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Chapter

A Perspective on Cognitive Decision-Making in Dynamic Systems: Are Decision Failures Indicators for a Mutation toward Processing New Concepts?

Bernard Cadet and Isabel Cuadrado Gordillo

Abstract

In numerous scientific disciplines, the decision-making process aims at choosing the most appropriate action to reach a defined objective is a central issue. Scientific literature demonstrates that a wide range of often prescriptive models is available to deal with this sequence. However, one category of situations, involving the intervention of complex, dynamic, and changeable systems (a forest fire for example) generate imprecisions, difficulties, or even incorrect decisions. This largely prospective chapter aims to study these situations from a cognitive point of view to reveal certain recurrent properties of their operation. These indicators may represent milestones for the construction of a new epistemology that would refer to the globality and the dynamism rather than to isolated and analytical entities.

Keywords: decision-making in systems, failures as positive indicators, epistemology and cognition, complex systems and cognitive psychology

1. Introduction

People frequently say that the objective of scientific research is to pursue knowledge to take appropriate action over the world. Adhering to this principle involves special epistemological procedures both as regards the information selection and how it is organized. This document will discuss the diagnosis and decision-making activities, in complex systems. The six sections of this chapter aim to introduce a few fundamental properties to be taken into consideration in the action choices. Section 1 emphasizes that the choice of action is a mental (cognitive) construction to be performed in each occurrence. Section 2 presents the paradigm as a tool for processing information. Section 3 examines the structure of paradigms that aim *objectivity*. In Section 4, examined paradigms aim to ensure that the action is adequate and *appropriate* to achieve the desired result. Section 5 recommends a change in format to study societal or group decision makings. Section 6 analyses decision-making as a dynamic process made from

interactions between sub-systems. Section 7 evaluates the possible consequences of the notions of complexity and dynamism on the subsequent evolution of psychology.

Various epistemological processes will be analyzed, not only as regards their intrinsic content (the case being processed), but also with respect to their contribution to the general evolution of the discipline toward new conceptions and innovative epistemological repositioning using systems rather than variables.

2. Cognitive decision-making from a constructivist perspective

2.1 Salient characteristics

Reduced to its most basic characteristics, decision-making process consists in choosing one specific action amongst those available, than in performing it effectively to obtain the desired effect. The chosen action must be relevant since it meets a requirement. Its implementation must obviously modify the situation in the desired direction. To achieve this effect, a diagnosis must first be made. It consists of a cognitive construction that includes the information selected and processed by the decision-maker[1] as in medical diagnosis.

2.2 A constructed choice and its consequences

How is the choice made? The decision maker's cognitive activity expresses this preference. It refers to the constructivism theory developed at an early stage by Jean Piaget [1, 2]. This pioneering author demonstrated that cognition is far from being an innate characteristic or a predetermined choice of action.

A fundamental epistemological principle must already be laid down the appropriate action choice is not only established on the general properties of certain information. It must also incorporate situational and temporal particularisms. Such a perspective is well illustrated in decisions regarding diagnosis and decision-making issues (in medicine or engineering sciences for instance). The general properties of an illness are given by the nosography, but the particularities result from an individual examination carried out by a clinician.

Nowadays, constructivism has gone far beyond its initial target (the study of reasoning modes in infancy) to be implemented, thanks to technological progress, in social contexts [3]. This current of studies has its distant roots in the work of Vygotsky (1896–1936) in terms of the decision that will be analyzed. The introduction of reference to social groups allows us to study social decisions and social choices. Referring to groups permits to include collective problem-solving and studying group decision-making and its effects on population or social groups, such as acceptability of laws.

2.3 Information: Collecting and formatting in a system

This chapter studies situations in which information is organized in systems. Following a seminal work [4] and for psychologists "A system can be defined as a set of elements that interact with each other." Decision-making is studied in

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[1] To avoid the complexity of inclusive writing, the masculine gender will be used herein. It takes a generic meaning to designate the human being. Its use is therefore not intended to be discriminatory toward anyone.

self-organized systems where all information is organized into interactive systems that, at first glance, seem complex and need a cognitive treatment to be read.

3. The paradigm as a tool

3.1 Definition

The paradigm is defined as being a "dominant theoretical concept taking place during a certain period in a given scientific community, which lays down the possible types of explanation and the types of fact to be discovered in a given science." Note the extreme caution and relativism demonstrated by the authors of this definition[2].

