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## Chapter

# Cognitive Decision-Making in Dynamic Systems: When the Objectivity (of the Processing) Does Not Guarantee the Validity (of the Choice of Action)

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## Abstract

Since around 1970, academic studies on decision-making have changed in nature. Whereas they used to be laboratory studies of selected situations giving rise to the expression of individual choices, nowadays studies focus on real situations. These situations are processed in their natural contexts at the time they occur. The decisions to be made concern generally social problems (for instance forest fires, maritime pollution or global warming). This mutation in the nature of situations studied requires a paradigm shift, which leads to elaborate decisions in complex, dynamic and evolving systems, even sometimes resilient to human actions implemented to control them. This chapter analyses, at individual and group level (crisis units), cognitive difficulties encountered by decision-makers in handling such situations. These situations consist in treating information by assigning them, from the outset, meanings (sometimes personal). This is done by looking for temporary interactions, while respecting the global nature of the situation, by focusing on knowing the properties of context as well as those of the temporal evolution of the system concerned. This chapter analyses a case study for which urgent and fundamental decisions could not be taken and proposes an interpretation in terms of paradigms. Previous studies noted that the decision in complex systems, could entail paradoxes. This study on the decision-making dynamic shows that seeking objectivity, as defined under its current intangible form, does not produce a significant increase in the validity of choices made.

**Keywords:** Decision-making, Complexity, Dynamism, Systems, Holism, Paradigm

## 1. Introduction

Since psychology has set as its main purpose the study of behaviour, decision-making behaviour represents a stimulating subject for studies and research. Not only are there numerous circumstances in which it proves necessary to make a choice, but they are also highly varied. This chapter analyses a quite specific category of decisions: those concerning the action choices in complex and dynamic systems. Highly different from other decisions studied in fixed environments,

they lead us to explore the field of epistemology and cognitive psychology and offer the advantage of generating sensitive crossed interrogations in these two disciplines also required for the construction of knowledge.

This chapter will focus on one of these, in other words the relations between the choice of an objective epistemology and the absence, observed in the field, of relevant decisions. The argument has seven facets. The first describes the cognitive and epistemological specificities of decision-making in complex and dynamic systems. The second deals with the assignment of meaning to information, while the third describes a selection of real situations which led to decision-making difficulties. The fourth facet is dedicated to the examination of an investigation tool: the paradigm, and refers to a particular paradigm; the objective experimental paradigm (OEP) which underlies scientific progress in numerous disciplines. The fifth facet focuses on its transferability to decision-making in complex and dynamic systems and any resulting cognitive dilemmas. The sixth facet raises the question of the globality of the situations to be processed (rather than their breakdown into variables) by taking as guideline an attempt made to this effect in psychology. The seventh examines the epistemological position of the decision-makers faced with a paradox which seems to be related to valorisation at all costs of objectivation, at the expense of other characteristics of the decision.

## **2. Decision-making aimed at cognitive psychology**

### **2.1 A decision-making proto-schema**

The most concise characterisation of decision-making facing with uncertainty [1] consists in describing it as an approach prior to choosing one action [Ai] amongst a set of  $n$  actions [An] considered as being potentially relevant. In this characterisation, decision-making consists in generating what psychologists call a conduct (a behaviour in common language) in order to choose the action [Ai] amongst a set of  $n$  possible actions. This action is evaluated as being the most relevant to change an existing situation considered to be inappropriate or dangerous. For example: which action(s) should be chosen to stop the persistent financial losses of a company? However, the cognitive approach is not solely interested in the end result (the chosen action); it attempts to explain the characteristics which led to this conclusion. These characteristics must be found in the information present in the situation and with respect to the objective to be reached. The theoretical references used will therefore concern cognitive psychology, whose purpose is to study how to process the information which will lead to a judgement, then to a decision.

### **2.2 Decision-making as cognitive management of systems and networks**

It can be observed that, in this conception, decision-making is not limited to initially selecting outcomes to create the set  $n$  and to making a limited number of binary comparisons. This type of limitation would exclude from the field of the decision any “surprise” which could arise from the reality of the situation processed. We will then observe that the informational characteristics of the environment and even more its ability to evolve, are largely or totally absent from this approach. While the condition that the set of  $n$  actions must be exhaustive is initially put forward, it is not always possible to meet this condition. All operational decision-makers are aware of the frequency of unexpected or unforeseen conditions in the initial plan [2]. Mental fixism, which consists in thinking that “everything is under control” and that everything has been planned, is often accepted too readily due to the sole fact that it confirms an earlier mental representation.

