Intuition and Rationality in MCDM

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In the Newsletter issue of spring 2006, Paul Slovic published a paper on affect, reason, risk and rationality. While agreeing with most of his arguments and conclusions, I differ concerning some fundamental assessments or tacit assumptions of this paper: that the *experiential side* of our mental life "appears every bit as important as the analytic/deliberative side" - we shall see below that it is, in some aspects, *at least ten thousand times more important;* and that the binary classification *affect* versus *reasoning* is complete – we shall see below that the trinary classification *emotion (affect)* versus *intuition* versus *rational reasoning* is much more adequate. The fundamental importance of intuition is usually overlooked today, for some historical reasons we shall explain below; but *intuition is the source of our meta-theoretical assumptions about truth and of our most innovative ideas* and, as such, cannot be neglected. The paper presents recent theories and results concerning intuition and knowledge creation, together with conclusions implied by them for multiple criteria decision making (MCDM).

Short Review of the History of Reflection on Intuition

The debates of meaning and importance of the concept of intuition have a very long history, in a sense from the beginnings of Occidental philosophy – from Plato to Descartes, Kant, Husserl, Heidegger; Oriental philosophy has possibly even longer tradition in this respect, see, e.g., Wang (2003), but Occidental thinking started earlier critical reflection and debates about the nature of intuition. Since Plato (380 BC) reported the dialog between Sokrates and Menon, there is a tendency, at least in the Occidental tradition, to understand intuition as a source of inner certainty about the essence of basic concepts. This source was usually interpreted as infallible – after an appropriate critique, such as Kantian critique of pure reason or Husserlian phenomenological reduction. For Kant (1781), intuition was the source of *a priori synthetic judgments,* our fundamental convictions about nature – e.g., about space and time – that were for him obviously true. Thus, from Plato through Descartes to Kant, philosophy believed in *infallible intuition.*

However, the discovery of non-Euclidean spaces in 19th Century, later generally the relativism of knowledge, recognized in the 20th Century, has led to considerable skepticism about such interpretations and thus generally about the value of intuition, see, e.g., (Bunge 1962). The role of intuition remained extremely important in mathematics, and even in the 20th Century was stressed by such thinkers as Poincare, Brouwer or Gödel. Nevertheless, philosophical reflection on intuition in 20th Century – as represented by Bergson (1903) or later by Polanyi (1966) with his concept of tacit knowledge, practically equivalent to experiential knowledge thus including both emotions and intuition - attached great importance to intuitive reasoning but treated it as a mystic force and refused to analyze it in rational terms. Another part of philosophy refused to even speak about intuition, as stressed by Wittgenstein (1922), who said in his famous quotation "wovon man nicht sprechen kann, darüber muss man schweigen" (loosely translated, "if we cannot speak about it, we must remain silent") – meaning that we should not analyze metaphysical concepts, including such concepts as intuition. This conviction became popular among natural sciences in the 20th Century, where the term intuitive became almost equivalent to non-scientific. This is also probably the reason why Slovic (2006) uses the term *intuitive* in a similar sense, almost *close to erroneous*.

At the end of 20th and in the beginnings of 21st Century, however, new interpretations of the power and the role of (even if *fallible*) *intuition* emerged. This concerns two issues:

1) The power and the role of intuition in generating new ideas was explained in an evolutionary, naturalistic and rational theory, see Wierzbicki (1993; 1997; 2004); Wierzbicki and Nakamori (2006);
2) The role of intuition as the source of our meta-theoretical assumptions about truth of mathematical axioms was clarified, see Król (2005, 2007). Therefore:

We must stress that we understand *intuition* or *intuitive* here in a realistic and naturalistic but broader meaning of the concept: *as a source of cognitive and creative insights that often might be fallible, but is nevertheless very powerful.* We are interested in a rational explanation of the strength of this human faculty and of its functioning.

An Evolutionary, Naturalistic and Rational Theory of Intuition

This theory is based on a result that combines modern knowledge from two disciplines of contemporary informational sciences: of telecommunications and of computational complexity theory. Telecommunications has classified in detail the necessary requirements for transmitting various signals. Most elementary is the comparison of a verbal (or audio) signal that requires a bandwidth of ca. 20 kHz with a visual (video) signal that requires a bandwidth of ca. 2 MHz, approximately 100 times more. This ratio is actually a lower bound estimate for human senses, since a typical television is not as precise as human vision, while human hearing seldom exceeds 20 kHz.

Computational complexity theory deals with the assessment of the growth of the number of necessary operations necessary to algorithmically solve certain computational problems on contemporary computers depending on the amount of data used in the problem. This theory is quite advanced and complex itself, but we need here only its basic results that can be summarized as follows. In practically all computational problems, the necessary number of operations has a nonlinear dependence on the number of data used. Only the simplest computational problems – such as sorting data – have simple nonlinearity of this dependence, of a polynomial type. Most computational problems are characterized by a strong nonlinearity of this dependence, of an exponential or combinatorial type.

Consider now a computational problem related to visual or verbal information. Let it be a similar problem for both types of information – say, the problem of word or image recognition (in digital computers, there might be other problems in processing such information types, such as sorting, searching, classifying, but the specific problem type is not essential for our discussion). Let us assume even one of the simplest and mildest forms of nonlinear dependence of computational complexity on problem dimension – say, quadratic dependence. Then the computational problem related to visual information requires at least 10000 (10^4) times more operations than the problem of the same type related to verbal information – and this is a lower bound estimate.

Human brain and mind works differently and is essentially more complex than contemporary digital computers – for example, mind is a device distributed not only in the brain, but also in the entire body. Human mind also does not process information in the *digital* sense, but uses a broader, *analog-digital* type of processing. However, we can safely assume that the essential comparison of the difficulty of processing visual and verbal information does not change much for distributed and even analog processing. The old proverb: *a picture is worth one thousand words* must be thus corrected: *a picture is worth at least ten thousand words.*

When we reflect, this comparison seems obvious. Suppose we want to describe verbally, in detail, what we are seeing at a glance, looking, e.g., even at a sparsely furnished room. Then we realize immediately that to describe *all* that we are seeing in just a fraction of a second would need many minutes or even hours of speech. While describing our visual perceptions, we are forced to make selections and generalizations. Moreover, noticing important details in a visual perception is difficult, requires special *training to see* – possibly because the necessity of making selection of the details in order to use our verbal abilities is dominating the perception of what we actually see.

Visual and verbal information do not exhaust all types of information processed by human minds. We have other senses that also give us rich information: smell, taste, touch. But it can be argued that vision is the sense most rich in information; even if the signals from other senses might be more difficult to record electronically. They only strengthen the estimation: processing words is at least ten thousand times simpler than the processing information from all our senses.

- Thus, we can safely adopt the first assumption of the theory of intuition: *our senses give us much more complex information than we can express by words.*
- The second assumption of this theory is simply that we follow the evolutionary theory of biological species and accept that *humans developed speech at some level of their evolution.*

Then we can consider the question: *how did people process signals from their environment just before the evolutionary development of speech?* They had to process signals from all their senses holistically, though dominant in received information was the sense of sight. Yet they were able to overcome this difficulty, developed evolutionarily a brain containing 10^{11}-10^{12} (some say up to 10^{14}) neurons. We still do not know how we use the full potential of our brain – but it was needed evolutionarily, hence it was probably fully used before the development of speech (primate apes have just about the same number of neurons in their brains). Naturally, the reasoning is somewhat simplified: the development of speech was not instant discovery, only a process, probably rather long. Many animals have ways of communication; what distinguishes humans is that *we developed speech much further and used it to start the evolution of civilization.* Therefore, even if the process took a long time, after the development of speech we were in a radically different situation.

