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The Role of Intuition and Creativity in Decision Making

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THE ROLE OF INTUITION AND CREATIVITY IN DECISION MAKING

Andrzej P. Wierzbicki[1]

Summary.

The paper starts with a reflection on various perceptions of rationality in decision making; by concentrating on so-called deliberative decision making and examining its analogy to cognitive processes, a case for including intuitive decisions into the concept of rational decision making is made. The role of "Gestalt" images and basic concepts in perceiving reality is stressed. Intuitive decision making is operationally defined and various phases of intuitive decision processes are examined. Special attention is paid to creative decision processes, when the decision maker is facing a novel problem of strategic importance. Issues of possible empirical studies of intuitive decision making are outlined. Since this paper is constructed as a "thought experiment" (Kuhn, 1964) in order to clarify some concepts of perception related to intuition, possible implications for the philosophy of science are also indicated.

1. Introduction.

The term "rationality" is used differently in various scientific disciplines. A possibly broadest sense of this word is implied by its use in the philosophy of science (see e.g. Popper, 1983). Even in this field, there are diverse interpretations of this term (falsificationism by Popper, historicism of changing paradigms by Kuhn, competition of scientific programmes by Lakatos, etc., see Hacking, 1981 - versus evolutionary epistemology as initiated by Lorentz, 1965, see Wuketits, 1984). From the more normative, Popperian perspective, rationality of a statement concerning the real world implies its empirical testability and falsifiability (at least in principle); if a statement relates rather to a method of communication than to the properties of real world itself (as, for example, a mathematical theorem) then it must be logical and consistent with the assumptions of the method.

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When seen from this perspective, the term "rationality" in the theory of decision making has been often used in a rather unfortunate sense: a decision maker is considered rational if he/she chooses the most preferred decision, defined usually as maximizing his/her utility or value function. Interpreted as a mathematical statement, such an assumption is logical and consistent with many other developments of decision theory. However, interpreted as a description that real "rational" decisions are always made in the best perceived interests of the decision maker, this assumption is itself not rational in the normative, Popperian sense of the theory of science. Popper uses precisely this as an example of an unrefutable theory. If any other concerns - honor, altruism, etc. - can be subsumed into the individual utility, then the assumption of best perceived individual interests cannot be falsified in principle and expresses rather an ideology than science - at least, according to Popper, while Kuhn argues that certain components of ideology are always present in a paradigm of normal science (see Kuhn, 1970).

Thus, we shall not relate here in much detail the voluminous discussions of this difficulty in decision theory ("descriptive" versus "prescriptive", "perfect" versus "imperfect" rationality) and treat them rather as one of the examples of an unfortunate confusion of the language we use to describe the world and of the way we actually perceive the world; as we shall see later, even the philosophy of science is not quite free from examples of such confusion. We shall also use the term "rational decision" in a possibly broadest sense: while stipulating that the specific meaning of this term might depend on professional and cultural background (see e.g. Grauer et al., 1985, or Yu, 1990), we shall require that a rational explanation of the way decisions are made should itself be - at least in principle - empirically refutable. In this sense, we shall show that it is rational to investigate the role of intuition in decision making.

2. The Paradigm Versus Diverse Frameworks of Rationality of Decisions.

With all the reservations stated above, it is useful to recall that the assumption of choice based on preference, on the maximization of an utility or value function has been very productive in the development of economic theory and mathematical game and decision theory. It has a long research tradition, starting with old, intuitive perception of economic "utility", formalized by v. Neumann and Morgernstern (1944) through the

concept of a (cardinal) utility function, further by Debreu (1959) through the study of preference orderings and the conditions of mathematical existence of an (ordinal) value function, and many other theoretical developments. This has led to such an expansion of mathematical economics, game and decision theory that no single book today would even list nor summarize the existing literature of the subject. Indeed, a paradigm (in the sense of Kuhn) has been formed around this assumption, with all its features - including also a psychological commitment to this assumption, reinforced by the sociological aspects of a field of science.

As described by Kuhn, a paradigm is not necessarily formed nor changed because of its empirical testability; its central statements are often chosen in order to simplify analysis, as in the case of Copernican theory, and its testability depends on additional assumptions and interpretations; the same applies to the paradigm of utility maximization. If modestly interpreted in its descriptive power, this paradigm might be treated as empirically testable and thus rational in the sense of Popper. Indeed, a statement such as "an averaged behavior of certain aggregate classes of individuals acting on economic markets is usefully described by assuming that they maximize utility or value functions" is falsifiable and has been tested in several economic studies. Unfortunately, this aggregate statement has been often individualized which led to an unrefutable, absolute interpretation that every individual does (or should, or could) maximize his/her aggregated, best perceived interests in every decision. Although such an interpretation has instigated much criticism in the history of decision theory, it served also as a way of an ideological reinforcement of the paradigm.

A school of criticism of this interpretation, usually dependent on a certain disciplinary or cultural perspective, will be called here **a framework of** perceiving **rationality of decisions** (for the lack of a better word, while being aware that the concept of a framework can instigate even more discussion and criticism than that of a paradigm).

The most notable between such frameworks is the theory of **satisficing behavior** developed originally by Simon (1955, 1957) reflecting more managerial and microeconomic perspective (but also consistent, for example, with an engineering behavior). According to Simon, individual decisions are not optimized because it is too difficult (particularly in situations with uncertainty), because the access to information is limited and because an

individual optimization might lead to unnecessary conflicts in non-market situations with a limited number of actors (as in management). Instead of optimizing, an individual decision maker forms his/her own **aspirations** - adaptively, through learning processes that play an important role in this theory - and is satisfied with his/her decisions if the aspiration levels are attained.

The satisficing framework of rationality was further developed through intensive studies, including empirical tests; finally, it was assimilated also in the utility maximization paradigm under the name of **bounded rationality** (this choice of the term reflects the ideological aspect of the paradigm: while believing that a "perfectly rational" individual should optimize, it can be admitted that most individuals are less than perfect). Recently, the concept of adaptive aspiration formation was even shown to be a useful instrument for explaining market equilibration mechanisms, consistent with long-term utility maximization (Wall, 1992).