This type of difficulty is frequently encountered in situations where behavioural automation is important, for example when piloting an aircraft. While it undoubtedly reduces the mental effort, automation may nevertheless prove to be disconcerting faced with unplanned situations, especially if the level of concentration drops temporarily. Amongst the causes mentioned during “inappropriate decision-making”, analysts estimate that “airline pilots do not receive sufficient training on manual piloting”.

### 2.3 Epistemological characteristics of the chosen action

The chosen action [A1], also referred to as the dominant action, is that which, at the end of the decision-making process, is the one most likely to achieve the required effect. This first requirement applies to all decisions to define the objective to be reached but involves specificities in decisions qualified as complex. In such contexts, deciding is much more than choosing a subject or a procedure. Based on the dynamics of the systems concerned, we must consider that the decisions are taken to cause *state changes* in order to set up new operating balances in the systems: the health system, the economic system, the company, the emergency systems, etc.

Except in special cases, to obtain these state changes, the “decision” entity must itself be composite, i.e. must consist of a set of elementary actions ( $a_1, a_2, \dots, a_k$ ), where each individual action has an impact on the system and where the set of actions taken together forms a global action module. The decision as such is the equivalent of a vector.

Scientific knowledge requires that the epistemological characteristics of the chosen informations must be clearly defined. The most obvious are the validity ( $v$ ), the generality ( $g$ ) and the fidelity ( $f$ ). The sequence of elementary actions must prove that it is composed in such a way that it can act on the system in the required direction ( $v$ ), do so for all situations of the same type ( $g$ ), with a stability of effect which is repeated over time ( $f$ ). These qualities can be used to distinguish the daily information forming know-how from the scientific information which satisfied these requirements, substrate on which the theoretical systems are built.

## 3. Information, cognition, and assignment of meaning

### 3.1 Perception and interpretation

In the press and in the media, the discriminating power of the sensory functions is largely overestimated. Taking vision for example, the eye, compared with a camera, which would record events, is supposed to provide a faithful image of the external context sometimes called reality. However, the information that we will use to build an adapted our conduct is necessarily obtained by *interpretation*. It consists of dynamic entities to which meanings are assigned due to the mere fact they have transited via the neural networks of the brain. The retinal image therefore acquires, in the brain, a meaning related to the decision-maker’s knowledge networks.

### 3.2 Two cognition modules (levels)

Decision-making thus appears as a mental task involving two different but complementary types of operation corresponding to two cognition levels, each one representing a homogeneous subset of operations and therefore deserving to be considered as a module.

### 3.2.1 *The information sampling process (module 1)*

The first cognitive operations consist in collecting information by performing a global inspection of the situation; the subsequent operations, carried out in successive steps, will then reduce the field explored.

All human-decision-makers absorb the situation to be processed using data supplied by their sensory functions. Two important points must nevertheless be specified. Firstly, the term “sensory functions” must be understood in a very broad sense not restricted to the well-known five senses but also including all the receptors involving movement, sensitivity and possibly intuition. The range of information available therefore extends far beyond the data processed in the specific areas traditionally mentioned. Secondly, we must stress, as said previously, that each sensory input is processed and *interpreted* by the brain. Apart from its physiological properties, we must therefore point out its main characteristic: being an element which brings meaning.

### 3.2.2 *The information formatting processes (module 2)*

The level-2 cognitive processes are referred to as executive functions. They differ from the previous functions by the fact that they regulate the scheduling (planning) of the behavioural construction sometimes as activation (useful information) and sometimes as inhibition (interfering information). The main functions concerned are attention, flexibility of thought, implementation of adaptive feedback loops, global reformulations, etc. They are involved in determining the behaviour at a global activation level. The most illustrative example is that of attention, which does not belong to any specific item of information but which can be applied to each one.

## 3.3 Complementarity

In line with the systemic outlooks, it is important to consider that these modules represent two entities which, far from being opposed, complement each other in numerous circumstances. It would be worthwhile considering them as inducing each other mutually. Module 1 samples information in situ whereas module 2 handles the formatting and organisation of the set so created. Module 2 is involved in the creation of the cognitive maps which will be described in greater detail in this document.

