate how to treat a particular sickness, they have to select one method, and this selection is based on a theory. They may decide to do nothing, but this is also a theory-based selection. Their debate should relate to reasonable theories only. And so, the question is: How can we distinguish between reasonable and non-reasonable theories? Fallibilism does not answer this question.

5. FACTS AND LOGIC

In the previous sections, I presented skeptical arguments regarding theories about the empirical world. What about statements that denote facts? As mentioned, the skeptic claims that *all* statements are doubtful, including statements about facts which I’ll discuss now and statements in logic and mathematics to be addressed later on.

Everybody is aware of cases where we err about facts. For example, we meet person A and mistakenly think that we met person B. Therefore, not all observations are certain. What about a statement like “I see a yellow splash here and now” that presents a so-called immediate experience? Many philosophers claim that such a statement is certain, but contrary to this popular position, even this statement is not certain, since I may err in identifying the color (it is not yellow but green).

Can we calculate the *plausibility* of statements about facts? No. Many research projects in psychology lead to the conclusion that our perceptions are based on expectations. This is obvious in experiments where subjects need longer time to perceive taboo words, since they don’t expect to see such words. And it is likely to hold true for any perception. We cannot perceive without expectations. And expectations rest on theories, but as stated previously, we cannot calculate the plausibility of theories. Therefore, we cannot calculate the plausibility of statements about facts.

As I already mentioned several times, the skeptic refers only to the epistemological status of statements. Skeptics may believe that usually statements about facts, seen by many viewers, are likely to be true (in other words, they will be *surprised* if they discover them to be untrue). The beliefs are determined by psychological processes and not by epistemological status.

Note: one may criticize the idea that perception rests on expectations by raising the question: How are first expectations created? Are we born with some expectations, or are some perceptions not based on expectations? This is a legitimate criticism to which I have no answer, and will omit it from the discussion of this paper.

Skepticism regarding statements in logic and mathematics

What is the epistemological status of statements in logic and mathematics? Allegedly, a statement like “15 + 27 = 52” is certain (and therefore plausible). But what is the difference between saying that this statement is certain, versus saying that it is true? Does the claim that this statement is certain add any information to just saying that it is true?

Mathematics includes hypotheses, such as the Goldbach conjecture (every even natural number greater than 2 is the sum of two prime numbers). We don’t know yet if this conjecture is true. But it makes no sense to assign it epistemological status. Is it 90% plausible? or just 70%? Many mathematicians are convinced that it is true and will be surprised if a counter-example is discovered. But there is no way and no need to calculate its epistemological status.

In other words, the concepts of certainty and plausibility are redundant when applied to mathematics and logic. We can give up these concepts without losing anything.

6. ORDINARY LANGUAGE

Cultures without the concepts of certainty and plausibility

Apparently, one may criticize the skeptical position by the following argument: The concepts “certainty” and “plausibility” (in their epistemological meaning) are so common and useful that it makes no sense to claim that we can give them up. But the skeptic may point out that these concepts (in their epistemological sense) were unknown in the old Chinese and Hebrew cultures. The concept of “knowledge” was used in these two cultures, but there are no epistemological discussions in the Bible or the ancient Chinese texts. And despite this lack of epistemology, these two cultures were quite developed and discussed questions about the world and advanced technology (the Chinese technology was more advanced than the European till the end of the 18th century).

Ancient Greeks discussed these concepts of “certainty” and “plausibility.” One reasonable explanation for this phenomenon is that the Greeks discussed epistemology after developing the system of proofs in geometry. Discussions about geometrical proofs led to the questions “What can be proved?” and “What is the status of proven statements?” These questions then led to epistemology. Their idea was that the axioms are obvious and thereby certain statements about the empirical world, and that the theorems that the axioms entail are certain too. Nowadays the accepted view is that the axiom of parallel lines that some Greeks view as obvious and certain is in fact not true as an empirical statement.

Once again, we see that we can give up the use of the concepts “certainty” and “plausibility” in their epistemological meaning without losing anything.