The second question is thus: *what were the importance and the basic consequences of the development of speech?* When reflecting, we realize that the development of speech was an excellent evolutionary shortcut. It turned out that we could process signals 10^4 times more simply. This enabled the intergenerational transfer of information and knowledge, and we started to build up the cultural and intellectual heritage of mankind. The biological evolution of people slowed down and eventually almost stopped – including the evolution of our brains – but we accelerated our intellectual and civilization evolution. Many biologists wonder *why* our biological evolution has almost stopped. We think that the analysis described here gives a convincing theory as to why that happened. Due to the concentration on words, our brain had 10^4 times more capability than previously needed and a further increase in the number of neurons was not necessary.

Now we can ask the third question: *what happened to our original capabilities of holistic processing of signals* – let us call them *preverbal,* since we had them before the development of speech? An alternative description would be *animistic,* but we had a brain greater then most animals even before discovering speech. We still share at least one preverbal ability with some animals – *imagining;* anybody observing cats wonders at how strong their imagination is when they play. The use of speech has stopped the development of these abilities, pushed them to the subconscious or unconscious (in the sense of common use of these words, not their technical sense). Our conscious ego – or superego, at least its analytical and logical part, identified itself with speech, verbal articulation. Because the processing of words is 10^4 times simpler, our verbal, logical, analytical, conscious reasoning utilizes only a small part of the tremendous capacity of our brain that was developed before the use of speech. The capabilities of preverbal processing of memory and of information from our senses remained with us – *but lacking better words, we call them intuition,* and we do not always know how to rationally use them.

We can thus define intuition as the ability of preverbal, holistic, subconscious (unconscious, quasi-conscious) imagining and processing of sensory signals and memory content, left historically from the preverbal stage of human evolution.

The concept of quasi-conscious can be defined as an action we are aware of doing, but do not concentrate conscious on; every day we perform many quasi-conscious actions, such as walking, driving a car, etc. The above is naturalistic and *an evolutionarily rational definition of intuition,* because it is deeply related to the evolution of human civilization, it follows from a rational set of assumptions and we can draw from it diverse conclusions that can be variously tested – in comparison with other parts of knowledge or even empirically.

However, we must enhance this definition with a differentiation of the sense of the concept of *intuition* from other concepts of experiential ("irrational" or a-rational) abilities of our mind, in particular *instincts* and *emotions.* Intuition is related to imagining and to the holistic processing of information, visual and in other forms, that is, either currently available or, more importantly, residing in the deep memory of our brain, mostly as a result of life-long learning. Thus intuitive behaviour is predominantly a result of learning, not of inheritance, while instincts and emotions are mostly inherited. We do admit, on the other hand, that there might be a rough border between intuition and instincts, since reality is better described by multivalued, fuzzy or rough logic, than by binary logic. Thus there might be some inherited aspects in intuition, beside the obvious fact that all a-rational abilities of our mind – emotions, instincts, intuition etc. – are the results of biological evolution, hence are in a sense inherited. And obviously, intuition can be also influenced by emotions.

These fundamentals of a evolutionarily rational theory of intuition can be subjected to diverse validation or falsification tests. It follows from the above definition that *intuitive abilities should be associated with a considerable part of the brain.* Then these abilities should be noted in the research on the structure of brain, on neurophysiology, etc. And in fact they were noted – for example, by the voluminous results on the hemispherical asymmetry of the brain. These results suggest that a typical left hemisphere (for right-handed people; for left-handed we can observe the reverse role of brain hemispheres) is responsible for *verbal, sequential, temporal, analytical, logical, rational* thinking, while a typical right hemisphere is responsible for *non-verbal, visual, spatial, simultaneous, analog, intuitive (!).* We also do not maintain that intuition is equivalent to rational thinking, we only propose a rational explanation and theory of intuition.

Another conclusion – among diverse others – from the evolutionarily rational definition of intuition is: *memory related to intuitive thinking should have different properties than memory related to rational thinking.* And so it has – modern research on the functioning of memory, see e.g. (Walker et al., 2003), shows that deep memorization occurs during sleep, when our consciousness is switched off. Thus, the knowledge of diverse functions of left and right brain hemisphere and the knowledge about mechanisms of memorization do not falsify, but much rather support the conclusions drawn from the evolutionary rational definition of intuition.

Yet another conclusion: *if intuition is mostly learned, then training should increase our intuitive abilities.* Were there any experiments performed to answer this question? Yes, there were; they are described in an excellent book *Mind over Machine* (H. Dreyfus and S. Dreyfus 1986). The Dreyfuses describe in their book a crucial experiment related to the question: *how does the level of expertise influence the way decisions are made?* They saturated the analytical part of the brain of chess players (by giving them more and more complicated arithmetical problems, controlled by a computer) and then compared how such saturation influences their chess play. For expert players, masters or international masters, such saturation did not influence their play at all. For novices, beginners, and weak players, such saturation destroyed their ability to play chess. Moreover, such dependence has a universal character: a beginning driver must analytically understand what he does, a master driver reacts intuitively. Thus, the Dreyfuses conclude that the kind of decision making depends critically on the level of experience: it is analytical for beginners and deliberative or intuitive for masters. Observe that *deliberation is thus related* not to rational analysis, but *to intuition*.

However, intuition is not only accumulated experience; if it were, how could a young person have good intuition? Young people compensate for their lack of experience by *imagination, another side of the preverbal, intuitive capabilities of our brain.* Note that the word *imagination* stresses the visual aspect of this ability, but it is actually broader: you can imagine a tune, a taste, a smell, imagine being an object of study in order to better understand it. Imagination is the basis of creativity – obviously in arts, but also in mathematics, even more in engineering – which might be difficult to understand for people who have never constructed something themselves.[1] Constructing a house, a technical system, or even a plan of action, is in its essence not a logical but rather a creative activity – though we certainly apply logic in further steps of the process, when we try to test the consistency of the plan of action or to communicate it to others.

On the other hand, accumulated experience is no doubt a very important part of intuition. In this sense, intuition includes and also explains the concept of *background* or *habitus,* introduced by some philosophers – see, e.g., (Searle 1992) – trying to explain the human ability to understand the dependence of the meaning of a sentence on a multidimensional context. *Background* or *habitus* are the results of accumulated experience, put into deep memory and used unconsciously or quasi-consciously as *linguistic intuition.* In a similar way, we can understand the role of *hermeneutical horizon* used in (Król 2005) – see also below - to describe the results of accumulated reflection on the tradition and knowledge in a given discipline or subject of study.

Another example related to linguistic intuition might be the puzzling problem of *children's ability to rapidly learn languages and correct grammar.* In his seminal work, (Chomsky 1957) used this example as a substantiation of the need to develop a theory of universal grammar, interpreting children's ability as an inheritance of a *natural universal grammar*. However, Chomsky's explanation might be unnecessarily complicated. The rational evolutionary definition of intuition provides also a rational explanation of this ability. Children have brains of 10^{11}-10^{12} neurons, almost empty, and they need 10^4 times less, only 10^7-10^8 neurons, for speech. Children observe mothers when speaking, visually note their facial expressions of approval or disapproval, and quickly learn what language usage is correct. Naturally, they might also have an inherited propensity for linguistic intuition, on the border of instincts and intuitive ability. After all, even if intuition is preverbal, it is used when we speak; this *linguistic intuition* is mostly learned. Reflect that we use language for the most part intuitively, quasi-consciously. Words come from themselves to our minds; only later do we consider rationally whether our usage of the words is correct. Fully distinguishing which the part of this linguistic intuition is inherited and which is learned would require a careful research, but we see that the evolutionarily rational theory of intuition offers new explanations and opens new possibilities for research.

Rationality and Its Limitations

It should be stressed that I do not understand *rationality* here in the narrow, technical and paradigmatic sense of economics and classical decision theory – that of slelecting most preferred decisions, maximizing own utility or value function. This sense is not only too narrow, but also un-falsifiable: for every decision, it is easy to find a value function that is maximized at this decision. Rationality is understood here much broader, as the ability of logically explaining given

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[1] Which is one of the reasons why social and human scientists, sometimes even hard scientists, usually fail to understand technologists and their episteme – see later comments.

fact or decision, in relation to other knowledge; thus, rationality is based on language (or its more specialized forms, such as mathematics or computer languages).