## 4. Epistemological characteristics of the situations studied

### 4.1 Structural data

To complete the data collection, it is necessary to mention a few real decision-making situations in complex systems which occurred since about 1960. The situations studied by the social sciences exhibit four properties:

- complex situations which include a large number of dimensions with non-linear relations, making it difficult to assess how the situations are going to evolve.
- systems organised in subsystems, not around variables. These subsystems represent activation “focal points” which create dynamisms.

- evolving entities which change state over time. Time must therefore be taken into consideration when determining the appropriate action.
- situations which often have a strong societal dimension. In numerous contexts, the action choices are designed to put an end to a damaging situation by controlling its effects and the situation itself (for example, controlling a technological accident such as the Chernobyl disaster). The decisions must be made rapidly, under the pressure of public opinion, in a context where stress is highly present.

## 4.2 Field data

In natural situations, this type of characterisation applies to events which appear to be quite different from the outside but which are relatively similar as regards their underlying architecture and organisation. The media report these events regularly when they have harmful effects.

The events most frequently encountered are:

- Forest fires, extremely difficult to control, whose recurrence and duration (sometimes lasting several months) are retrospective signs of decisions that are hard to take. Recently in California and Australia, despite major and appropriate firefighting measures, the fires lasted for several weeks, even several months, and caused serious human and material damage.
- Marine pollution due to oil spills from tankers. Coastal areas have been polluted by hydrocarbons from shipwrecks on numerous occasions. Those which received the most media attention, due to the scale of the damage caused, are remembered by the names of the oil tankers themselves. We may mention Amoco Cadiz (1978), Exxon Valdez (1989), Aegean Sea (1992), Erika (1999), Prestige (2002) and Hebei Spirit (2007).
- Global warming represents another complex and dynamic system for which decisions must be taken at large scale. Scientists quickly raised the alert on the need to “manage” the climate. The Swedish chemist Arrhenius (1859–1927) was the first to establish a link between energy production (coal at the time) and global warming. Over the next decades, however, there was such a gap between the perceived reality and the difficulties announced that these predictions were forgotten by the public opinion. More recently, a predominant political factor has been added to the initially scientific treatment given to this issue. Since 1995, the United Nations has organised in a different country every year a conference hosting some 185 nations. Known under the acronym COP (Conference of Parties), these meetings have already been held 25 times. COP 26 to be held in the United Kingdom in 2021 for about ten days has been postponed due to the Covid-19 pandemic but finally will take place, another example as disconcerting as the previous ones regarding the management of a complex system.
- The management of pandemics exhibits all the above-mentioned characteristics of a complex system. The objective to be reached is clearly determined and the means to change it from its current state to the final required state consist in setting up a decision-making sequence. This entity, which includes an evolving time dimension, comprises a series of successive decisions, each one being designed to make the system evolve in the required direction. The decision is built one step at a time, so as to preserve what has been achieved and validated and to duly validate the changes introduced. Examination of the strategies

implemented in the countries of the European Community, federated around a common project, reveals, both in terms of time and structure, major differences in the way the situation is processed and the decisions made.

In all these categories (the types of situation which have just been mentioned), the decision-makers encounter major difficulties in managing the active systems not only individually but also as a committee: the collective intelligence so often proposed as the solution is temporarily inoperative. Some forest fires last for weeks, even months, damaged oil tankers continue to spill their cargoes for weeks and sometimes much longer, the issue of global warming proves difficult to manage, like the pandemic which, since the alert was raised in 2019, has not yet been controlled at the time this document was written.

In view of such obvious and recurrent difficulties, we must examine the methods and cognitive strategies involved in the decision-making process when faced with complex systems.

## **5. Decision-making in dynamic systems: the paradigm tool**

### **5.1 Cognition and complex systems (reminder)**

Historically, relations between cognition and complex systems have been difficult to manage. It was around the 1900s with the studies conducted by J.H. Poincaré (1854–1912) that the first evidence relating to a problem observed in astronomy was detected. It was only in the 1970s, however, probably out of despair, that the expression “chaos theory” was introduced. It was to experience a major impact in relation with the quasi-oxymoron characterising it. The project to theorise disorder is in fact the exact opposite of the deterministic conceptions on which scientific theories are built and based. In other words, chaos seemed to be a chance event.