Beyond reasonable doubt in the legal system

Allegedly the concept of “plausibility” is required for our legal system. When the defendant is convicted, the conviction should be beyond a reasonable doubt. But if we cannot assign plausibility to statements, how can we claim that the conviction is beyond reasonable doubt? My answer is that the idiom "beyond reasonable doubt" does not refer to the epistemological status of the conviction, but rather to the following psychological statement: Following the facts discovered in the testimonies, and the law, if we discover that the defendant did not commit the crime, we will be extremely *surprised*.

As I mentioned in the previous paragraphs, ancient Chinese and Hebrew cultures were unaware of the concept of "plausibility." Still, they had advanced legal systems, quite similar to the current legal systems, including rules of evidence. Witnesses presented evidence supporting or refuting the conviction, and judges decided according to this evidence and the laws.

7. THE PSYCHOLOGY OF BELIEFS

In the previous pages, I presented the idea that skeptics refer to the epistemological status of statements and do not refer to beliefs. Skeptics say that the statement "jumping from a high-floor window is risky" is doubtful (like all statements), but the skeptics may believe that jumping from a high-floor window is risky. This position raises the question: why do skeptics believe that jumping from a high-floor window is risky? To answer this question, one should present a psychological theory of beliefs, or in other words, a theory that explains under what conditions one believes that a particular statement is true. As I already mentioned in the beginning of this paper, the word "believe" does not refer to its religious meaning, but rather to thinking: One *believes* that a particular statement is true if one *thinks* that the statement is true.

Philosophers of science discussed the question: What is the rational way to accept a theory? But as I pointed out earlier, this question assumes that we choose our beliefs in a similar way to choosing products in the store, and this assumption is not true. We cannot choose to accept the belief that jumping from a high-floor window is not risky. Our beliefs result from psychological processes, and our control of these processes is quite limited.

Some psychologists discussed the question, under what condition does one believe that a given statement is true. But almost all discussed the sub-question: Under what conditions does one *irrationally* believe that a given statement is true? They have not addressed the question: under what conditions one *rationally* believes that a particular theory on the empirical world (such as “all ravens are black”) is true. For example, Tversky and Kahneman [13] presented a list of cases where many people consistently tend to estimate probability contrary to the law of probability. In one well-known experiment, Kahneman and Tversky described Linda as young and deeply concerned with discrimination and social justice issues. The subjects of the experiment were then asked which option is more probable: (1) Linda is a bank teller, (2) Linda is a bank teller and is active in the feminist movement. Many subjects selected the second option, although this is contrary to the laws of probability since option (2) is a subset of option (1).

But these types of experiments are irrelevant to the question we discuss here: under what conditions do people rationally believe theories about the empirical world? No logical or mathematical laws dictate how one should derive theories from observations (if there were such laws, skepticism would have been mistaken).

Indeed, people usually follow the laws of logic. If one believes that statement A is true, and if statement A logically entails statement B (and if these two statements are simple enough for one to understand their contents), then one tends to believe that statement B is true. In this sense our psychology follows logic. But as Hume [3] taught, logic does not tell us interesting theories about the empirical world. So, we are back to the question: What psychological processes determine what we rationally believe about the empirical world? We will proceed by discussing this question.

The inductive psychological theory of belief formation

Hume [3] suggests that we believe that the sun will continue to rise every morning and that bread will continue to feed us, because we observed those phenomena many times and did not observe counter-examples. These beliefs then result from customs and mental habits. In other words, the psychological process of belief formation rests on a mental process that functions as induction. If one observes a particular phenomenon often and does not observe counter-examples, one tends to believe in a theory that generalizes this phenomenon. And our belief strengthens as we observe many more positive cases (and no counter-examples). When philosophers of science present their ideas as descriptive theories about the way good scientists behave, in many cases they present a similar idea. Scientists generalize observations. I call this idea the inductive psychological theory of belief formation.

The inductive psychological theory of belief formation is empirically refuted. The refutations rest on the paradoxes of induction that I reviewed in section #3. Based on these paradoxes, one can easily construct psychological experiments that refute the inductive psychological theory of belief formation.

Suppose the inductive psychological theory of belief formation were true. In that case, our tendency to believe in the theory “all emeralds are green” should have been equal to our tendency to believe in the theory “all emeralds are bleen” (since the observations support these two theories equally).