There is no doubt that language has been decisive in the development of human civilization. Without language we would not have intergenerational transfer of ideas, and without this transfer we would not have tradition, neither cultural (in history and literature), nor technical (in crafts and technology). Without the accumulation of human knowledge we would not have today's civilization, and this accumulation of human knowledge has depended almost entirely on language and tradition.

In his basic book *Wahrheit und Methode,* Hans-Georg Gadamer (1960) very rightly accuses modern hard science of abandoning and undermining tradition and defends the hermeneutic role of tradition. Indeed, truth for soft, humanist sciences is personal and its intersubjective aspect depends not only on interpersonal discussion, but also on a holistic understanding of the entire tradition of a given field (this holistic understanding creates a type of disciplinary intuition, but we shall discuss this later). In hermeneutics, language carries not only information, but also emotions and irrationality, myths and the debates about the nature of being, etc. Depending on the context and on the disciplinary or cultural tradition, every word can have a thousand meanings, can evoke feelings, can represent myths.

However, language created logic. Logic was actually discovered as a tool of discourse, of politically convincing the interlocutor: *this must be true or not, there is no third way.* Adherence to binary logic is actually a limitation of language, a simplification of reality, but this simplification has been very productive in the development of the hard sciences and of modern philosophy. The development of industrial civilization and fast accumulation of wealth resulted, on one hand, in an increased standard of living – unfortunately, not uniformly for all countries and all people of the world, but nevertheless showing the possibility of a decent life for all. On the other hand, this development enabled the beginnings of a revolutionary change that we call the informational society and knowledge civilization. But these developments would not be possible without logic. Attempts of modern mathematicians to formalize logic, to reduce all mathematics to binary logic, may have been not entirely successful, but they helped to develop computers without which we would not have the knowledge civilization. Similarly, earlier developments of industrial civilization would not be possible without the abandoning of tradition, at least in the hard sciences and technology. Thus, abandoning certain traditions and relying only on scientific logic and the results of experiments were important ingredients of the evolution of human civilization. But even in the hard sciences, and especially in technology, we need intuition for creativity, and intuition is deeply related to learning and experience, hence to tradition which cannot be abandoned entirely.

In modern information technology, there are actually two streams of such tradition. One is the tradition of making computers more intelligent, of striving to build them so well that they could replace human intelligence, produce *artificial intelligence* – in other words, to *automate* most difficult human work. This tradition is typical for classical computer science. As a research goal it is a legitimate objective, but in applications it often encounters human resistance, for diverse social and psychological reasons. Hence, another stream of tradition is the construction of *intelligent decision support systems* that would not replace humans but help them in difficult work by assuming *the sovereign role of the human user*. This tradition is typical for applied informational sciences: computational science (using computers for solving scientific models), computerized decision support, etc.

However, the tradition of artificial intelligence was often dominant and created *cognitivism,* the conviction that all cognitive processes, including perception, memory and learning, are based on a language-like medium, on a *language of thought* - see e.g. (Fodor 1994), (Gardner 1985) - and thus functioning of mind can be modeled as the functioning of a giant computer. This was essentially criticized by some philosophers, such as in (Dreyfus 1972) or (Searle 1992). Searle uses many arguments to criticize the opinion that the human mind can be interpreted as giant digital computer. The definition of intuition described above gives a much shorter argument: *cognitivism is a simplification to the same degree as language is a simplification of the original capabilities of our mind.*

Language is so important for human civilization that the entire philosophy of the 20th Century rightly concentrated on language, starting with logical empiricism and ending with constructivism and postmodernism. However, with this concentration we overlooked the limitations of language. The fact that language might be only a very imperfect tool for describing reality was not seriously considered. For example, Thomas Kuhn in his recent work (Kuhn 2000) notes only with one sentence the possibility that language is not sufficient to describe reality, but does not pursue this idea any further. This fact alone would be sufficient to substantiate a fundamental revision of the philosophy of science.

> If any *language is only an imperfect code to describe a much more complex world,* simplifying the processing of information at least 10^4 times, than each word – out of necessity – must have many meanings, and to clarify our meaning we have to devise new words.

By multiplying words, we gradually describe the world more precisely, but we discover new aspects of an infinitely complex world – e.g. the *microcosmic* or *macrocosmic* aspects – more rapidly than we succeed in creating new words. Arguments of our *mesocosmic* perception of the world – see e.g. (Wuketits 1984) - were used to substantiate the opinion that we are imperfect as knowing subjects, see also (Czarnocka 2003). An opposite opinion is rational: seeing how inadequate our tools are – not only language but also all other tools of cognition, how imperfect our measurement instruments, our computers[2] etc. – we should marvel at our cognitive power.

However, if our knowledge must be expressed in language, if only for interpersonal verification, and language is only an imperfect code, *then an absolutely exact, objective truth and knowledge are not possible* – not because the human knowing subject is imperfect, but because she or he uses imperfect tools for creating knowledge, starting with language.

Naturally we can – and should – make statements that are true; but absolutely true statements are possible concerning only verbal relations or very simple facts. Truth is relative even for simple facts, depending on the adequacy of language; for more complex facts and statements, dependent on a complex set of concepts, relations, theories, the relativity of truth is evident. What might be seen as an obvious truth by a representative of one scientific discipline might be questioned by a representative of another one. [3]

On the other hand, we must strive to be truthful, otherwise human cooperation is endangered – and the development of human civilization has been based on language used as means of human cooperation. And we must strive to be objective, for all our technology is based on applications of reasonably objective knowledge. Thus, objectivity is a goal, an ideal or a concept of a higher level; but this concept is needed in hard science and especially in technology creation. The attempts of postmodern social sciences to reduce objectivity to power and money – see, e.g., Bruno Latour (1987) – are based on incorrect use of more advanced forms of logic. We know today what is feedback - a dependence of evolving time-streams of effects and causes in the dynamic sense – thus the argument of (Latour 1987, p. 99) against objectivity, "since the settlement of a controversy is the cause of Nature's representation not the consequence, we can never use the outcome – Nature – to explain how and why a controversy has been settled"

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[2] Computers are in fact very inadequate instruments of cognition: because of the nonlinear increase of processing complexity, we can easily saturate even most powerful computers by slightly increasing the complexity of models analyzed by them.

[3] Thomas Kuhn (1962) called this fact *incommensurability of paradigms;* but people are faced with the incommensurability of personal languages all the time and cope with this difficulty by using intuition.

indicates a clear lack of understanding of the dynamic character of the causal loop in this case and of the circular, positive feedback-supported evolutionary development of knowledge and science.

On this example, we can analyze the relation of intuitive – or even possibly instinctive – judgments and rationality. It is difficult to experimentally verify knowledge in social sciences, hence they instinctively (or rather intuitively, in their hermeneutical horizon, see next section) prefer subjectivity or intersubjectivity to objectivity. Later they try to *rationalize* related conclusions – such as the reduction of objectivity to power and money. But the role and *power of rationality* is precisely to check such judgments for all logical consequences and for consistency (or, in this case, for the lack of consistency) with other parts of human knowledge – with the rational heritage of humanity.

Thus, intuition is very powerful, is the source of most original ideas – but is fallible, hence we must check such ideas using the power of rationality.