When studying turbulences, Ruelle and Takens [3] indicate quite to the point that, beyond an apparent disorder, chaos is in fact “deterministic”, but this observation introduces a new paradigm into the scientific research activity. Today the complexity of the situation and the dynamics that underlie it are no longer considered to be disruptive elements but as structuring characteristics of the situation and can be used to find the appropriate concrete action [4].

### **5.2 Roles and functions of the paradigm**

Very broadly characterised, a paradigm, sometimes defined as a “school of thought” is the combination, within a given set, of theoretical and methodological notions with concrete cases which are compatible together so that there is no rupture in the approach to build a corpus of knowledge. For the last two centuries, the objectivity required to choose the relevant action has been related to the experimental method resulting in the construction of the objective experimental paradigm (OEP) which has witnessed major successes. OEP has led to the development of physical sciences, material sciences, life and health sciences. This paradigm underlies experimental medicine, as well as the progress made in the techniques which have accelerated its development.

### **5.3 Objective experimental paradigm and psychology**

While the formalised sciences (virtually) never raise the question of which paradigm to use since the OEP is the obvious choice, in the human and social sciences,

it must be chosen in a preliminary step. This is clearly the case of psychology where the OEP has been used for many years in laboratory studies (Wundt created the first experimental psychology laboratory at Leipzig in 1879. His initial training as a physiologist probably contributed to the transfer of skills and models to psychology). The central theme studied by this laboratory was in fact perception. More recently, from the 1960s, cognitive psychology has made extensive use of this OEP adding new technological tools in order to study the dynamics of the brain processes during information processing operations.

#### **5.4 Characteristics and migrations of the PEO**

The well-known OEP has become so dominant that it represents an idealised conception of research built around clearly defined options. The main ones, apart from the public nature of the investigation procedure, include the permanent concern for verification using a device conceived and/or built by the researcher. To meet these epistemological requirements, a workplace and clearly defined working conditions are necessary. The workplace is the laboratory, isolated from the influences of the outside world, to prevent unwanted influences - without really knowing what they are - from disturbing the network of relations between variables. The device used is a reconstruction simplified by means of the "scientific reductionism" of potential relations between certain (potentially causal) independent variables and (resulting) dependent variables. Validation tools, sometimes statistical, are used to check whether or not the links proposed are valid.

In view of the guarantees it offers regarding the objectivity of the conclusions and their applicability in real situations, the OEP has been adopted in numerous human and social science research studies [5], rarely in its canonical form and frequently in forms adapted to the situation being processed. The latter forms may be increasingly remote from the basic schema. From an epistemological point of view, it is interesting to consider these successive shifts. They highlight the existence of a compromise, in other words an attenuation of the generality and rigour of the method by considering the specific characteristics of each situation.

#### **5.5 Epistemological functions of the paradigm**

In addition to the intrinsic functions of the paradigm, those of information processing, Kuhn [6] adds a global, trans-situational function. This author points out that the results obtained during its applications to situations of different type but of similar architecture (organisation) are indicators of its validity (the generality requirement is met). Due to scientific progress, all paradigms are superseded as soon as they are no longer able to provide answers to the questions raised. A new epistemological option and a new paradigm become necessary. Kuhn designated this moment of transition "a scientific revolution". The progress made in scientific knowledge is neither linear nor regular; it is built up discontinuously by a series of leaps separated by periods of stability, of irregular duration, but which shorten according to the degree of progress of science.

### **6. Cognitive dilemmas**

#### **6.1 Opposed characteristics**

The most recent paradigmatic leap in the evolution of human sciences is that marking the transition from the objective experimental paradigm to the systemic

paradigm. What are the consequences? The study of dynamic and complex situations using the OEP analysis grid is unable to determine the efficient decision which would bring the system to the required state (how to put out the forest fire, for example).