If the inductive psychological theory of belief formation were true, then we could have convinced people that all ravens are black by showing them white shoes (entities that are neither black nor raven).

If the inductive psychological theory of belief formation were true, we could have convinced people by presenting arbitrarily created ad hoc theories.

The psychological Bayesian theory of belief formation

Frank Ramsey [14] suggested a psychological theory of belief formation that rests on the Bayes formula. This theory suggests that degrees of belief or credence denote people's willingness to bet money on a claim that the belief is true. These degrees of belief are called subjective probabilities.

The following factors determine the degree of belief that a given theory is true:

- one’s *a priori* level of belief that the theory is true. One’s other prior beliefs determine this degree of belief.
- how much the observations were unexpected prior to accepting the theory.
- To what extent does the theory imply the observations? If the theory logically entails the observations, this factor is 1.

The higher

- the a priori degree of belief
- the level of unexpectedness of the observations
- the extent the theory entails the observations

the higher the degree of belief that the theory is true.

For example, suppose that one hears the theory “all ravens are black” and assigns a 0.2 a priori probability to this theory. Before accepting the theory, one expects that ravens have many colors. Therefore, the observations of many black ravens (and no non-black ravens) are unexpected. The theory predicts these observations. So, as long as one observes more black ravens (and no non-black ones) one’s degree of belief that the theory is true increases.

But this theory belief formation is refuted by Popper’s and Agassi’s argument that was reviewed in section #3. The Bayesian says that we assign probabilities to all our beliefs, including beliefs about theories. This position implies the absurd prediction that before 1918 the subjective probability that physicists (should have) assigned to the statement “either Newton’s theory or Einstein’s theory is true” was higher than 1.

Note that this criticism of the Bayesian psychological theory of belief formation refers to cases where the Bayes formula is applied to *theories* (that refer to an infinite number of cases). As long as the beliefs are not about theories but about *events*, Popper's and Agassi's argument does not apply. For example, using the Bayes theorem in the following well-quoted case makes sense: The frequency of a particular illness in the population is 1%, and the accuracy of a certain medical test that detects the illness is 95% (in regard to both misses and false alarms). If the test's result is positive, what is the probability of the event that the person is sick? The Bayes' theorem helps us calculate this probability (less than 20%). And as mentioned, this application of the Bayes theorem refers to the probability of an *event* (not to a theory), and as such is not problematic.

8. A NEW THEORY OF BELIEF FORMATION

In the previous pages, I reviewed and criticized popular psychological theories that try to explain how we form beliefs. In what follows, I'll present my (and Agassi's) theory.

I suggest the following hypothesis: The function of ordinary beliefs is to reduce surprise. People tend to believe in a given statement if it reduces the unexpectedness of the empirical world; if it makes us expect our experiences as we live them.

(1) People assign probabilities to events in some vague sense of probability, where the probable is expected or unsurprising.

(2) Surprise, unexpectedness or improbability of events are relative to given beliefs. Events surprise if they are experienced more frequently than extant beliefs warrant, especially if these beliefs rule them out.

(3) When people consider a new idea, they also consider the rationale for its proposal in the first place. If that rationale depends upon some events, then people also consider whether these events are to be expected.

The surprise that certain events regularly occur is reduced by postulating regularities that govern them. Thus, for example, the supposition that all ravens are black renders quite expected the unexpected and initially surprising observation that ravens are regularly black (since without the theory all colors may be expected). It is the theory that alters probabilities – quite in accord with the calculus of probability – and with them, the theory alters surprise values: Accordingly, the observation of a non-black raven would surprise, and the observation of black ravens would not.

Let us see how this theory deals with the above arguments against the induction theory of belief formation and the Bayesian psychological theory of belief.

Goodman's emerald paradox: The question was: Why do we consider the theory "all emeralds are green" as a reasonable theory, and consider the theory "all emeralds are grue" as a non-reasonable one? My theory of belief formation answers this question as follows: The theory "all emeralds are grue" was deliberately created arbitrarily. Our experience teaches us that arbitrarily created theories, like guesses, are usually refuted. Therefore, the assumption that the theory "all emeralds are grue" is reasonable *increases* the strangeness of the world. This explanation rests on point (3) of the theory, according to which we consider not only the facts that the theory predicts, but also how the theory was created.