Related to the satisficing framework but distinct by stressing a big organization perspective (in corporate or military planning, but also in centrally planned economies) is the framework of **goal-oriented behavior**, discussed e.g. by Glushkov (1972), Pospelov and Irikov (1976), independently operationalized by Charnes and Cooper (1975) as a **goal-programming** method of multi-objective decision support.

From the perspective of decision support in multi-objective situations, a methodology of **reference-point optimization** was later developed (see e.g. Wierzbicki 1980, 1986, 1992, Lewandowski and Wierzbicki 1989). This methodology uses both optimization and adaptive formation of aspirations, but rather as instruments of interaction between the decision maker and the computer than assumptions concerning human behavior; while it generalizes the goal-programming method and can support decision makers which adhere to various rationality frameworks (e.g. such that believe either in satisficing or goal-oriented or utility-maximizing behavior), it also stresses **the dynamics of a decision process**, adaptive learning and stimulation of the intuition and creativity of a decision maker.

There was also much criticism of the assumption of utility maximization coming from the psychologists' perspective, e.g. **the theory of regret** by Kahneman and Tversky (1982), or from a purely mathematical perspective when examining extreme consequences or paradoxes related to

this assumption - we might mention here **the paradox of Allais** (1953) that lead eventually to a postulate of nonlinear dependence of expected utility on probabilities (see e.g. Machina, 1983) or **the impossibility theorem of Arrow** (1951) that illustrates the difficulties of a social aggregation of individual utilities. Coming from the outside of the paradigm but related to some of its central issues was the development of **the possibility calculus of multi-valued logic**[2] **or fuzzy set theory** introduced by Zadeh (see e.g. 1978) as a more consistent tool than probability calculus when describing subjective evaluations of uncertainty in decision making.

Another important avenue of criticism of extreme interpretations of individual utility maximization resulted from the evolutionary perspective, with the introduction of the concept of **evolution of cooperation** - see Axelrod (1984), Rapoport (1989). In a perfectly logical and mathematically valid way, this approach shows that evolutionary interests of a population - and also individual interests of members of this population - might be better served by adopting certain individual decision rules that take into account cooperation principles than by pursuing maximization of purely individual interests (no matter whether short- or long-term). At a first glance, this finding only proves that our mathematical and logical language of describing the world is not inconsistent with various empirical findings of cultural anthropology that stress the evolution of ethical norms as necessary cooperative principles. Also, this finding actually does not invalidate the paradigm of individual utility maximization, since we could interpret it as an indication that individual utilities should better take into account also social values (although such an interpretation does not help in answering the question which social values and how social ethics might be further developed or reformed).

Upon a deeper reflection, however, the concept of evolution of cooperation does contradict the more extreme interpretations of the paradigm of individual utility maximization (that it is better if everyone pursues his/her own individual interests). Moreover, this concept also contributes further to the criticism of one of the basic postulates of logical positivism and empiricism of the early XX-th century: that the questions of ethics can be discussed only in "emotive", not "cognitive" expressions[3].

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[2] With a set of truth values between 0 and 1, of continuum power - as opposed to binary or trinary etc. logic.

[3] The criticism of this postulate concerns rather the social then the individual aspects of ethics; see e.g. Janik et al. (1973).

We can summarize this overview of various analytical explanations of the mechanism of human decision making by stating that **while average economic decisions on a market might be well described by utility maximization, it is not necessarily useful** (and it can be debated, whether it is actually rational) **to assume the same about individual decisions in other contexts; they are usually made in a much more complicated way.**

One avenue of criticism went even further to claim that individual decisions are too complicated to be explained by **analytical** decision theory, that decisions are rather made in a **deliberative** way.

3. Soft Decision Making and "Mind over Machine".

This criticism was often presented from the perspective of general systems theory (Bertalanffy, 1968) as so-called **soft systems approach**; it stressed the role of **synergy** - that the whole is bigger than the sum of its parts - as well as the fact that in a more complex cognitive or decision process, there is a moment of a **heureka** (after Archimedes) or **aha** effect, which can be also called a **cognitive enlightenment** effect. Thus, **soft or deliberative decision making** consists in trying to perceive the whole picture, to observe it from various angles, and finding the right decision by expert intuition.

Various additional observations can be made to support such an approach. One of them is the argument about **holism** versus **reductionism**: an analytical approach induces us to a reductionist concentration on parts, while deliberation helps to concentrate on the whole (the "Gestalt" perception of a problem). Another is the following taxonomy of cognitive approaches by Harold Barnett[4], expressed in a discussion about the role of mathematical modeling at IIASA: **hard models - soft thinking, soft models - hard thinking** (this implies that if we concentrate too much on analytical approaches, we might miss insights which result rather from deliberation).

Most completely and consequently, this avenue of criticism is presented in the book **Mind over Machine** by H. Dreyfus and S. Dreyfus (1986).

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[4] Private communication; with thanks to his memory for stimulating discussions. IIASA is the International Institute for Applied Systems Analysis in Laxenburg, Austria.

Actually conceived as a criticism of concepts of artificial intelligence[5], this book most convincingly presents the case for deliberative decision making. One of the best documented theses of "Mind over Machine" is that **there is a change in the way decisions are made with the increasing level of expertise of the decision maker**. While a beginner, novice or apprentice needs analysis to support his/her decisions, specialists, experts and master experts rely increasingly more on deliberation:

LEVELS OF EXPERTISE	TYPE OF DECISION MAKING
- BEGINNER - NOVICE - APPRENTICE	ANALYTICAL DECISION MAKING
- SPECIALIST - EXPERT - MASTER EXPERT	DELIBERATIVE DECISION MAKING

In the case of operational decision making, the empirical evidence for such a thesis is abundant: e.g. when driving a car, a novice has to think before shifting gears, while experts make decisions with "entire body". In the case of strategic decision making, when often new types of decisions are needed, Dreyfuses designed and conducted a special experiment involving playing chess: they **saturated the analytical part of the brain** of a player with tedious computations in interaction with a computer, while letting him/her at the same time compete at chess; the results were analyzed depending on the level of experience of the player.