The Role of Intuition as the Source of Meta-Theoretical Assumptions about Truth

The rational checking of intuitive assumptions is not always easy. Let us recall here some elements of the theory of truth in formal languages. According to Kurt Gödel, the question of truth cannot be answered inside a given formal system; Alfred Tarski (1933) formalized this issue further, postulating the use of a formal meta-language in order to meaningfully address the issue of truth in a given language. However, Zbigniew Król (2005, 2007) stresses that it is impossible to create and study mathematics as a purely formal, meaningless game: there is no mathematical theory which is absolutely (i.e., actually) formalised, there is no mathematical theory given as a formal system with a formal meta-language. To have a strictly formal language one needs a formal meta-language, to have a formal meta-language one needs a formal meta-meta-language, and so on – an infinite recursion. Thus, the only possible way is to stop and study fundamental assumptions in a non-formal, *intuitive* meta-environment. This intuitive environment is called *hermeneutical horizon;* Król shows that hermeneutical horizon has been changing historically, that "Euclidean geometry" has been understood differently (in the deepest interpretations of its axioms) by ancient Greeks, differently in times of Descartres, Newton, Kant, differently today. If this can be observed in mathematics, it applies as well in other parts of science: different paradigms use not only different, incommensurable languages, but – more fundamentally - are also related to different hermeneutical horizons, intuitive environments for interpreting axiomatic truths. This phenomenon is called *horizontal change.*

According to Król (2007), the emergence of a new concept takes place in the established hermeneutical horizon if the concept is non-revolutionary. The emergence of a revolutionary new concept is preceded by a basic change in the hermeneutical horizon. Changes of the hermeneutical horizon in so-called "pure" mathematics are shown to have been important for the emergence of new concepts in science. There are also many such examples in other parts of science, but they still remain unexplored. For example, one of the first changes in the hermeneutical horizon that was vital for the emergence of new scientific concepts was the transition from the conviction that the earth is a flat surface to the theory that the earth is a sphere. The belief in a flat Earth was a typical conviction from the hermeneutical horizon, implicit but actively ordering human perception. Another example is the gradual expansion of the size of perceived universe; the invention of the telescope was one of the factors stimulating this development, and also was important for the emergence of a new model for Euclidean geometry. Incidentally, that infinite Newtonian model for geometry is no longer valid in modern science and is not a determinant of today's hermeneutical horizon. The rise of quantum mechanics and the theory of relativity were connected with other changes; absolute space lost its position in the hermeneutical horizon. There are many theories and explanations of intuition; however, for the creation of mathematics and science most important is intuition that matches the frame of the hermeneutical horizon.

Changes in science are not only caused by social, economic, political, and psychological factors. If they were, and if "anything goes," we could, for example, change our intuitive notion of a polyhedron and propose any number of unacceptable properties; the most important frame for the change of concepts in science is the objective common ground of the hermeneutical horizon. The change in the hermeneutical horizon essentially causes the emergence of new concepts, and social and political determinants are not on same level as ontological and objective ones. It is clear that scientific and mathematical theories are created in the hermeneutical horizon as the part of the process of the intuitive analysis of concepts. If we concentrated only on the formal apparatus and reduced all science and mathematics to this apparatus, then basic concepts would appear incommensurable, non-comparable, etc. The reconstruction of the hermeneutical horizon shows that the meaning of basic concepts does not remain unchanged historically. Hidden (active and passive) aspects of the hermeneutical horizon determine their meaning. Every meaning has two parts: one consists of explicitly described elements, the other provides an implicit way of understanding these elements; but even this implicit part is determined by some rational conditions, capable of rational explanation. The hermeneutical horizon is not a psychological or subjective structure, it is ontological and objective, though given in hermeneutical phenomena, fundamental for the mode of existence of a human being.

The above, Platonian theory of intuition as the source of meta-theoretical assumptions about truth is different, but not contradictory to the naturalistic, evolutionarily rational theory of intuition described earlier. Intuitive hermeneutical horizon is formed historically, thus it is a part of tradition of a given discipline, preserved and perpetuated by teaching, a part of the civilization heritage of humanity.

The Civilization Heritage of Humanity and Implications for Micro-Theories of Knowledge Creation

If language is so important but has its limitations, the question is whether the civilization heritage of humanity, the *giant upon whose shoulders we stand,* is composed only of linguistic records? Obviously not, at least in the arts; paintings and music also belong to this heritage. But is intuition, or are instincts, also a part of this heritage?

In a broad, social sense we use the word *knowledge* to describe the *accumulated experience and heritage of humanity,* including science, arts, religion, myths and magic, etc. Karl Popper – see (Popper 1972) defined his concept of *the third world* – the world of ideas, knowledge, arts existing independently of individual perception and of actual reality – as actually equivalent to social knowledge in the broad sense. However, this definition is too broad; we should differentiate in this concept its significant parts, such as emotive and mythical heritage, or the ideas called *a priori synthetic judgments* by Immanuel Kant, or *hermeneutical horizon* by Zbigniew Król.

The old distinction between subjective and objective, rational and irrational is too coarse to describe the development of knowledge in the time of informational civilization; it is better to use three-valued logic such as utilized by (Pawlak 1991) in rough set theory. Thus, *there is a third, middle way: between emotions and rationality we have an important layer of intuition.*

In this sense, we can distinguish three basic constituent parts of our civilization heritage:

1) The *rational heritage*,

2) The *intuitive heritage*,

3) The *emotive heritage.*

We shall not discuss here the best known rational heritage in detail; it consists of all experience and results of rational thinking – of science in its broad sense (including the *hard sciences* – science and technology, the *soft sciences* – humanities and history, sociology, but also other *human sciences* –economy, law, medicine etc.). This heritage is recorded mostly in the form of books, but the informational revolution brought about here a change towards *multimedia form* of record.

The emotive heritage consists of the arts – music, paintings, but also literature, all fiction, movies – the last have only about a hundred year history, but recently became the main factor in trans-generational learning of emotive heritage. However, we can argue that this emotive heritage also promotes the unconscious perception of *myths of humanity.* This is the concept of (Jung 1953) who called it the *collective unconscious,* also including in it basic human instincts. Alina Motycka (1998) used this concept in her theory of the creative behavior of scientists in time of scientific crisis or the Kuhnian revolution: in order to have help in creating essentially novel concepts, scientists revert to the collective unconscious (Motycka called this *the process of regress*). There is no doubt that emotions play an essential role in creative behavior and it is known that artistic training influences creativity.

So does intuition; and we do have an intuitive heritage of humanity. This includes what Immanuel Kant (1781) defined as *a priori synthetic judgments,* our concepts of space and time that appear obviously true to us. He followed Platonian tradition, since the existence of concepts and judgments that appear obviously true had been already shown by Plato. We know now that these concepts that seemed obviously true to Kant are not obvious and not necessarily true: space might be non-Euclidean, time might be relative or have several parallel scales, etc. Thus, these concepts are not *a priori* truths, although they seem to be true. As analyzed by Zbigniew Król (2007), they are part of a *hermeneutical horizon,* are changing historically and are transmitted by teaching. We learn spatial relations when playing with blocks or Lego as children and such relations are the basis of our mathematical intuition; this intuition is strengthened by learning mathematics at school. Thus, the paradigm of teaching mathematics at school reinforces the hermeneutical horizon and constitutes a part of the intuitive heritage of humanity.

Finally, as shown by (Nonaka and Takeuchi 1995), in questions of knowledge creation we have not only the individual-humanity dichotomy, but also, between these extremes, an important middle level: a group, an organization, a firm. Thus, below the heritage of humanity there might be the specific heritage of a group: rational knowledge of the group versus intuitive knowledge of the group versus group emotions, instincts and myths. The intuitive and emotive heritage of the group constitutes the *group tacit knowledge* postulated and used by Nonaka and Takeuchi. But the importance of their work, in particular of the concept of *SECI* (Socialization-Externalization-Combination-Internalization) *Spiral* of organizational knowledge creation, corresponds to their stress that knowledge creation processes rely on the interplay of tacit (thus intuitive and emotive) knowledge and explicit, rational knowledge as well as on the interplay of individual and group knowledge.