Hempel's paradox of corroboration: The question was why observations of non-black non-raven things, such as white shoes, do not strengthen our belief that all ravens are black? The answer: the existence of non-black non-white entities is not a strange phenomenon, and therefore, as long as these are the only relevant observations, the theory "all ravens are black" does not reduce the strangeness of the world.

Ad hoc theories: The question was why the theory "all dogs are black, with the exception of all the non-black dogs we observed" is not reasonable? The answer: the event that "we *accidentally* observed *all* the dogs that have different colors" is highly unexpected, and therefore this ad hoc theory *increases* the strangeness of the world.

Simplicity: The question was why do we tend to believe in the theory that explains the dots by a straight line or another simple function (and do not believe that the explanation is a complicated function)? The answer: the assumption that an arbitrarily created complicated function is true *increases* the strangeness of the world.

Assigning probability to theories: The theory of beliefs suggested here does not assign probabilities to theories but only to events. Therefore, the criticism that Popper and Agassi raised against assigning probabilities to theories does not apply to my theory of belief.

How does my theory confront the fact that some people strongly believe in nonsenses such as conspiracy theories? I don't have a full explanation for this phenomenon, but it does not refute my theory of beliefs. Those who believe in conspiracy theories try to convince us by presenting arguments that allegedly reduce the strangeness of the world. For example, those who claim that the election which Trump lost was fraudulent, usually point out strange facts such as: The counting of the votes till 10 PM was in favor of Trump, and he lost just because of the votes sent by mail. Another example is that those who believed in The Protocols of the Elders of Zion pointed at the strange phenomenon that many Jewish people are rich. Still another example: Those who believe in the Moon landing conspiracy theories point at allegedly strange facts such as the waving flag. In all these examples, the conspiracy theories allegedly reduce the strangeness of the world by explaining the allegedly strange phenomena.

My theory may also be relevant for Kahneman and Tversky's above-mentioned experiment about irrational beliefs (see section #7). The idea that Linda works as a bank teller in spite of being deeply concerned with discrimination and social justice issues, increases the strangeness of the world. The idea that she is active in the feminist movement reduces it.

9. SCIENCE

What is science? Usually, following Popper (and Agassi) I refrain from discussions about proper definitions of well-known concepts. For example, it makes no sense to discuss the definition of the concept of “table.” Usually, there is no definition that everybody agrees on. And when one asks what is a table, instead of presenting a definition, we can point at clear examples of tables, and we can also point at things that some people classify as tables and some do not. The same method can be applied to the question: What is science? Physics and chemistry are clear examples of science; sociology and political science are less so. Some people classify them as science, and some do not.

Still, it makes sense to discuss what science is to discover why we trust science more than myths and stories.

Positivists claim that scientific theories are inductively corroborated. But as I maintain in section #3 of this paper, the idea that observations can corroborate theories leads to unsolved paradoxes.

Popper [9] suggested that a theory is scientific only if is empirically refutable. But this idea is inconsistent with the fact that Neo-Darwinism (the theory of evolution by natural selection) is considered a paradigm example of good science. As Popper himself admitted (though he later changed his mind) this theory is hardly refutable, and many scholars claim that it is not refutable at all. We will return to this theory shortly.

My suggestion is that scientific theories highly reduce the strangeness of the world. When researching these theories scientists look for surprising predictions. When an observation matches the prediction, it increases the strength of our belief in the theory (since without the theory, the surprising observation would increase the strangeness of the world). And when the observations are inconsistent with the theory, the strangeness of the world increases. Then scientists search for ways to reduce it by discovering errors in the observations or suggesting new theories that explain these and previous ones.