The results were actually predictable (by any good chess player): apprentice players cannot play chess when analytical parts of their minds are saturated, while **for chess masters it does not make any difference.**

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[5] With which I only moderately agree: my own experience concerning the superiority of certain aspects of analog computations and the complexity of modeling neurons suggests that methods employed until now by artificial intelligence are too simple to achieve its goals. This might change, however, if studies of neural networks mature and take into account more realistic models of neurons.

Dreyfuses express their opinion that these results are related to the way we perceive reality by images and "Gestalt" and recognize patterns, to the typical connections of "roads of the brain" established by training, to the functions of "the right part of the brain" and to the concept of intuition, but refuse to analyze the latter concept - possibly, because intuition is often perceived as a not quite rational, scientific issue.

4. A Thought Experiment and Creative Processes.

A reasonable definition of intuition should take into account a theory how people perceive the world. This is a theme with a long tradition in philosophy; however, I could not find there - neither in Wittgenstein (1922), nor in Ingarden (1972), nor in more contemporary texts, such as Vollmer (1984) - a theory satisfactory for my purpose. The closest to my needs is the theory of inner representation - that we might communicate by words and think abstractly by symbols, but perceive the world by images and have an internal, mental image representation and processing, see e.g. Kosslyn (1980). Although this theory has much empirical support, it was strongly criticized from the epistemological - mainly logical - perspective, see Pylyshyn (1984) and Gardner (1984) for a broader description of this dispute. If we approach this theory, however, from the perspective of evolutionary epistemology, I believe that a strong case supporting the concept of internal representation can be made. I am ready to stipulate that this concept might be considered contrary to many assumptions of more traditional epistemological approaches; but this means to me that alternative methods of investigation should be tried in relation to this concept.

An important contribution to the philosophical debate by Kuhn (1964) shows that basic concepts applied in any scientific theory include very deep, often hidden assumptions about the real world; if these assumptions are too simplistic, the best way to examine their inconsistency is not necessarily through empirical experiments, because more convincing and enlightening might be "thought experiments". I would like, therefore, to examine here - by means of an abstract "thought experiment" - some of the concepts of representation of elementary facts of reality in our minds and their further representation by language, including the concept of inner representation.

Thus, let us consider a society of intelligent beings living on a world similar to our Earth. In order to simplify analysis and to illustrate a tangent conclusion, let us assume that the individuals of this intelligent race do not have to compete for the resources of their globe, although they might work. More important assumptions are, however, that this race has an inbred strong instinct of curiosity - perhaps as a result of an evolution[6], that the individuals of this race perceive their world by optical, acoustic, etc. signals and senses similarly to humans, and that they have had a long period of evolution until they discovered language.

The processing of optical and other sensual images as informational objects[7] and their classification into a system of categories is a hard computational task, many orders of magnitude more difficult than processing words - if measured by our contemporary knowledge of information processing and computational complexity; parallel processing of various types (e.g. by artificial neural networks) is necessary to accomplish this task efficiently. Thus, it is reasonable to assume that the minds[8] of this race developed - even before they discovered language - a potential similar to that of humans, estimated at 10^{11} of rather intricate neurons.

Such large computational tasks cannot be performed at the central, coordinating unit of a processing system; they have to be delegated to specialized units. If we use the analogy of a central coordinating unit to the conscious, willing part of the mind, it is reasonable to assume that

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[6] This is consistent with modern theories of evolution in which the survival of the fittest is not the unique and not necessarily the most important mechanism. Note that human curiosity is also out of proportion to direct economic or survival needs of an individual, but might be essential for dealing with unpredictable effects - natural catastrophes etc. - by groups of humans. I leave to the readers the task of imagining the details of diverse models explaining how such an instinct could be inbred.

[7] Here we use the word "images" in an almost photographic (or phonographic, if it concerns e.g. a melody) sense and the words "informational objects" in the sense of information processing, i.e. that of large and structured information units (as e.g. in an "object oriented computer language"). This meaning of an "object" is thus similar but one step removed (after all, it is only an informational representation of an object from the real world) from the accepted sense in philosophy, used e.g. already by Kant, while the word "image" has been used in philosophy often differently and in a varied sense.

[8] In order not to enter too broad areas of dispute, I will use the word "mind" in the biological sense of brain and other parts of neural system, while stipulating that there is also an intentional, conscious and willing "ego" part of the mind.

large parts of information processing - in particular, image processing - in the minds of this race would be done at a subconscious level. After all, we also recognize optical images or musical patterns often subconsciously; the conscious recognition of a pattern is usually somewhat delayed. Moreover, a mind does not stop working when the consciousness sleeps[9]; even animals dream. Finally, we shall assume that the individuals of this race perceive - beside curiosity - also other personal emotions, say, triggered by some visual or musical impressions.

Now we come to a set of critical questions; consider a point in development of this race when the language is young yet and only a small number - say, a few thousand - words are used in their language. **What would be then the prevalent mode of thinking in their minds: by words or by images (large informational objects)? Would they process emotions mostly in words, or in a manner similar to images? What would be the role of words and language at this stage of development?** Suppose their world is similar to ours in relations between objects (in the Kantian sense); **what would be then the logic used** (perhaps implicitly) **to describe these relations: binary or multi-valued?** Suppose an individual of this race is driven by curiosity to consider epistemological questions; **what would be then a possible theory explaining how does the race perceive their world?**

As to the first three questions, there is no doubt that **they would think mostly and more efficiently in images; since thinking is useful evolutionary, a race cannot wait with it until it discovers language**[10]. Emotions would be also processed in a manner similar to images; we also often associate the feelings of happiness, beauty - or hatred - with some optical images. Words and language are needed for communication (motivated e.g. by curiosity what others think); **but a small number of words implies**

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[9] Since we did not assume any specific role of sex for this race, this would be not necessarily a Freudian subconsciousness.