3.2 Specificity

Decision-making is not limited to accumulating information. To be useful, the collected set needs to be organized and structured in order to make it easier to choose appropriate action. Human cognitive abilities are indeed limited not only in working memory but also in various other cognitive tasks (limited perceptual empan (items of information not perceived); illusory correlations, misinterpretations, conservatism, etc. [5]. The operations prescribed by the paradigm can be considered as guarantees against discrepancies in collecting a set of compatible information. Cognitive decision-making (CDM) tasks as a whole need to be constructed taking into account the characteristics of each occurrence. We may, therefore, already think that initially applying general treatment strategies does not appear to be a suitable choice.

3.3 Internal compatibility

Widely used in human and social sciences, the paradigm ensures the consistency and compatibility of the various steps involved in a research approach. This means that the chosen reference theory, the methodology used, the nature of the collected data, and their processing modalities need to be made compatible.

The criterion that such compatibility has been achieved is empirical. It translates experienced people (experts for instance), into fluidity of the linking of the different processing operations when constructing the choice of action.

Choosing an appropriate paradigm is one of the most important cognitive operations to perform to set up the epistemological framework necessary for CDM.

3.4 Epistemological indicator

Paradigms' functions are not, however, limited to these aspects, which can be qualified as internal. In addition to these properties, it is useful to add a new function of any paradigm: its operating value. A paradigm is also a tool set up to produce convergence in information and ultimately achieve a single final action value, which is better than any other.

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[2] *Bibliographic note: CNRLT Ortolang. Centre National de Ressources Textuelles et Lexicales (National Centre for Textual and Lexical Resources). Definition of paradigm [Translated from the French by the authors].

Kuhn [6] gives it a function indicating whether a paradigm is adapted to the problems it studies. When a given paradigm repeatedly fails to deal with concrete situations, a shift to another one is essential. Referring to the title of the book by Kuhn, we are talking about a "scientific revolution," which marks the need to build and use a new paradigm that performs better.

Currently, psychologists mainly use two kinds of paradigms (P1 and P2) to construct CDM. Paradigms of type 1 (a.k.a. P1 type) search for an *objective* choice of action; those of type 2 (a.k.a. P2 type) are looking for an *appropriate* choice.

4. Paradigms of P1 type used in CDM

4.1 Paradigms that search for "objectivity" (type 1)

The implemented action, with a high degree of probability, makes the expected changes to the situation or obtain the expected advantages. This implicit but prevailing condition has led researchers in human sciences to valorize the quest for objectivation. They adopted a paradigm that, since the mid-nineteenth century, has largely demonstrated its efficiency: the objective experimental paradigm (OEP).

4.2 The objective experimental paradigm (OEP)

Although attempts were made previously, particularly in physics and chemistry, it appeared for the first time in the book by Claude Bernard [6] dedicated to medicine. Since then, the approach has witnessed numerous "aggiornamento" and is now considered to be an organized series of well-defined operations [7]. In view of its undeniable successes, in a wide range of disciplines, extending from the formalized sciences to the human and social sciences, at the present time, those adhering to the qualities of objectivity and replicability consider that the OEP and the experimental approach underlie numerous research strategies.

The purpose of this chapter is not to provide an exhaustive analysis of this approach, which specialized reviews do very well [8, 9]. We will simply make comments on two characteristics of this method; a *place* (the laboratory) and a *strategy* (in processing information).

4.3 The laboratory: A privileged location

So that it can be applied, the experimental method must be implemented in a special location, protected from external influences considered to be disturbing: the laboratory. Used systematically in the material and life sciences, it was used for the first time in psychology by Wundt in 1879. Wundt wanted to make psychology a science by aligning the research studies with the procedures used in physiology.

While the laboratory led to the definition of the psychophysical laws concerning the relations between perception and sensation, it only became widely used following Pavlov's studies on conditioning and Watson's behaviorist theory, resulting in the emergence of experimental psychology. More recently, cognitive psychology uses experimental approaches in the study of brain activity in relation to the fundamental conduct of the human being.

The main feature of the laboratory is that it is carefully isolated from the outside world which is, in fact, *a priori* considered as a source of disturbance (interference

variables). We remember the "towers of silence" built by Pavlov to study conditioning. The laboratory provides controlled conditions under which reasoned operations can be conducted on properties considered, by assumption, as being essential.