The theory of evolution

As mentioned earlier, the theory of evolution by natural selection is considered a leading scientific theory. But contrary to other scientific theories, it is hardly refutable, and many claim that it is not refutable at all. Consider the well-known case of the Peppered moth (Biston Betularia). In a typical form this moth has a white body, and the wings appear to be seasoned with pepper. This peppering acts as a camouflage against predators. During the Industrial Revolution, when pollution from coal covered everything, this camouflage was ineffective. Then a mutant with black wings appeared and became the dominant type in the polluted cities. When factories stopped using coal and the pollution was over, the moth with white wings returned. The theory of evolution by natural selection explains these facts. And several scholars claimed this could be considered as a (natural) scientific empirical experiment of the theory. But this claim meets the following criticism: If there were no black-winged moths when the cities were polluted, or if no white-winged moths had returned at the end of the pollution, we should not conclude that the theory of evolution by natural selection had been refuted.

Similarly, suppose we discover an old sub-species of a horse buried in a new geological layer, and a new sub-species of a horse buried in a lower layer. In that case, we cannot conclude that the theory of evolution by natural selection was refuted. An alternative conclusion would be that we were wrong about the order in which these two sub-species were created.

Why do many of us, myself included, believe that the theory of evolution by natural selection is a paradigm of a scientific theory? My answer: The theory of evolution by natural selection explains the existence of various species and their traits as a result of accidental processes (mutations), and this explanation highly reduces the strangeness of the world.

Geological and historical theories

My theory of belief formation can explain the debate about theories like the continental drift. The continental drift theory claims, among other things, that Africa was connected to South America. This theory is not a generalization but a statement about a fact in the past. When the theory was presented by Wegener [15], it was a speculation. It explained strange observations such as the match between the sea shores of West Africa and South-East America and the rare vegetation on both shores. So, the theory was attractive since it decreased the strangeness of the world. On the other hand, it increased the strangeness of the world since the idea that continents can move was considered very strange. (Nowadays the theory has a status of an observation following the discovery of volcanic activity in the middle of the Atlantic Ocean that pushed the two continents apart).

Questions in history can serve as another example. Historians ask questions such as: Why did the Scientific Revolution start in Europe, not in China? Why did the Industrial Revolution start in England? These questions point at strange phenomena and we look for explanations to reduce the strangeness that they create. These explanations are usually based on accepted ideas and facts about human behavior. For example, one popular explanation for the question of why the Industrial Revolution started in England is that, among other things, England had many coal deposits that were very easy to mine.

Beliefs in logic and mathematics

The theory presented in the previous pages refers to beliefs about the empirical world. It does not deal with beliefs in logic (for example, everything is A or not-A) or in mathematics (for example, 8+5=13). The question, when do we believe that a certain statement in the fields of logic or mathematics is true, is beyond the scope of this paper. Still, I find it appropriate to present the following half-baked idea for further research: People check if a given statement is logically or mathematically true by trying to *imagine* that it is false. If they fail to imagine a situation where the statement is false, they tend to believe that the statement is logically or mathematically true. Sometimes people are wrong about their ability to imagine a situation where the statement is false, and then their conclusion about the status of the statement is wrong. A well-known example is the belief that was quite common regarding the necessity of Euclidian geometry as a theory of the empirical world.

10. PRACTICAL APPLICATIONS

The theory of belief formation presented above (section #8) has several practical applications.

You may apply this theory when debating. If you want to convince others that a particular statement about the empirical world is true, try to show that this statement reduces the strangeness of the world.

One may also apply this theory of belief formation regarding debates about which theory should be applied to solve a particular problem. For example, when facing a macro-economic crisis, we debate whether we should deal with it according to Keynes' theory, Milton Friedman's monetarism, or some other theory. Some counter examples refuted these theories, and many *ad hoc* corrections were suggested. And the practical question is: How should we select the proper theory to be used in the current crisis? Following the psychological theory presented here, we will tend to adopt the theory that minimizes the strangeness of the world (the economic phenomena in this case). Therefore, during the debate it is preferable to concentrate on the question: Which theory minimizes the strangeness of the world.

A similar application refers to cases where we examine a new idea, for example, when considering an investment in a technological start-up that suggests a new idea, perhaps a new method to treat a particular disease. It makes sense to examine how this new idea decreases the strangeness of the world: (1) Does it predict unexpected phenomena? (2) Is it consistent with accepted theories in the field? (3) Is it non-trivial or why have other people not thought about it?