[10] Thus, an evolutionary perspective does support the internal representation theory. One might feel an intuitive aversion against admitting that we think also in images, because that would "lower" us to an animal level. One could argue also that we cannot think in images about abstract issues, such that go beyond our "mesocosm" experience - see Vollmer (1984). But I have often felt that also my abstract, mathematical thinking relates to images, although they are not necessarily simple visualizations; many of my colleagues mathematicians are of similar opinion. I suggest to the readers that they devise personal experiments to determine, whether they think more in images or in words and which mode is faster for them.

necessarily that they have multiple meanings. They could use word sequences to describe more complicated objects, but there are practical limits to such expansion: the time for discussion is always limited.

Each word would then have - at least - a double role: to **describe** (in only an approximate sense) certain states of the world that they have perceived by images, and to **invoke**, trigger a large number of associated images or feelings. I use this term, because this might be related to the belief in a magical power of words at certain stages of cultural evolution, also to the role of poetry. When trying to be more precise in the descriptions of their world (to formulate something that we call science), this race would start to dispute the meaning of the words and their relation to reality, invent new words and assign new meanings to them, perhaps even strive to determine the meaning of each word uniquely.

As to the question of logic, **the issue of similarity of certain images forming a category is better expressed in terms of multi-valued logic, of fuzzy sets, than in binary terms.** This follows not only from recent approaches to in computational pattern recognition; experimental studies of categorization (see e.g. Rosh et al., 1978) suggest also that a category is not necessarily defined in the mind by a sharp logical definition, much rather by the similarity to a prototype. However, a conscious ego needs to be convinced in order to act: **when trying to convince others,** this race would **use more decisive, binary logic** in language. Still, when using words of more rich meaning, they would have to stick to multi-valued logic. Another question is whether they would do it only subconsciously, or could do it consciously; well-formalized logic is difficult (requires first a good understanding of abstractions of arithmetic type), multi-valued logic even more difficult to formalize - and it is hard to imagine that we, humans could develop the multi-valued variant first.

But suppose this race - driven by curiosity - would develop mathematics and logic (both binary and multi-valued) faster in relation to natural sciences and language than we did. What would then a penetrating individual of this race postulate about the methods of perceiving and describing their world? It would be stressed that they have (at least) two types of thinking: a **pre-linguistic form** of processing of images, patterns of sound and emotions - large informational objects, and a **linguistic form** of processing of words, necessary for communication. The linguistic form is not necessarily easier for the race - it is more recent and has to express

with few words much richer aspects of the pre-linguistic form. Since objective statements about the word must be such that can be formulated in words - to be communicated and tested by the curious society - they might better follow binary logic; but there is an inherent contradiction in such a custom, because the original pre-linguistic form uses multi-valued logic and the original deliberation is performed on the pre-linguistic level. Thus, a cautious scientist (of this race) should rather state a theory describing the real world in terms of a large degree of possibility of truth and invite others to test its truth value. A theory that has a large truth value in sciences like physics should have rare and unimportant theoretically cases of falsification; in social sciences, where more subjective uncertainty can be expected, more frequent but also theoretically unimportant exceptions are admissible. Only in language and mathematics, the truth can be defined absolutely as consistency with logic and axiomatic postulates.

Imagine the discussions that such a set of postulates would provoke - which, necessarily, would enlarge the number of words they use, because the meaning of many new concepts would have to be debated. Some would ask which part of these postulates is empirical, describing their world as it is, which is transcendental or has perhaps a normative character. Others would argue that a social acceptance of a theory should depend on probabilistic induction; but then they would also debate the differences between probability and multi-value possibility and how to overcome them. Others would say that they do not believe in induction, because the theoretical significance of exceptions is more important - and debate how to define such significance, including also possibly some aspects of practical importance. Some would concentrate on the process of deliberation, but also on individual feelings and perceptions, on the ego of an individual. Some would ask why it is that certain phenomena in the material world - as in physics - can be described with a greater certainty, while other - as in biology - with not so much certainty?

Some would wonder how did it happen that the language and logic they developed is adequate to describe their world, what is the sense and limits of this adequacy? The conclusions that they would draw could be in many points similar to that of Wittgenstein, but they would also differ in some essential points. **Limits to language would result, primarily, from the double-layer representation of reality**. The deeper layer of pre-linguistic image representations in their mind would be richer in a factual,

descriptive sense. The layer of linguistic representations would be necessarily poorer in the descriptive power - but, perhaps, more rich in the abstractive power of invoking many associated images related to an abstract word. Thus, this race could not postulate that they directly compare their "pictures" or models of facts to reality and obtain a binary logical evaluation of truth.

The crucial remaining question of the "thought experiment" is as follows. **Are the implications of this experiment applicable also to our world, or are the assumed differences essential?** These differences relate to the role of the competition for resources and the number of words in our language.

Competition for resources - but also cooperation in human groups in order to intensify the acquisition of resources - has prompted us to develop natural language and natural sciences faster. Philosophical, epistemological questions were formulated before the formal language of logic was perfected, which prompted the development of binary logic and its application to philosophy - but lead to the concentration on the role of language and to the binary perception of truth. Thus, we overlooked the fact that the double-layer representation (first from the real world into images or large informational objects in our mind, then from these objects to categories, symbols and words) might involve multi-valued logic on the deeper layer; but the possibility of applying multi-valued logic is quite recent in our history. These differences are not essential now - only we have a much larger number of words at our disposal; does it really matter?

Assuming that the real world is infinitely complicated (there were many attempts to falsify this assumption - schools of thought trying to explain the world absolutely - and they all failed, we always found something new to study), **we will always have too few words to describe the world**, no matter whether their number is two hundred or two million. Thus, some crucial words - e.g. basic concepts, such as **time, cause and effect, feedback, uncertainty, evolution** - will be always very rich in meaning, powerful enough to invoke many associated images.

Thus, **we can conclude the "thought experiment" by stating that its implications apply also to humans.** If we acknowledge the essential difference of difficulty between processing images and processing words, we can postulate that our minds work also on a deeper layer of pre-linguistic

image processing - which task employs a large part of mind's processing potential, is sometimes conscious but often unconscious, and uses rather multi-valued than binary logic. Our language can only try to approximate this deeper level by words and by a simpler, more decisive binary logic; but words will always have multiple meanings.

As to the last conclusion, we might ask the question: is this good or bad?