Due to the recurrence of difficulties and failures, a more in-depth epistemological analysis must be conducted. This could be explained, for example, by the fact that the characteristics of the complex and dynamic situation to be analysed (S) and those of the tool (paradigm O) used to do so, clearly appear to be contradictory in many respects. As regards the structuring units considered: dynamic subsystems (S) against variables (O); a problem *reconstructed* to be operationalised in a laboratory isolated from the outside world (O) faced with a *real* problem observed in natural environment (S); non-linear relations (S) translated by linear relations (O); dismissal of the temporal perspective (O) although the time of observation and evolution of the system is a determining factor for the decisional choice (S). This amounts to applying a tool built using properties which are rigorously opposed to the situations to which it is applied.

## 6.2 An epistemological choice and its consequences

Due to another source of malfunction, the scientific reductionism operation must be re-examined. In this case, the methodological reductionism will be considered differently from its ordinary meaning: we will consider it as a methodological approach aimed at condensing a real situation to reduce it to its most fundamental components. This type of operation, also used for a quite different purpose, has been called “eidetic reduction” by the phenomenologists, to shift, using their terminology, from the “existence” of things to their “essence”.

Thus, a natural situation (i.e. outside the laboratory) is an instantiation surrounded by a “clutter” of temporal or circumstantial particularisms, which prove secondary for those wanting to isolate *general* information to be used for theorising and modelling. Moreover, this reduction also takes a material form when it allows researchers to build the device mentioned above in order to select from the flow the information which must be kept and then test the information which seems important, in particular that used to satisfy the objectivity.

## 6.3 Cognitive map / heuristic map

The cognitive map, sometimes also referred to as the heuristic map, is a mental model or representation that a human individual makes of the arrangement of steps, methods or conditions which he/she considers necessary to decide what to do. In other words, it is an organised representation of knowledge. It indicates the time required to identify a task (about one minute), in forms that are sometimes rather basic, it transmits, when necessary, the information to the long-term memory which stores it for future reuse.

Like numerous cognitive productions, this map is subject to the heuristic approaches identified by Kahneman, Slovic and Tversky [7]. While numerous occurrences exist, they all have the same objective: introduce simplicity into a situation which, due to its complexity, appears to be disconcerting. We may mention again the initial lack of understanding conveyed by the term “chaos theory”, direct reflection of a cognitive failure. As confirmed subsequently by the research studies in cognitive psychology on judgement, as part of the basic need of every human being to understand the present world, individuals will perform heuristic reductions of this complexity which will then be used to produce simplified cognitive

maps. However, although the mental representation is simplified, the reality of the situation nevertheless remains complex. Applying the simplified mental models to the reality of the situation fosters errors of judgement and therefore inappropriate decisions. (A very similar approach in the field of perception underlies the development of conspiracy “theories”.)

## **7. Management of globality: counterproductive simplifications**

### **7.1 An essential requirement**

In the decision-making concerning the complex situations mentioned in 2.2, the decision is more complex than choosing a single action directly. The term “decision-making” means determining a *sequence of actions* meeting the characteristics stated at the start of this study. Each situation chosen must be considered as a reactive systemic globality. Trying to isolate the elements, separate them from the set means simultaneously altering the system and fragmenting the relations between elements. Unlike the device built in the laboratory whose architecture is intangible and where only the intensities vary, the complex system is an evolving and reacting entity: a forest fire does not have the same characteristics when it has just broken out as when it has lasted for several days. The temporal dynamic aspect becomes preponderant.. Assessing the potential of a complex system implies being able to quantify a global index that expresses its evolutionary power. Entropy represents a reference often used although in different forms: quantified when the data allow it [8], cognitive in other cases [9].

### **7.2 Consider the globality: the example of gestalt psychology**

How to conceive the processing of globality? A first option mainly consists in not breaking it down according to the Cartesian and Newtonian analysis methods, which are highly attractive since they have demonstrated their usefulness for the construction of numerous highly attractive disciplinary corpuses. The recommended strategy in this case is not to discard them but to examine, when analysis tools are concerned, the conditions and benefits of preserving the globality.

The Gestalt Psychology initiated by German researchers working in the United States, and pioneered by Lewin (1890–1947), attempted to do so. The Gestalt movement does not refer to the laboratory and adopts the principle based on the analysis of global entities. These terms designate the situation as such (often referred to as the figure) and the informational field in which it is immersed (often referred to as the ground). According to this epistemological movement, trying to distinguish between the elements is pointless since “the whole is more than the sum of its parts”. The whole has its own characteristics (we might be tempted to say its own “personality”) which is more than the sum of the elements taken individually.