There are diverse epistemological consequences of the theories indicated above, e.g., consider the consequences of the individual-group dichotomy and of the role of language and fallible intuition in civilization evolution. If language was used as a tool of civilization evolution, individual thinkers were prompted to present their theories obtained by fallible intuition to the group, even to beautify and defend their theories – which confirms the Kuhnian concept of a paradigm (Kuhn 1962). Such creative individuals might have been rewarded evolutionarily in the biological sense, since eloquence might be considered as a positive aspect of mating selection. However, the evolutionary interest – in the civilization sense - of the group that used the knowledge to enhance success and survival capabilities was opposite: personal theories and subjective truth that were too flowery must have been considered suspicious, so Popperian falsification (Popper 1934, 1972) was necessary. Thus:

The Popperian falsification and the Kuhnian paradigm (or their extensions) are two sides of the same coin in an evolution of civilization.

It should be noted that postmodern social sciences, while utilizing (and simplifying) the concept of Kuhnian paradigm, ridicule Popperian falsification saying that scientists aim rather to defend, not to falsify their theories. But social sciences typically do not understand technology creation (see Wierzbicki 2005), thus they do not note that fasification in technology belongs to everyday practice, where technological artefacts (e.g., cars) must be submitted to destructive tests in order to check their safety and reliability.

However, both Kuhnian and Popperian approaches belong to the traditional concern of philosophy with long term, historical change in science; we can call them *macro-theories* of knowledge creation. At the end of 20^{th} Century, new needs of understanding knowledge creation emerged. Informational revolution, *information society* and the beginning transition towards *knowledge economy* – that can be jointly called beginnings of *knowledge civilization* – created the demand for *micro-theories of knowledge creation,* advising (descriptively) how we do create or (prescriptively) how to create knowledge for the needs of today and tomorrow. The popularity of Nonaka and Takeuchi results and of SECI Spiral confirms the existence of such demand.

Responding to this demand, the authors of the book *Creative Space* (Wierzbicki and Nakamori 2006) used the naturalistic, evolutionarily rational theory of intuition to propose an extension of the SECI Spiral using three-valued instead of binary logic. *Creative Space* is a multidimensional space whose dimensions represent the essential aspects of creativity, usually ordered according to a three-valued logic into three *nodes* on each dimension: *rational, intuitive, emotive; individual, group, humanity; disciplinary, transdisciplinary, interdisciplinary;* etc.

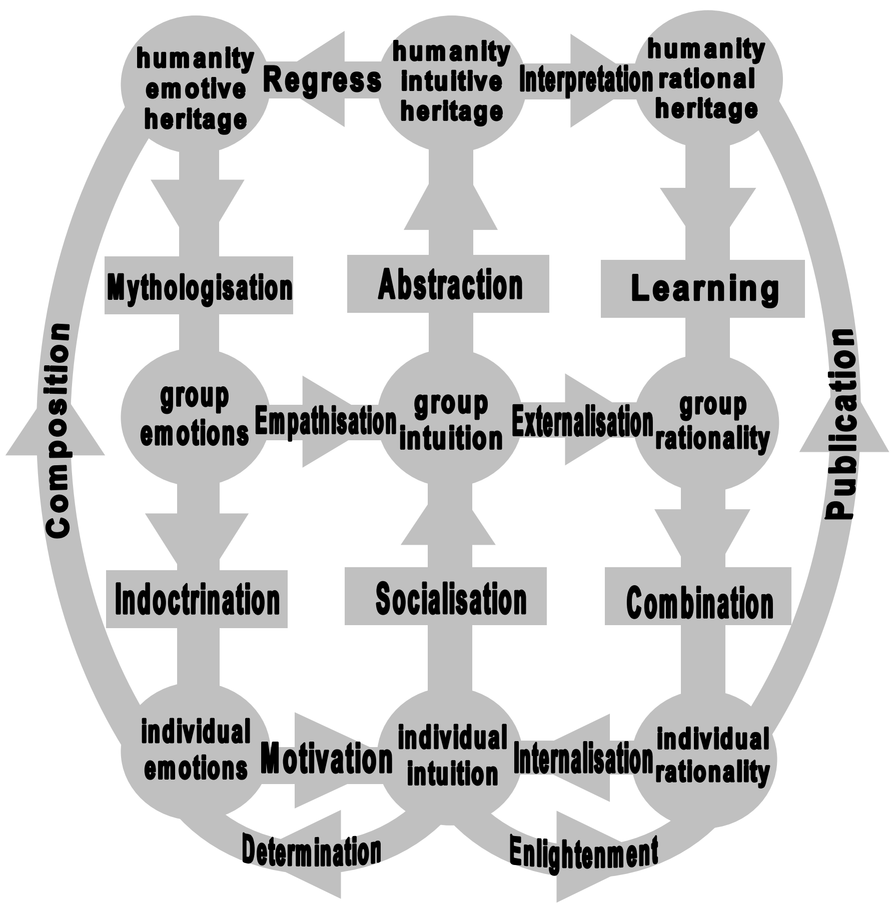

Fig. 1 Basic dimensions of *Creative Space*

The first two dimensions of *Creative Space* – see Fig. 1 - correspond to two dimensions used by Nonaka and Takeuchi (1995) when defining the *SECI Spiral*. For example, in the dimension concerning *explicit-tacit* knowledge used by Nonaka and Takeuchi, we prefer to consider three objects: *rationality, intuition, emotion.* Rationality is here understood as roughly equivalent to explicit knowledge and the combination of intuition and emotion is roughly equivalent to tacit knowledge. Roughly, because both intuition and emotion have components – such as human heritage, discussed above – that were not included in the definition of tacit knowledge by (Polanyi 1966), while, on the other hand, explicit knowledge contains emotive elements. We believe that the distinction of intuition and emotion as components of tacit (and partly explicit) knowledge has more explanatory and predictive power. The two fundamental dimensions of *Creative Space* are represented in Fig. 1.

The model of *Creative Space* consists of *nodes* – such as *individual rationality* or individual rational knowledge – and *transitions*[4] between the nodes – such as *Internalisation* from *individual rationality* to *individual intuition.* Note that the *SECI (Socialisation-Externalisation-Combination-Internalisation) Spiral* of (Nonaka and Takeuchi 1995) is essentially preserved in the lower right-hand corner of Fig. 1; but *Creative Space* involves also many other transitions. For example, the upper left-hand corner of Fig. 1 represents the (Motycka 1998) theory of revolutionary scientific change in the form of the *ARME (Abstraction-Regress-Mythologisation-Emphatisation) Spiral*, see (Wierzbicki and Nakamori 2006) for a more detailed discussion.

Other dimensions can be added to the model of *Creative Space,* e.g., when motivated by the *I-System Pentagram* of Yoshiteru Nakamori (2000) or the tradition of *Shinayakana Systems Approach* (Sawaragi and Nakamori 1993), and many other knowledge creation processes can be represented in the model. Knowledge management is naturally more interested in the processes of *normal* knowledge creation (as opposed to *revolutionary;* see Kuhn 1962). In (Wierzbicki and Nakamori 2006), two types of normal knowledge creation processes are distinguished:

- *Organizational* processes in market or purpose-oriented knowledge creation, such as the *SECI Spiral* of Nonaka and Takeuchi. Such processes are motivated mostly by the interests of a group and two other spirals of this type can be also represented in *Creative Space;* these are the *Brainstorming DCCV (Divergence-Convergence-Crystallisation-Verification) Spiral* (Kunifuji 2004) and the Occidental counterpart of *SECI Spiral,* the *OPEC (Objectives-Process-Expansion-Closure) Spiral* of (Gasson 2004).
- *Academic* processes of normal knowledge creation, in universities and research institutes. Such processes are motivated mostly by the interests of an individual researcher. Three typical spirals of this type are distinguished as parts of *Creative Space* in (Wierzbicki and Nakamori 2006): the *Hermeneutic (Enlightenment-Analysis-Hermeneutic Immersion-Reflection) EAIR Spiral* of reading and interpreting scientific literature, the *Debating EDIS (Enlightenment-Debate-Immersion-Selection) Spiral* of scientific discussions and the *Experimental EEIS (Enlightenment-Experiment-Interpretation-Selection) Spiral* of performing experiments and interpreting their results. Here we should note that all these three spirals begin with the transition *Enlightenment* from *individual intuition* to *individual rationality* (called also variously *aha, eureka, illumination* – simply having an idea – and indicated in the bottom right-hand part of Fig. 1). Because of that, we can switch between these three spirals or perform them parallel. This is indicated in Fig. 2, where these three spirals are presented together as a *Triple Helix* of normal academic knowledge creation.