Language, logic, mathematics are just instruments of description, discussion, formalization of our deeper thoughts that might occur - as the "thought experiment" shows - **deliberatively, on a pre-linguistic level, in terms of images and concepts**. It is obviously better for communication that basic concepts are well understood - and some directions in philosophy concentrated on clarifying the role of ideas and phenomenons in cognition and communication (see e.g. Husserl, 1911, Tymieniecka, 1972). From the perspective of evolutionary epistemology, it is also better (for the survival of humans) to clarify our abstractions, to compare and try to falsify them by scientific discussions and experiments - see e.g. Mohr (1984).

On the other hand, we know today enough to **value a concept the more the richer it is**, in a synergistic sense; and the number and value of associated images related to a concept depend on the level of expertise. Consider the concept of **time** - a specialist will ask you whether you prefer one sentence of a definition, but warn you that one hour lecture might be better, while the subject deserves a full course of lectures. Moreover, a physicist will then talk about the relativity of time, an economist or system scientist - about various aspects of time discretization and time discounting, a mathematician - about co-existing time-scales and boundary layer effects.

The same applies to many other concepts fundamental to our perception of the world, such as evolution or uncertainty. Especially important - as illustrated by the "thought experiment" - is the concept of **cause and effect**; but it is understood still by most people, even philosophers, in terms of binary logic[11], while we know today that there are situations in

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[11] Because of a cultural delay effect in our education systems: concepts developed in some disciplines need often several generations before they can fully influence the way most people think.

which fuzzy or multi-valued logic is more adequate, and that this concept is even more fundamentally changed if we include also feedback mechanisms.

The concept of **feedback** is essential for a modern, systemic understanding of the world - but it is differently perceived by an economist who has often been taught only the basic definition of this concept, differently by a control theory specialist who spent a life investigating various feedback effects, and a specialist in the theory of chaos would say "feedback with nonlinear dynamics might produce chaos in a deterministic system, which changes the way we should think about the indeterminism of the universe".

Moreover, even an agreement on a single meaning of a concept would not necessarily guard us against hidden presuppositions in its accepted definition, as illustrated by the paper of Kuhn where the "thought experiment" was related to the (relatively simple) concept of velocity. Thus, I would rather draw a conclusion that while the clarity and (fortunately, not attainable) single meaning of a concept are needed for communication, there might be other aspects of cognitive processes for which the richness of meaning is more valuable; one of such aspects is **creativity.**

Any scientist with some experience in creative processes - such that require not only mere search and logical or experimental testing, but also result in new cognitive insights - would acknowledge the basic role of the richness of concepts related to his/her field of study. The dynamics of a creative process is very similar to the process of arriving deliberatively at novel, strategic decisions as described by Dreyfuses. We often perceive uneasiness about an aspect of a scientific problem; then we try to look at it from various angles, through diverse images related to our basic concepts; after some time, a moment of cognitive enlightenment, a heureka effect comes. The mechanism of this effect relates to subconsciousness and intuition (there are many examples documented in the history of science), but sometimes we at least partly understand this mechanism. Often a vague association, an analogy helps; but not all analogies are good and it is dangerous to equate creativity with analogies. More important is an intuitive focusing on a small part of an image that seems to deserve attention; if this part and the angle of focusing are chosen rightly, this part suddenly expands, rich in associated ideas.

It obviously helps to study your subject thoroughly and to discuss it with others - we are forced then to at least partly formulate our thoughts, and even casual remarks of others might trigger associations; it also helps to relax after some time of study, forget the problem for a while - an intuitive answer might need such a gestation period. It might be also helpful to extend your interests beyond the strict boundaries of your discipline or even embark on some interdisciplinary research; it pays to travel and be exposed to cross-cultural influences. How soon you perceive a heureka effect and how good your answer is, depends on many aspects: on the level of expertise, on the thoroughness of study (the old computer science principle "garbage in, garbage out" applies also for humans), on cross-fertilization through discussions, interdisciplinary and cross-cultural contacts - and on personal creativity or intuitive capabilities, admittedly hard to define.

Parts of the above description are actually too simple and might be criticized as too subjective, depending on personal impressions - because we are trying to describe in words an emotive process that often proceeds on the pre-linguistic level of images and sometimes even subconsciously; hence we are forced to use analogies. The analogy to optical sensations - images, angles of observation - might be, however, appropriate, as illustrated by our "thought experiment". This description might be also shortened to a more objective thesis: **creative and cognitive processes are relying on the richness of images and concepts - or also on the richness, even redundancy, of information; they often occur on a deep level of pre-linguistic associations, often subconsciously or intuitively.**

This thesis is supported by the experience of many scientific disciplines. If you ask a mathematician: "There is an infinite number of true mathematical theorems to be proven yet; how do you choose which are important, which to prove next?" he/she would answer "by taste and intuition". Obviously, it might happen that subjects of study are also chosen because of the sociology of modern scientific "mass production" - to increase the intensity of publications and probability of their acceptance by respected journals; younger scientists often choose their subjects because they follow their mentors or accepted scientific schools; but truly creative findings, be it in mathematics or in empirical disciplines, are guided "by taste and intuition".

This thesis is also implicitly supported by the modern philosophy of science - which does not analyze intuition, but admits its importance. Popper (1983) observes that scientific theories are neither deductions nor, especially, inductions (in a classical sense[12]) from the facts; he admits that they might be created by intuition. What he insist on, however, is that a theory should be considered preferable to another if "it has hitherto withstood criticism better than another"; his insistence on subjecting theories in empirical sciences to falsification tests can be viewed as logically consistent with his admission that theories might be generated by intuition.

Until now, we discussed creativity and intuition in science. We can also ask the following question: is this description much different from the way other important and novel decisions, say, of political nature, are actually made? Being a specialist in mathematical optimization and decision theory, I had nevertheless the opportunity to observe much political decision making[13]; and the answer is: not quite different, they are also made intuitively (if the political decision maker is any good in his/her field of expertise). The same applies to managerial or even economic decisions. One could ask: if even economic individual decisions are made intuitively, how can they maximize utility? But there is no inconsistency in these statements: if intuitive decisions are rational in a broader sense, they might be also "rational" in the more narrow sense of utility maximization.