4.4 An adapted strategy

The laboratory also implies the use of a quite specific epistemology whose function is to "eliminate" from the system the momentary or incident characteristics which exist in concrete situations. The purpose of the epistemological section is to reveal fundamental information, which is always present under all circumstances. To achieve this, the situation studied will be reduced to a set of relations considered by the researcher as being fundamental while excluding, whenever possible, all the others. This cognitive operation is the first step of *scientific reductionism,* which will be accompanied by a second epistemological section.

A *deconstruction-reconstruction* strategy is then implemented and applied to what could be considered as being a cognitive model of the actual situation. Variables are isolated, processed, removed, added, correlated, etc. using procedures intended to reveal their effects and their relations. By manipulating or acting, using an ad hoc device built in the laboratory, any variations observed in the entity studied can finally be recorded.

4.5 The cognitive consequences

As implied by the etymology of the word, epistemology is a branch of philosophy concerned with knowledge. This knowledge stems from the choices of researchers at the two levels of cognition: first collection and then organization of the information collected. The resulting knowledge will depend on the initial stamp of the choices made at these two cognitive levels. These two operations will foster what can be considered a simplified mental reconstruction of the situation rather that the situation itself, which will then only appear in the background.

At this stage, the search for simplification still prevails, in a different form, by explicitly seeking *parsimony* [10] of the explanation (often called Occam's razor). Let us take the example of a researcher who would have two distinct mental constructions explaining the same conduct with equal efficiency; application of the parsimony criterion would lead us to choose the simplest form. However, this type of simplifying approach to knowledge has its downsides, which will appear—which is not at all paradoxical—with the progress of knowledge.

5. Paradigms of P2 type used in CDM

5.1 Paradigm looking for an appropriate choice

One of the main criticisms of the objective experimental paradigm is its highly analytical nature. The initial breakdown into elementary units (or considered as such) does not guarantee that the conduct studied will not lose some of its fundamental aspects, which is all the more likely if the entity studied is complex, like all human conducts.

One of the strategies selected to dismiss this risk simply consists of referring to totality as a source of information. In this paradigm, the very idea of looking for

variables is abandoned, and the situation will be considered as an entity whose global configuration must be respected.

This choice turns out to be quite the opposite of the analytical approaches conducted in the laboratory, which consider globality as being an obstacle to knowledge. The question is nevertheless worthy of being discussed at the cost of an epistemological revolution, can we consider that the concept of globality is a provider of information?

5.2 The processing of globality

Regarding this aspect, psychology may claim a concept developed in the middle of the twentieth century, first in Germany, then in the United States, by psychologist Kurt Lewin. Considered one of the founders of Gestalt Psychology, this author recommends considering conducts (and choices) as global entities which cannot be reduced to the sum of their parts. Globality has its own specific properties: it, therefore, provides information that will be lost if any analytical reduction attempt is made.

Gestalt psychologists are known by the public for having provided examples that involve visual perception applied to reversible figures, demonstrating that the "background" and the "shape" can be alternated. The same graphical representation results in the successive perception of *two* quite different objects or scenes. Far from being merely entertaining, these situations, widely published in magazines, identify two epistemological properties. Firstly, the figure "stands out" from the background *dynamically*, suggesting the underlying presence of active forces. Secondly, the functional alternations imply (semi-) global entities, that is, the figure and the background, but which only have temporary perceptive status. Apart from the dynamism, this type of phenomenon reveals the relativism of visual perception too often considered objective and, finally, may question the validity of the visual testimony.

5.3 The contributions of the gestalt paradigm

The psychological Gestalt concepts have introduced new strategies in the construction of decision-making conduct. The two main references concerning the purpose of this conceptual current are the notions of *force* and of *field*, both used in physics. The decision-making process involves several forces and the action selected is in some respects, the result of a system.

Inventor of action research, promoter of group techniques, and author of a fundamental book, Lewin [11] introduced numerous innovations in psychological research. He emphasizes the importance of the field (environment) and of the time when processing takes place, and alongside this time perspective, he introduces the notion of forces as a determining factor in the choice of action (these properties being adapted to decision-making). Applying the fundamental Gestalt principle, these field characteristics, even when they are evaluated by the same decision-maker, do not necessarily have either the same value or a fixed nature since the time, the environment and objectives of the planned action may vary.