Thus, academic knowledge creation processes are quite different than organizational knowledge creation; understanding their differences might help in overcoming the difficulty of cooperation between academia and industry. Alternatively, we could try to combine them, see (Wierzbicki and Nakamori 2007). The three spirals contained in the *Triple Helix* do not

[4] Originally called *conversions* by (Nonaka and Takeuchi 1995), but knowledge is not lost when used, hence it cannot be converted; thus we prefer the more neutral term *transitions.*

exhaustively describe all what occurs in academic knowledge creation, but they describe most essential elements of academic research: gathering and interpreting information and knowledge, debating and experimenting.

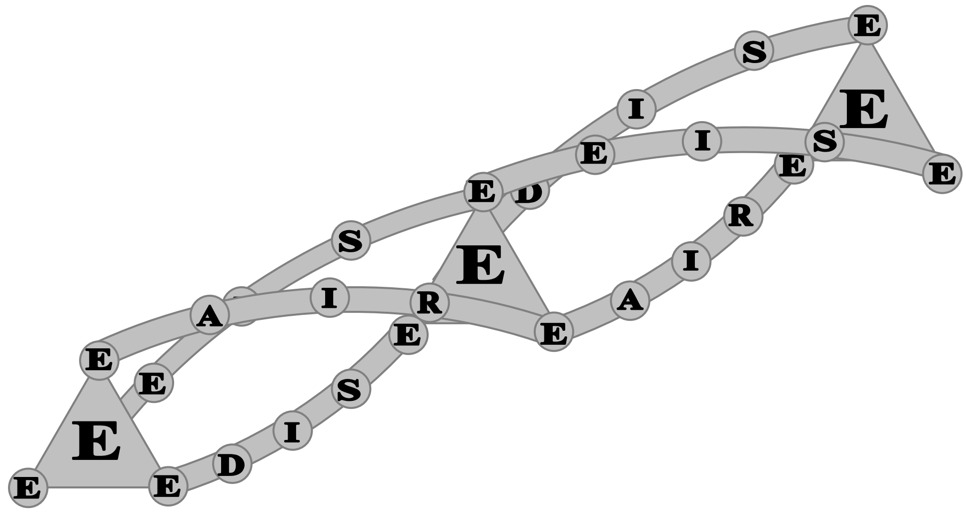

Fig. 2 The *Triple Helix* of normal academic knowledge creation

Let us discuss, for example, the *Hermeneutic EAIR Spiral*. It has been long known that hermeneutics – originally, the art of interpretation of holy texts – can be interpreted as the basis of all humanistic sciences and philosophy, see, e.g., (Gadamer 1960). It has been also known that a hermeneutic process is circular – the issue was only how to close the hermeneutic circle, some authors believed this closure must be transcendental. In (Wierzbicki and Nakamori 2006), we observed that hermeneutic activity is not restricted to humanities, applies also to hard and technical sciences; moreover, that the hermeneutic circle can be closed by the power of intuition. That was the origin of the *EAIR Spiral* – see Fig. 3 - that consists of the following transitions.

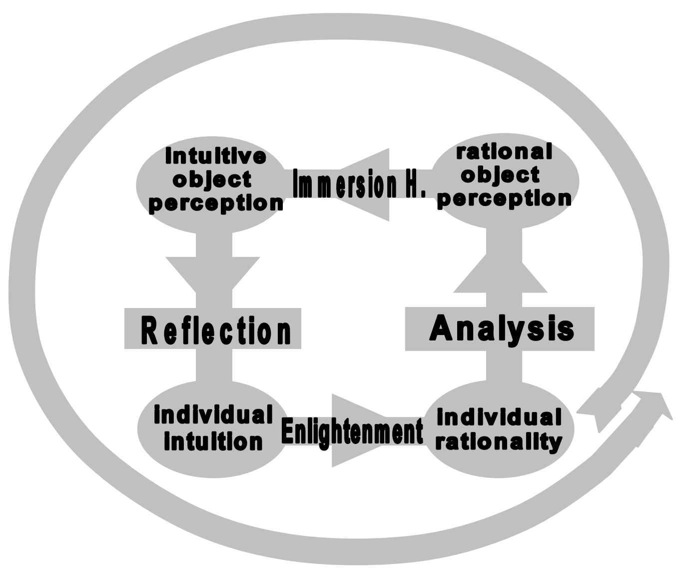

Fig. 3 The *hermeneutic EAIR Spiral* (Wierzbicki and Nakamori 2006)

The transition *Enlightenment* means generally creating an idea and occurs from individual intuition to individual rationality (it is called alternatively *aha, illumination, eureka*), but here it corresponds also to creating ideas where and how to find research materials; *Analysis* is a rational analysis of the research materials, *hermeneutic Immersion* means some time necessary to absorb the results of analysis into individual intuitive perception of the object of study, *Reflection* means intuitive preparation of the resulting new ideas. Each transition and each repetition of the spiral can only enlarge the individual knowledge. *Hermeneutics* is the most individual research spiral, but its importance should be well understood even in fully industrial group-based research.

In fact, recent research including a questionnaire on creativity conditions in JAIST supported, both directly and indirectly, the conclusion that the elements of *EAIR Spiral,* as well as of other spirals contained in the *Triple Helix,* are very important for academic knowledge creation, see (Tian et al. 2006, Wierzbicki et al. 2006). However, these spirals are *individually oriented*, even if a university and a laboratory should support them; e.g., the motivation for and the actual research on preparing a doctoral thesis is mostly individual. Moreover, the *Triple Helix* only describes what researchers actually do, it is thus a *descriptive* model. Obviously, the model helps in a better understanding of some intuitive transitions in these spirals and makes possible testing, which parts of these spirals are well supported in academic practice and which require more support; but it does not give clear conclusions *how to organize research.* This has motivated yet another, *prescriptive Nanatsudaki* (seven waterfalls – a metaphor for seven spirals) model of knowledge creation processes, see (Wierzbicki and Nakamori 2007).

Implications for Multiple Criteria Decision Making (MCDM) and Conclusions

Turning back to the naturalistic, evolutionarily rational theory of intuition, we might ask how does it relate to decision theory and to multiple criteria decision analysis. In fact, the development of this theory was motivated by an attempt to apply multiple criteria decision support at a high political level. Having served at a position equivalent to a deputy minister of science in Poland, I have once suggested to the minister of science – himself a professor of neurophysiology – that we might use multiple criteria decision support in the processes of evaluating diverse decisions in scientific policy. His answer was "I was elected to this high political position because of my ability to make good intuitive decisions based on limited data". Thus I concluded that intuitive decision processes should be better understood.

The concept of intuitive decisions is often used, particularly in the formal utilitarian theory of decision making, usually assuming – without proof – that a formally justified analytical decision must be better than intuitive one. It might sometimes be true, but already the results of (Dreyfus and Dreyfus 1986) quoted earlier indicate, conversely, that an intuitive decision might be much better, if made by an expert.