5. How to Define Intuitive Decisions?

Human mind is undoubtedly working in a complicated, **parallel and distributed** fashion. The potential of our mind is enormous and by far not efficiently utilized (this might be because we concentrate too much on words in the linguistic form of processing, while earlier in evolution we might have had to rely exclusively on more complicated image processing in

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[12] This statement obviously depends on the interpretation of the concept of induction; Popper denies the role of induction, but defined in a rather specific sense, while other philosophers defend this role and the importance of corroboration of a theory, while understanding them in a broader sense. One might even argue that a theory which is preferable according to Popper because it has withstood many empirical tests is therefore a result of an induction in a more general sense.

[13] Mostly in the field of funding scientific research in Poland.

the pre-linguistic form). Parts of the mind work **consciously** (we want to do it and are aware of it) - often in linguistic form, but sometime also in pre-linguistic form. Parts of the mind work **quasi-consciously** (we want to do it but leave the details to other parts of the mind). Finally, parts of the mind work **subconsciously** (we do not know that we want to do it and are not aware that we do it, but we can become aware a posteriori of the results of subconscious work of our mind). This classification has actually some analogies in psycho-physiology and it is reasonable to assume that specialized parts of our mind are involved in quasi-conscious or subconscious activities, but we use the classification here rather for the purpose of defining intuitive decisions.

The linguistic form of processing includes logic and mathematics - although mathematicians, both in creative and teaching capabilities, often employ also graphic images. It is perhaps interesting that a movement in mathematics around the middle of the XX-th century which turned against using images both in teaching and research (perhaps influenced by the principles of logical empiricism) was also against an excessive use of intuition in mathematics.

It would be thus tempting to define intuition as the use of a pre-linguistic form of processing in human mind. However, such a definition would not be sufficiently operational, or rational in the Popperian sense: since we do not know enough how our mind works, how should we determine experimentally what form of processing it uses in a given case? Moreover, it is questionable whether we should include our normal perception of optical images into intuitive activities.

For the purpose of preparing a broader but more operational definition of intuitive decisions, we can first reflect on various functions of the mind while using above classifications:

- **Perception and recognition**; while perception might be conscious or quasi-conscious or even subconscious, it is often pre-linguistic, by images and "Gestalt"; recognition is usually conscious or quasi-conscious and expressed in linguistic terms;

- **Processing** can have many purposes, such as reflection on perceptions and storing them in memory, or quite a different purpose of preparing physical action; we shall concentrate here on a special type of actions related mostly to communication and subdivide thus related processing into:

- **Communicative** - which is usually perceived as conscious, linguistic, logical and analytical, but actually often performed in a quasi-conscious way though in linguistic form, as when preparing a speech;

- **Pre-communicative** - by which we should not understand the quasi-conscious communicative processing as when preparing a speech or a manuscript, but rather reflection when ordering our arguments; this reflection can be conscious and linguistic, or conscious but pre-linguistic, by images; or often quasi-conscious, either linguistic or pre-linguistic;

- **Deep** - subconscious, either linguistic or pre-linguistic (although we know that our mind works even when we sleep and various schools of psychology investigated dreams as expressions of our subconsciousness, we do not know enough to state precisely how our subconsciousness works in relation to creativity and cognition);

- **Action,** especially **communication** might be consciously prepared and executed, but more usually involves a mix of conscious and quasi-conscious activities; finally, many of us could quote examples of subconscious actions.

Thus, we propose here to **define intuitive decisions as quasi-conscious and subconscious processing, leading to an action, performed** (possibly) **by a specialized part of human mind**. Together with this definition, we shall also distinguish two types of intuitive decisions: **operational**, when performing functions to which we are well trained, and **strategic**, when solving a novel problem (including creative activity).

Note that this definition is rather broad: it includes in intuitive decisions also such that have conscious components but take advantage of the parallel processing by the parts of our mind specialized in subconscious or quasi-conscious operations. Thus, our mind makes every day many intuitive operational decisions (e.g. when we take a walk, but think during the walk on other matters). The role of training in making these decisions well is fully understood and institutionalized in human society through our education systems. For example, a well trained driver usually disregards most motions that are parallel to his/her car but reacts intuitively by putting his/her leg on the brake if he/she perceives a sudden perpendicular motion (even before recognizing the object that moves). Good teachers in driving schools know about this, call this

phenomenon "instinctive breaking readiness" and try to accelerate the acquisition of such intuitive reaction by explaining it first and then calling "brake!" in various driving situations which do not necessarily call for braking. All training in repetitive activities is actually aimed at delegating them to the quasi-conscious level, "automating" them - by establishing shortened or more easily used connections between synapses, some specialized "roads in the brain".

One could object that including these trained activities into the concept of intuitive decisions is not necessary. However, such an inclusion corresponds well to the everyday understanding of intuition; for example, many persons would tell that they intuitively or instinctively turn off an alarm clock when waking (this is also the reason of producing alarm clocks that are difficult to turn off, for heavy sleepers). The use of the word "instinct" is less substantiated in this case since it has the connotation of an intuition that is acquired genetically, not through learning.

Moreover, such an inclusion broadens the possibilities of empirical studies of intuitive decisions. The definition of such decisions given above makes empirical studies possible: we can ask subjects of experiments not to use conscious parts of their minds, we can make sure that they do not use them by turning their attention to other matters or, as done by Dreyfuses, by saturating the conscious part; we can distinguish the cases when the subjects are well trained in certain operational decisions. The inclusion of intuition acquired by repetitive training is reasonable also because, after all, it must have some common aspects with the truly creative intuition.

These possible common aspects lead us to the following question: how can we better understand and institutionalize creative or strategic intuitive decision making?

6. Phases of Creative or Strategic Intuitive Decision Processes.

Simon (1957) defined essential phases of an analytical decision process as **intelligence, design and choice**; later (see e.g. Lewandowski et al., 1989), another essential phase of **implementation** was added. In order to better understand creative or strategic, intuitive decision processes, we should propose a different distinction of their phases:

1) **Recognition**, which starts with a subconscious feeling of uneasiness (well known, for example, by top-level decision makers: if they are not satisfied by some part of information in a briefing, they would ask "Please, amplify on that point - I am uneasy about it"). This feeling is sometimes followed by a conscious identification of a type of problem.