Ostensibly, one may criticize these suggestions. If we are already determined to believe in ideas that reduce the strangeness of the world, then there is no need for these suggestions. My answer is that we can control our tendencies to a quite limited degree. When we become aware of the way we believe in new ideas, we can concentrate on the question of how much the idea reduces the strangeness of the world, avoiding irrelevant destruction.

Machine learning

Another application is in the field of machine learning.

There are many machine learning algorithms, where the software learns from examples (so-called supervised learning). The data set is an Excel-like table of several columns or fields; each record is another example. For example, a medical data set may list the data of many subjects. The columns display various features (age, gender, blood pressure, weight, and so on). These are the independent variables. One column, the dependent variable, denotes whether or not the subject suffers from a particular sickness (for example, T – indicates a positive example, F – indicates a negative one). The algorithm searches for a valid model of the patterns that explain which subjects suffer from the sickness, and which do not suffer from it. The validity of the model is then tested on another sample from the same population. The model issues predictions regarding the subjects in the second sample, the predictions are compared with the real values, and so the prediction accuracy is measured. When building the model and issuing the predictions, the algorithm also considers the cost of errors – predicting that subjects are sick while they are healthy, and vice versa – predicting that subjects are healthy while they are sick. The target is to minimize the total cost of errors.

There are many algorithms for such learning from examples. They use various heuristics and there is no proof that a particular algorithm is the best for all possible data sets. They are relevant to the discussion in this paper since they can be interpreted as possible theories about the way people create beliefs rationally.

I am the manager of a software company that among other things developed the machine learning application, WizWhy. The algorithm implemented in this application is based on the theory of belief formation presented in this paper. The WizWhy algorithm searches simple rules explaining as many cases as possible. The rules' structures are if-then, if-and-only-if, mathematical formula, and a combination of an if-then rule and a mathematical formula. (See Appendix A for examples). This algorithm provides a full explanation for each prediction. The explanation is the rules. The WizWhy algorithm imitates a scientist looking for a theory that explains the data in the simplest way and thereby reduces the strangeness of the world. The accuracy of this algorithm is as good as the accuracy of well-respected algorithms such as Artificial Neural Networks and Random Forest.

Allegedly, following the description of the WizWhy algorithm, one can criticize the position presented in this paper as follows: Skepticism implies that there is no way to calculate the plausibility of statements. Therefore, there is no way to calculate the plausibility of the rules that the program discovers. So, what is the justification for the criteria of selecting the rules that comprise the model? (As stated, the WizWhy algorithm selects the simplest rules that explain as many cases as possible). My answer: We believe in a theory that minimizes the strangeness of the world, since this is our psychology. And it makes sense to apply this psychology in a machine learning algorithm, since the theory of evolution suggests that that this psychology is quite efficient. We would not be alive if our psychology led us to have many wrong beliefs about the world.

As I mentioned earlier, many machine learning algorithms for learning from examples exist. I suggest the hypothesis that all of them can be interpreted as decreasing the strangeness of the world. But this discussion exceeds the scope of my paper.

CONCLUSION

Agassi taught me that philosophy in general and epistemology and philosophy of science in particular have practical implications. The paper starts by discussion of the allegedly abstract question about the status of skepticism. But as I tried to show this question leads to practical applications.

Philosophers have viewed skepticism as a teaser, they have tried to find a good answer to the skeptical arguments. In this paper I presented the opposite position. I suggested that skepticism is true: statements cannot be justified (in the epistemological sense of justification). This position leads to the question: why we believe that jumping from a high widow is risky. The answer: we don't choose our beliefs like selecting a product in the store. Rather our beliefs are determined by a psychological process. When a statement reduces the strangeness of the empirical world, we tend to believe that the statement is true. This psychological theory of belief formation has implications in the philosophy of science and machine learning.

Appendix A

Examples of the rules issued by WizWhy

WizWhy reveals various types of rules that explain the data, and thereby reduce its strangeness.

An example of if-then rule

If Gender is M

and Result of Test A is 200 … 300 (average = 255)

Then

Result of Test T is More than 500

Rule's probability: 0.70

The rule exists in 370 records

Significance Level: Error probability < 0.001

The if-then rules are either positive, as in the example, or negative, where the rule says: Result of Test T is NOT More than 500.