If we accept the definition of intuition as a preverbal, quasi-conscious mental activity, then we should note that today each person makes very many intuitive decisions of an operational, repetitive character. These are learned decisions because of their repetitive character: when walking, a mature man does not have to articulate (even mentally) the will to make next step. Intuitively we pass around a stone blocking our way, turn off the alarm-clock after waking, etc. These quasi-conscious *intuitive operational decisions* are so simple and universal that we do not attach any importance to them. But we should study them in order to better understand intuition. Note that their quality depends on the level of experience and, as shown by the Dreyfuses, is best at master-level experience. This might be the result of the formation of *intuitive paths in the brain* resulting from the automation of repeated activities. Such automation occurring in our brain is one of the basic components of intuition resulting from *learning by doing.* The other basic component, as we stressed before, is *imagination.*

Now there comes a critical question: does consciousness help, or interfere with the good use of master abilities? If intuition is the old way of processing information, suppressed by verbal consciousness, then the use of master abilities must be easier after consciousness is switched off. This theoretical conclusion from the evolutionarily rational definition of intuition is confirmed by practice. Each sportsman knows the importance of concentration before competition. Best concentration can be achieved, for example, by Zen meditation practices, which were used by Korean archers before winning an Olympic competition.

We contend that *this theoretical conclusion is also applicable for creative decisions* such as creating scientific knowledge or formulating and proving mathematical theorems, new artistic concepts, and new technologic solutions. Creative decisions are in a sense similar to strategic political or business decisions. They are usually non-repetitive, one-time decisions. They are usually deliberative – based on an attempt to reflect on the whole available knowledge and information, or on imagining various aspects of the whole. They are often accompanied by an *enlightenment effect,* such as in the transition *Enlightenment.* Any creative scientist knows the phenomenon of having an idea, diversely called *eureka, illumination, aha* or *enlightenment effect:* we deliberate on a difficult problem and in certain conditions we suddenly know the solution. It is a creative unconscious (subconscious, quasi-conscious) effect, because relaxation and switching off consciousness helps - as in the case of Archimedes. Some writers distinguish between various types of enlightenment, but their character is similar: all consist of a sudden conscious realization that we have a new insight, new understanding or a solution to a difficult problem – apparently attained by employing our unconscious, subconscious, or quasi-conscious abilities.

Before describing a model of a creative intuitive decision process let us recall that (Simon 1958) defined the essential phases of an analytical decision process to be *intelligence, design and choice;* later – see, e.g., (Lewandowski et al., 1989, Wierzbicki et al., 2000) another essential phase of *implementation* was added. For creative or strategic, intuitive decision processes a different model of their phases was proposed in (Wierzbicki 1997):

1) Recognition, which often starts with a subconscious feeling of uneasiness. This feeling is sometimes followed by a conscious identification of the type of the problem.

2) Deliberation or analysis; for experts, a deep thought deliberation suffices, as suggested by the Dreyfuses. Otherwise any tools of analysis or an analytical decision process is useful - with intelligence and design but suspending the final elements of choice.

3) Gestation; this is an extremely important phase - we must have time to forget the problem in order to let our subconscious work on it.

4) Enlightenment; the expected eureka effect might come but not be consciously noticed; for example, after a night's sleep it is simply easier to generate new ideas (which is one reason why group decision and brainstorming sessions are more effective if they last at least two days).

5) Rationalization; in order to communicate our decision to others we must formulate our reasons verbally, logically, and rationally. This phase can be sometimes omitted if we implement the decision ourselves.[5]

6) Implementation, which might be conscious, after rationalization, or immediate and even subconscious.

It should be stressed that this process is essentially recursive: recourse can occur after every phase and go to any previous one. This process has rational and a-rational phases: *recognition* is a-rational, *deliberation* is a-rational but *analysis* is rational, *gestation* and *enlightenment* are a-rational, *rationalization* is a transition from a-rational to rational, and *implementation* usually

[5] The word *rationalization* is used here in a neutral sense, without necessarily implying self-justification or advertisement, though they are often actually included. Note the similarity of this phase to the classical phase of *choice*.

starts as a rational but might become an a-rational, quasi-conscious activity. The recursive character and the clear distinction of the rational and the a-rational phases of this process are the essential differences to the quite classical linear process of *preparation, incubation, illumination, verification* described by (Wallas 1926).

Especially important are the a-rational phases of gestation and enlightenment. They rely on utilizing the enormous potential of our mind on the level of preverbal processing: if not bothered by conscious thought, the mind might turn to a task previously specified as most important but forgotten by the conscious *ego* – or *superego*. The enlightenment can have diverse character and degrees. It might be a simple change of perspective; a revision of hidden assumptions – which often is sufficient for quite important change of perception; a deep change of perspective resulting from empathy with the object of enquiry; a novel synthesis of a thesis and antithesis that previously appeared incompatible; a new mathematical idea due, for example, to geometric imagination; a new construction based on a holistic perception of beauty; a new theory based on utilizing the emotive and intuitive heritage of humanity. The simple, small enlightenments can be thus called *aha* or *illumination,* the deeper and more important – *eureka* or *deep enlightenment.* Obviously, it is rather easy to achieve small illuminations (particularly if we use some of the practical tips outlined below) and difficult to achieve deep enlightenment. This depends on personality and on the problem being solved, but we can to some degree influence the depth of enlightenment by supporting the gestation phase.

There might be diverse practical advices resulting from the rational theory of intuition. One of them might be called *Limit TV*:

If you want to be creative, do not spend too much time in front of the TV set – because you should let your imagination play its own games, not only the games presented by others.

An important aspect to teaching creativity might be teaching what intuition is and how to stimulate it. However, even more important is to teach how to use imagination, how to imagine various perspectives of looking at a problem, to empathize with the object of your study, etc. *If you want to be a race driver, it is important to be able to imagine that you are your car and see the racetrack from its perspective.*

Another group of practical conclusions is related to the conditions that help to achieve the enlightenment effect. We already stressed that *emptying your mind*, *concentrating on void* or *on beauty*, *forgetting the prejudices of an expert* are useful in concentration before performing in a well-trained field like athletics. They might be equally useful in suppressing your conscious perception when trying to achieve enlightenment.

Thus, having a difficult problem you want to solve creatively, study it hard, but then forget about it and go to a tea ceremony or Zen meditation.

The same principle can be applied to group activities such as difficult negotiations or solving difficult problems through brainstorming. *Organize group discussions for at least two days, with relaxation and good sleep in between.* This *Principle of Double Debate* can be experimentally tested by simulated exercises in brainstorming or negotiations.

When it comes to personal intuition and creativity, the same theory implies that our best ideas for intuitive decisions might come after a long sleep, but before we fill our mind with the troubles of everyday life. Hence a simple *Alarm Clock Method*:

Set your alarm clock ten to twenty minutes before your normal waking time and immediately after waking try to find the solutions to your most difficult problems.

This *Alarm Clock Method* is most easy to test, and we advise all readers to test it personally. You will be astonished how clearly and fast you are thinking just after waking, and how easy it is to achieve if not a great enlightenment, than at least a small illumination.

Finally, there are also some conclusions related to the development of multiple criteria decision making (MCDM) theory and practice. We see that deliberation requires holistic information; thus, in a multiple criteria decision situation, the best computerized support stimulating intuition must concentrate first on providing an estimate of the *ranges of criteria change.* These ranges might result from considering all decision options, or only Pareto-optimal options, while in the latter case evolutionary multiple objective (EMO) algorithms might be helpful for estimating the ranges. It should be only stressed that finding so-called nadir point – the lower bound for criteria values in Pareto-optimal set – might be difficult (in the case of more than two criteria) even for EMO algorithms, thus they should be stopped first when a good estimate of the nadir point is obtained, see (Wierzbicki and Szczepański 2003).

Another related issue is the interpretation of the goals of computerized decision support. In classical interpretations, it should help the decision maker to find the best decision, fine-tuned to his personal preferences. If we want to support intuition, however, a decision support system should provide a *virtual laboratory* where the decision maker can learn about consequences of diverse decisions, ranges of criteria change, and fine-tune her/his intuition. This is perhaps best illustrated by a controversy from recent discussions at the Dagstuhl Seminar 06501: Practical Approaches to Multi-Objective Optimisation, see Fig. 4.