2) **Deliberation or analysis**: if we feel confident as experts, a deep thought deliberation suffices, as also suggested by Dreyfuses. Otherwise an analytical decision process with intelligence, design but suspending the final elements of choice is useful.

3) **Gestation and enlightenment**: this is an extremely important phase - we must have time for forgetting the problem in order to let our subconsciousness work on it. The expected heureka effect might come but not be consciously noticed; for example, after a night sleep it is simply easier to generate new ideas (which is one of the reasons why group decision sessions are more effective if they last at least two days).

4) **Rationalization**: this phase can be sometimes omitted if we implement the decision ourselves; however, in order to communicate our decision to others we must formulate our reasons. The word "rationalization" is used here in a neutral sense, without necessarily implying self-justification or advertisement, though often including at least the latter. For example, when writing a research paper, we obviously rationalize our deeper thoughts - and sometimes also advertise them.

5) **Implementation** - which might be conscious, after rationalization, or immediate and even subconscious.

Thus, there are five phases of this process, instead of four in an analytical one (and the second phase might include three previously known phases); but the strategic intuitive decision process is more complicated. It becomes even more complicated if it is a group decision process, e.g. a joint problem solving session, or a bargaining and negotiation process sufficiently complicated to require a group of experts searching for a novel, creative solution (as in difficult international negotiations). In such cases, the phase of analysis and deliberation must include learning about not only essential positions, but also all possible side-concerns of other parties; not only the phase of rationalization becomes essential, but also additional two phases of **reaching principal agreement on a solution**

and of **working out the details of the solution** must be added after phase 5). But even in the case of decisions made by a single person, an essential question is - can we support various phases of an intuitive decision process, as in an analytical decision support?

Not quite the phase of recognition - we must first learn more about it; but there might be a special training in perceptiveness. The phase of analysis can be supported by known analytical methods; but it is an open question, how can we support deliberation.

Especially important is the **phase of gestation. Its possible mechanism consists in trying to utilize the enormous processing potential of our mind on the pre-linguistic level: if not bothered by conscious processing, it might turn to a task specified before as the most important but forgotten by the conscious ego.** An interesting fact is that **there exist cultural institutions supporting gestation and enlightenment.** The advice of "emptying your mind" "concentrating on void" or "on beauty", "forgetting the prejudices of an expert" from Japanese **Zen meditation** or **tea ceremony** is precisely a useful device of letting your subconsciousness work[14]. The **diplomatic** custom of **receptions** to relieve the tension of international negotiations, sometimes (though not always) accompanied by tradition not to talk shop during the reception, might serve similar purposes.

As to the phase of rationalization, we have actually enough support - that includes all computerized means of supporting science and management, with graphic presentation tools, text editors etc. The issue of supporting the phase of implementation has been not sufficiently studied even for analytical decision processes and deserves more attention.

Can we draw analogies between the support of strategic intuitive decision processes and the training for operational intuitive decisions? There is at least one analogy: letting your subconsciousness work certainly

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[14] There is another factor of so called "Japanese style of decision making" that often baffles Westerners: Japanese usually delay decisions for no apparent reasons. This might be related to the high value of harmony of a group -"wa" - in their society, which implies consultations with group members before more important decisions; such delay was also sometimes explained as trying to get advantage in negotiations. But we can offer yet another explanation: through a cultural evolution, Japanese found that delaying important decisions at least a day gives them a gestation period and thus improves decision quality.

helps, if you are well trained. Korean archers won at the Olympics in 1992 while using Zen meditation techniques just before competition; is this irrational? No, every competing athlete knows the importance of a factor he/she usually calls concentration before competition; if we understand how our subconsciousness works, it might help in concentration.

Finally, we should note that **an intuitive decision process is actually multi-objective** - particularly if it should be creative, aim at novel solutions. If we support analytically such a process, the information not only should be presented to the decision maker in graphic terms, but also it should be rich, multi-dimensional; we do not know a priori on which piece of information his/her subconsciousness will focus. When supporting such a process, we should avoid an early aggregation of objectives into a utility or value function, avoid even pairwise comparison and other known techniques related to the paradigm of utility maximization, nor should we require consistency from the decision maker - since if he/she knew from the beginning what he/she precisely wants, the solution could not be creative. We should rather concentrate the support on helping to generate new options, even to reformulate the problem, on organizing the dynamics of the the decision process in such a way that it leaves enough time for gestation.

7. How to Study Intuitive Decisions?

If we want to support such decisions, we must obviously study them better. In this paper, we can at most outline possible research issues and formulate some questions.

In the case of operational intuitive decisions there might be many issues related to the most effective methods of training, often partly investigated in psychology. Can we, however, better use the insight that we are in fact training the subconscious or at least quasi-conscious part of the mind? Might it lead to some methods of increasing perceptiveness in learning?

In the case of strategic and creative intuitive decisions we can address several questions depending on the phases specified above. For the phase of recognition - how should we measure perceptiveness of strategic problems? We can, for example, devise experimental multi-objective games (see Wierzbicki, 1992) where not all objectives are apparent to the players

at the beginning and relate then the measurements of perceptiveness to the outcomes of such games. Another question is - what psychological features, training, external conditions are stimulating perceptiveness? Similar questions can be posed for the phase of deliberation.

Concerning the important phase of gestation - how should we measure its effectiveness? What methods of supporting gestation are most effective? The cases of consciously noticed heureka effects are not frequent enough for statistically valid experiments; but we could possibly measure the intensity of generating ideas without a consciously noticed heureka effect after various periods of gestation. Admittedly, organizing such experiments is a difficult task, which itself requires creativity. But some conditions for such experiments are implied by above analysis: they must be real life-like, involve basic concepts rich in meaning - even if they might be simple in their mechanics or organization. They might be in some sense similar to "thought experiments" but should take into account also the effects of synergy and focusing - therefore, they must be rich in additional information, best presented in a graphic form. Some of known experiments in psychology have these features and could probably be modified to study the period of gestation.