When issuing predictions based on if-then rules, there might be cases where some rules predict to one direction (Result of Test T is More than 500), while others predict to the other direction (Result of Test T is NOT More than 500). In such cases WizWhy applies an algorithm that calculates which prediction is less strange. This algorithm rests mainly on the rule's significance level, which denotes the probability that the event presented by the rule is accidental.

An example of formula rule

$A = B^2 + 30$

Where:

A – Result of Test T

B – Result of Test B

An example of a combination of If-then and formula rule

If Gender is F

Then

A = C*0.4 + 35

Where:

A – Result of Test T

C – Result of Test B

Accuracy level: 0.95

The rule exists in 80 records.

Formula rules are rare, and the probability that their discovery results from pure luck is very low. When issuing predictions, if such a rule is applicable, formula rules get priority (relative to if-then rules).

An example of if-and-only-if rule

The following conditions explain when the Result of Test T is more than 500:

If at least one of these conditions holds, the probability that the result of Test T is more than 500 is 0.9

If none of these conditions holds, the probability that the Result of Test T is not more than 500 is 0.95

The conditions are:

1. Gender is M and Result of Test A is 200 … 300 (average = 250)
2. Result of Test B is 360 … 380 (average = 370)

An if-and-only-if rule explains all the cases in the data, and when issuing predictions, there are no cases where the program has to select between two inconsistent predictions (as is the case in if-then rules).

Each prediction can be presented with the rules that explain it.

REFERENCES

[1] Agassi Joseph and Abraham Meidan, *Philosophy from a skeptical perspective*, Cambridge university press, 2008

[2] Agassi Joseph and Abraham Meidan, *Beg to differ*, Springer, 2016

[3] Hume David, *A Treatise of Human Nature*, 1739., John Noon. Archived from the original on 12 July 2018. Retrieved 11 March 2015.

[4] Frege Gottlob, *Grundlagen der Arithmetik*, Breslau: Marcus. 1934. (Reprint of the first edition of 1884).

[5] Goodman Nelson "A Query on Confirmation", *The Journal of Philosophy*, **43** (14), 383–385, (Jul 1946).

[6] Hempel Carl, “The White Shoe: No Red Herring”, *British Journal for the Philosophy of Science,* **18**, 239-240 (1967).

[7] Popper Karl, *Conjectures and Refutations*, Routledge, 1963

[8] Peirce, Charles S. "The Scientific Attitude and Fallibilism" (1896–1899). In Buchler, Justus, *Philosophical Writings of Peirce*, Routledge, 1940.

[9] Popper Karl, *The Logic of Scientific Discovery*, 1934 (as Logik der Forschung, English translation 1959)

[10] Quine W. V. (). "Two Dogmas of Empiricism", 1998. In Curd, Martin; Cover, J.A. (eds.). *Philosophy of Science: The Central Issues*, Norton. pp. 280–301.

[11] Duhem Pierre, "Physical Theory and Experiment", 1998. In Curd, Martin; Cover, J.A. (eds.). *Philosophy of Science: The Central Issues*, New York: Norton. pp. 257–279.

[12] Popper Karl, *Objective Knowledge*, Oxford University Press, 1972.

[13] Tversky Amos, Kahneman Dan, "Judgments of and by representativeness". In Kahneman, D.; Slovic, P.; Tversky, A. (eds.). *Judgment under uncertainty: Heuristics and biases*, Cambridge University Press, 1982.

[14] Ramsey Frank, Truth and Probability, 1926, reprinted in *The Foundations of Mathematics and Other Logical Essays*, R.B. Braithwaite (ed.), with a preface by G.E. Moore, Kegan Paul, Trench, Trubner, & Co., 1931.

[15] Wegener, Alfred, *Die Entstehung der Kontinente und Ozeane* [The Origin of Continents and Oceans] (in German) 1929. English language edition: Wegener, Alfred (1966). The Origin of Continents and Oceans. New York: Dover. Translated from the fourth revised German edition by John Biram.; British edition: Methuen, 1968.