### **7.3 Dynamisms**

Another extremely important property of the Gestalts is their dynamism. This can be easily observed by examining the reversible figures widely published in magazines, designed in such a way that the figure and the ground can be interchanged. It takes a few moments to observe the dynamism of the phenomenon which globally and suddenly modifies the nature of what is perceived.

When attempting to sketch out an epistemology of globality, Lewin, who developed the concept of group techniques, strived to study each situation, each type of behaviour, inserted in its natural context. One well-known example is that of purchasing behaviour. So no isolation and no more or less successful reconstruction. In his book entitled “Principles of Topological Psychology”, Lewin [10] studies social behaviour and is the first one to analyse psychological behaviour. His project consists in modelling the analysis approaches used in psychology on those of mathematics but mainly of the physics of his time, in other words in terms of forces and force resultants. Lewin also introduces the concept of psychological life space including space, time and forces as dynamic elements; entities which prepare the way for the distribution of dynamic complex systems in human sciences.

## 8. Structural differences between the object and the tool

### 8.1 The decision-maker’s locus of control in situation

Psychologists use the term “locus of control” to designate: *“the degree to which people believe that they, as opposed to external forces (beyond their influence), have control over the outcome of events in their lives.”*<sup>1</sup> In this case, the control concerns the choice of the action which would bring the system to the required objective.

### 8.2 Means underlying the locus of control

What means are available to decision-makers to consider that they can control the development of the situation? In actual fact, these decision-makers implicitly or clearly perceive that their resources are limited. They are not in a position to use a previous professional experience or an apprenticeship since, in most cases, the situations to be processed are both complex and infrequent; in human sciences, they have in fact given rise to very few conceptualised approaches. In terms of decision-making, the only “scientific” data regarding the action choices are determined based on case studies and generally to analyse errors or malfunctions. In such a context, few cognitive resources are assigned to the locus of control, based at best on “degrees of belief”, i.e. at best on subjective probabilities. The resulting uncertainty experienced has a negative effect on the action choices, especially if the stakes are high.

### 8.3 A transition

To reduce this uncertainty in order to choose the best actions, the decision-makers will opt for a strategy different from that of collecting ever more information. Although the PEO guarantees objectivity, this is at the cost of reducing the field of study. In addition, being a typical laboratory paradigm, it does not apply to the situations we have qualified as natural. Being unable to determine the action required with a sufficient guarantee of validity, the decision-makers will switch to type 2 information. They will build their decision using the properties of type 2 information, in other words giving priority to structuring a set rather than accumulating information (type 1). This emphasis placed on the tool before processing the informational context reminds us of the “toolbox” of Gigerenzer’s concepts (“The mind as an adaptive toolbox”) [11].

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<sup>1</sup> Wikipedia

## 8.4 Existence and consequences of a paradox

Not all the difficulties have been resolved, however. In view of the difficulties arising in the field situations, the verdict of reality suggests the potential existence of future obstacles. We will make the assumption, currently only supported by observations, that application of this toolbox depends on a cognitive map and that the map is a simplified representation of the reality of field data, which remain complex.

It is therefore not unreasonable to mention the underlying existence of a paradox for the decision-makers. Since [12] they are all scientists, engineers and high-level technicians experienced in traditional scientific procedures, they will seek to be objective in the decisional choices by applying, naturally one might say, the PEO via the cognitive map to data which are above all complex and dynamic. This paradigmatic tool, imported from the experimental paradigm, too fixist and too simplified and which, finally, provides quality (objectivity) but which in these situations considerably limits the validity. The PEO proves to be poorly adapted to the characteristics of complex systems.

## 9. Conclusion

What can be concluded from the decisional inabilities identified in this document? We observe firstly the importance of the internal consistency of the paradigm, in particular that required between the characteristics of the information and the tools used to process it. We then note that all subjective references involving the personal knowledge and experience of the decision-makers have been carefully avoided. The Italian statistician de Finetti (1906–1985) proposes abandoning the objective definition of probability without this affecting the quality of the judgments. The method used is that of the odds applied to bets on racecourses. This type of quantification known as “subjective probability” is considered as expressing the “degrees of belief” which are clearly cognitive.

## List of acronyms

DMCS	Decision making in complex systems
OEP	Objective experimental paradigm
COP	Conference of parties

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