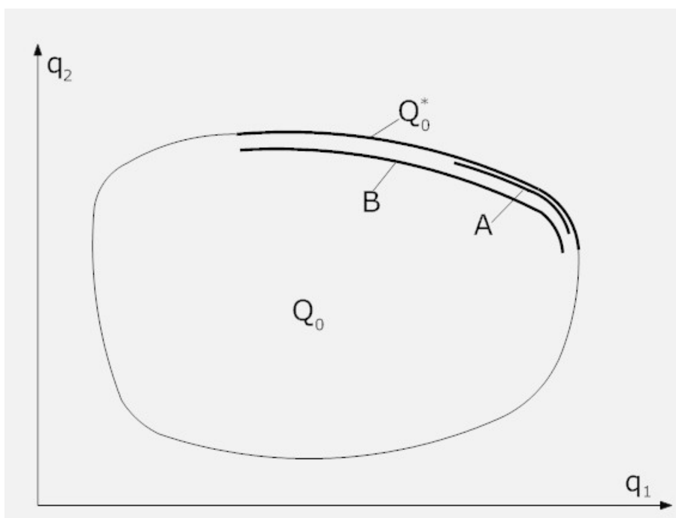

Fig. 4 A set of attainable (maximized) criteria values Q_0, its Pareto frontier Q_0*, and two approximations of Pareto frontier: *A* and *B,* while *A* strictly dominates *B*

The controversy is at follows: even if the approximation *A* strictly dominates *B* in the sense of the partial order of the criteria space (*B* is contained in $\mathrm{A} - \boldsymbol{R}^2_+$), is it better than the approximation *B*? If the goal of decision support is only to find the best decision, it might seem that the approximation *A* is obviously better than *B.* If the goal of decision support is to provide a virtual laboratory for experiments made by decision maker and give her/him a holistic information about the decision situation, the approximation *B* might be nevertheless considered better. This does not mean that the classical approaches to multiple criteria decision making are wrong; they might be useful when independently checking whether an intuitive decision is correct, but this is not the same task as supporting the decision maker and enhancing her/his intuition.

To conclude: a thorough understanding of the nature and essence of intuitive decisions might essentially change many paradigmatic preconceptions of multiple criteria decision making.

References

Bergson H (1903) Introduction to metaphysics (English translation 1911, New York)

Bunge M (1962) Intuition and science. Prentice-Hall, Englewood Cliffs, N.J.

Chomsky N (1957) Syntactic structures. Mouton, The Hague

Czarnocka M (2003) Podmiot poznania a nauka (in Polish; The knowing subject and science). Wydawnictwa Uniwersytetu Wrocławskiego, Wrocław

Dreyfus H (1972) What computers can't do. Harper and Row, New York

Dreyfus H, Dreyfus S (1986) Mind over machine: the role of human intuition and expertise in the era of computers. Free Press, New York

Fodor JA (1994) The elm and the expert: mentalese and its semantics. MIT Press, Boston

Gadamer H-G (1960) Warheit und Methode. Grundzüge einer philosophishen Hermeneutik. J.B.C. Mohr (Siebeck), Tübingen

Gardner H (1985) The minds new science: a history of the cognitive revolution. Basic Books, New York

Gasson S (2004) The management of distributed organizational knowledge. In Sprague RJ (ed) Proceedings of the 37 Hawaii International Conference on Systems Sciences (HICSS 37). IEEE Computer Society Press, Los Alamitos, Ca

Jung, CG (1953): Collected works. Pantheon Books, New York

Kant I (1781) Kritik der reinen Vernunft (Krytyka czystego rozumu, Polish translation 1957, PWN, Warsaw)

Król Z (2005) Intuition and history: change and the growth of mathematical knowledge. International Journal for Knowledge and Systems Science 2: 3: 22-32

Król Z (2007) The emergence of new concepts in science. In Wierzbicki AP, Nakamori Y, eds (2007) Creative environments: issues of creativity support for the knowledge civilization age. Springer Verlag, Berlin-Heidelberg (in print)

Kuhn TS (1962) The structure of scientific revolutions. Chicago University Press, Chicago (2nd ed., 1970)

Kuhn TS (2000) The road after "structure". University of Chicago Press, Chicago

Kunifuji S (2004) Creativity support systems in JAIST. Proceedings of JAIST Forum 2004: Technology creation based on knowledge science, pp 56-58

Latour B (1987) Science in action. Milton Keynes: Open University Press

Lewandowski A, Wierzbicki AP (eds) (1989) Aspiration based decision support systems: theory, software and applications. Lecture Notes in Economics and Mathematical Systems 331, Springer Verlag, Berlin

Motycka A (1998) Nauka a nieświadomość (Science and unconscious, in Polish). Leopoldinum, Wrocław

Nakamori Y (2000) Knowledge management system toward sustainable society. Proceedings of First International Symposium on Knowledge and System Sciences, JAIST, pp 57-64

Nonaka I, Takeuchi H (1995) The knowledge-creating company. How Japanese companies create the dynamics of innovation. Oxford University Press, New York

Plato (ca. 380 BC) Dialogs. (Polish translation: Dialogi. Verum, Warsaw 1993)

Polanyi M (1966) The tacit dimension. Routledge and Kegan, London

Popper KR (1934) Logik der Vorschung (English translation: The logic of scientific discovery, Basic Books, New York 1959)

Popper KR (1972) Objective knowledge. Oxford University Press, Oxford

Sawaragi Y, Nakamori Y (1993) Shinayakana systems approach: systems science and systems engineering. ICSSSE'93, Intern. Acad. Publ, pp 24-29

Searle JR (1992) The rediscovery of mind. MIT Press, Boston

Simon HA (1958) Administrative behavior: a study of decision making process in administrative organization. Macmillan, New York

Slovic P (2006) Affect, reason, risk and rationality. Newsletter of the European Working Group "Multicriteria Aid for Decisions", spring 2006

Tian J, Wierzbicki AP, Ren H, Nakamori Y (2006b) A study of knowledge creation support in a Japanese research institute. International Journal of Knowledge and Systems Sciences, Vol. 3, No. 1, pp.7-17.

Wallas G (1926) The art of thought. Harcourt and Brace, New York

Wang Z (2003) Systems intuition: Oriental systems thinking style. Journal of Systems Science and Systems Engineering 12:129-137

Wierzbicki AP (1992) The role of intuition and creativity in decision making, Working Paper WP-92-78, International Institute for Applied Systems Analysis, Laxenburg, Austria

Wierzbicki AP (1997) On the role of intuition in decision making and some ways of multicriteria aid of intuition. Multiple Criteria Decision Making 6:65-78.

Wierzbicki AP (2004) Knowledge creation theories and rational theory of intuition. International Journal for Knowledge and Systems Science 1:17-25

Wierzbicki AP (2005) Technology and change: the role of technology in knowledge civilization. Ith World Congress of IFSR**,** Kobe

Wierzbicki AP, Makowski M, Wessels J (2000) Model-based decision support methodology with environmental applications. Kluwer, Dordrecht

Wierzbicki AP, Szczepański M (2003) Application of multiple criteria evolutionary algorithms to vector optimization, decision support and reference point approaches. Journal of Telecommunications and Information Technology 2003: 3: 16-33

Wierzbicki AP, Nakamori Y (2006) Creative space: models of creative processes for the knowledge civilization age. Springer Verlag, Berlin-Heidelberg

Wierzbicki AP, Nakamori Y, eds (2007) Creative environments: issues of creativity support for the knowledge civilization age. Springer Verlag, Berlin-Heidelberg (in print)

Wittgenstein L (1922) Tractatus logico-philosophicus. Cambridge, UK

Wuketits FM (1984) Evolutionary epistemology – a challenge to science and philosophy. In Wuketits FM (ed) Concepts and approaches in evolutionary epistemology. Reidel, Dordrecht