8. Possible Implications for Philosophy of Science.

As we indicated before, the main theme of this paper - the role of intuition and creativity - is rather neutral for the philosophy of science. Not quite neutral, however, are two specific aspects of the above discussions: the distinction between linguistic and pre-linguistic processing in our mind together with the evolutionary priority of pre-linguistic forms, as illustrated by our "thought experiment", and the role of richness of meaning of basic concepts in perceiving the world. We shall indicate only some of possible implications of these aspects for the philosophy of science.

We communicate mostly in words, but perceive the world mostly by images. Most crucial words - basic concepts - contain presuppositions of which we are often not aware (we could quote many examples - a simple one is illustrated by the question how we can be certain that the real, physical time has continuous nature) and we probably never clarify all of them. That does not mean that we should not try our best. Certainly, the

philosophy of science would clarify many of its disputes if it tried to study the impact of more diverse aspects of basic concepts on philosophical questions (thus, Husserl was intuitively right after all, even if he did not perceive the value of the richness of meaning).

Take the concept of cause and effect. Shapere (in Hacking, 1981), when critically analyzing the views of Feyerabend and Kuhn, says ".. do logical terms, like 'and' and 'if-then', change their meanings under alteration of theory? Presumably, one would want to answer such questions in the negative ..". But the answer implied by the developments of this concept in the second half of XX-th century should rather be "unfortunately, yes: 'and' has several meanings in multi-valued logic, and 'if-then' changes even more substantively when we include feedback causal relations". Shapere actually anticipated these developments when he argued for a more "middle ground" interpretation of meaning than that of Feyerabend and Kuhn; indeed, incommensurability of theories is a concept biased by binary logic, while the concept of the degree of similarity of theories preferred by Shapere could be best expressed by multi-valued logic. But, not having expressed his arguments in these terms, Shapere was not consequent enough, and applied binary logic arguments against such concepts as "paradigm" - which Kuhn formulated in a fuzzy but rich in meaning way, hence rather multi-valued logic arguments are applicable here. On the other hand, had Kuhn thought about cause and effect more in terms of feedback processes[15], he would not present his theory as a sequence of incommensurable paradigms, changed only by scientific revolutions - he would incorporate then in his theory also more evolutionary and accumulative aspects as well as elements

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[15] This is not an argument against Kuhn, but rather against the tradition of philosophy of science that sees the world mainly through the matrix of basic concepts as implied by physics; and physicists seldom perceive full implications of the concept of feedback, tend to restrict arguments to binary logic and perceive uncertainty only in terms of probability; they often use the word "chaos" in probabilistic sense only and seldom perceive the potential revolutionary implications of the deterministic theory of chaos. The same applies to the writings of many philosophers, including Popper - whom I greatly admire even if I cannot always agree with him. For example, he is rightly fascinated by "the strange dualistic picture of a physical world of comparatively stable structures ... on all micro and macro levels; ... in apparently chaotically or randomly distributed motion; a random motion that provides part of the mechanism by which these structures ... are sustained" (Popper, 1975). I often wondered how much deeper would be this description if he were fully aware of the modern theory of chaos that was quite developed although largely unknown to scientific world at that time.

of competing scientific programmes.

We could also turn to the dual role of language in describing not only the world outside us but also our emotions and evaluations of the world. The concepts discussed above might have also some bearing on the old question how can we analyze the latter function of language.

Emotions and evaluations concern two spheres: individual or private versus public or social; let us take the latter first. The words describing human relations might be even more rich in meaning and even more approximate in a fuzzy sense than the words describing the material world. Yet people were forced in their cultural evolution to discuss their relations and clarify the sense of corresponding words, to develop social sciences. It would be irrational - inconsistent with Popper's own standards of rationality - to take seriously his opinion that it is logically impossible to predict social events[16]. But what are the pre-linguistic images concerning human relations? They include mostly not optical images but ideas and emotions; their approximations in words might be thus even more loaded with hidden assumptions (consider e.g. the words **fairness, equity**) than concepts concerning the material world. This is the reason that social sciences require even more care and "thought experiments" than material sciences. Therefore, the philosophy of science should also pay more attention to social sciences.

Finally, the individual sphere might relate more strongly to the concept of intuition. It is known that an individual - to be psychically healthy - must find a proper balance of his/her emotions and values, a personal ethics consistent with his/her perception of external world, both material and cultural. Part of this balance is supplied by the cultural heritage - religion, education, family and social relations. As the concepts and experiences available to an individual grow richer, this inherited balance might be perturbed. A new balance is then attained; poetic and artistic functions of language can help in attaining such a new balance by invoking emotions. Most probably, however - as intuitively perceived and rationalized in various ways by Kant, Kierkegaard, Schopenhauer, Wittgenstein ("an die Grenzen der Sprache anzurennen",

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[16] Popper excludes feedback in his paradoxes of prediction; they would cease to be paradoxical if a feedback understanding of cause and effect were included, as it is done in economics in the theory of "rational" expectations.

"worueber man nicht sprechen kann, ..." - see e.g. Janik et al., 1973) - such personal ethics might be also attained through a creative, intuitive process on the pre-linguistic level, similar to that described in this paper, which ends in a **personal enlightenment.**

9. Conclusions.

We shall try to keep the conclusions simple:

- Intuitive or partly intuitive decision making can be rationally defined and is a normal part of our everyday activities;

- We should learn more how our subconsciousness works and how to stimulate it; we can devise experiments for this purpose;

- Intuitive strategic and creative decision processes differ much from analytical ones, but we can define and analyze their stages;

- There exist traditional cultural institutions that support the phase of gestation in intuitive decision making;

- Intuitive decision making is essentially multi-objective; all analytical methodology of decision support is useful, but not much in supporting actual choice - more in providing instruments to support learning and organizing a decision process;

- If we want to use some of these insights to improve decision processes, we must at least account for the phase of gestation and enlightenment;

- While the issue of rationality of intuition is actually neutral for the philosophy of science, some concepts related to this issue might have implications in this field.

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