Lewin's premature death and the absence at the time of a methodological framework adapted to the treatment of these notions temporarily limited the scope of these concepts, some of which were only to be confirmed several decades later. We will remember from this trend that the laws stated concern the organization and the properties of the object studied in its entirety and not, as in the OEP, the method used to do so.

On a different subject, the studies conducted by Edwards [12, 13] represent a determining milestone in the "psychologization" of decision-making. By involving

the decision-maker from the start of the processing method as a stakeholder in the construction of the situation (and no longer as an arbitrator who chooses the action at the end of the processing), these contributions will allow new types of processing.

5.4 The notion of facet

As described in the previous paragraph, decision-making consists in identifying an underlying entity (a risk, a critical situation, a state, a disease, etc.) using signs that it produces, which can be observed or even measured in the outside world. The entity is considered in its entirety as being the common origin of the observed or measured signs also called facets, although they are nevertheless varied. This diversity deserves to be considered positively since the variety and diversity of the signs are desirable in order to decrease the initial uncertainty more rapidly.

However, even more than their number, the determining factor is consistency, a cognitive quality that reflects whether the signs are compatible with each other during the various processing operations. The inference approach regarding the nature of the entity concerned requires diversity rather than repetitiveness. The aim is therefore to collect different but consistent signs. For instance, it is possible to identify the composer of a piece of classical music from facets characterizing his style.

5.5 Facets and informational contents

Every facet is an observable expression issued by an underlying entity. It provides information from the outset regarding the source which produced it, so that action can be taken on this source.

Spontaneously, the facet has two epistemological qualities. Firstly, it is multi-determined due to the large number of conditions accounting for its appearance and resulting from interactions. Secondly, each facet has a quality label: it naturally shows the result of interactive effects without having to conceive them in an abstract manner before testing them. The facets result in fact neither from an experimental plan nor from a hybrid created according to previously selected procedures. The facet is determined from *tangible* influences, not from abstract suppositions.

6. A change of format for decision-making situations

6.1 A positioning in a natural, open space

By abandoning the laboratory and its associated methods, it will be possible to study new types of situations and direct the interest of researchers toward the processing of decision-making or prediction situations treated *in situ*. In view of the need for knowledge related to social evolution, psychologists have had to deal with a completely different type of decision-making, in which the effects are not expected but have already been produced. As a result, situations in natural environment (i.e., outside the laboratory) must be taken into account; these situations include numerous variables which are often difficult to identify and which generally include interactions at various levels.

Some concrete examples of this change of structure and of the decision-making difficulties it generates are deeply engraved in social memory. The collective memory

was marked by the forest fires in California (summer of 2018) and the bushfires in Australia spreading rapidly from December 2019[3] and which would only be brought under control in March 2020 despite the considerable firefighting means implemented.

6.2 Social decisions

These situations receiving wide media coverage include (in particular) forest fires and pollution.

Decision-making difficulties are also encountered in similar forms in the management of marine pollution due to oil spills from tankers. There are numerous examples. We will only mention three of the most well-known. The Amoco Cadiz (1978) [14] caused major pollution after sinking off the Brittany coast (France); in a similar event, the Exxon Valdez (1989) seriously polluted the Alaska coastline and the sinking of the Prestige (2002) led to an ecological disaster with a major tourist and economic impact to the northwest coastline of the Iberian Peninsula.

Other situations of identical architecture, such as management of a pandemic or of global warming place, the decision-makers in situations in which they are faced with cognitive obstacles. Unlike the previous paradigm, the decision-makers are not responsible for creating the situations, they simply observe that they exist and that they have their own dynamics.

6.3 Interpersonal decisions

On another level, which confirms that it really is the architecture of the situation and not only the number of persons concerned, which must be considered, we find two recurrent societal issues. There is in fact a need to make decisions rapidly to deal with situations involving clearly identified individuals or social groups. In this respect, two types of situations are characteristic: firstly, family violence and abuse by adults on children, and secondly, school or group harassment by peers.

The studies conducted on bullying Refs. [15, 16] demonstrated that while the conduct of the persons involved, aggressors and victims, depended on personal psychological characteristics, those of the field (cyberspace) played a determining role in the expression of their intensity, their permanency or their termination.

Whether social, within the meaning of the group, or social, within the meaning of the presence of another person, these situations require a different epistemological position.

7. An epistemological shift: intermediate and complex systems

7.1 A necessary intermediate formation

At the time of Gestalt, since no suitable epistemological framework was available, the Gestalt concepts were easy to observe (descriptive validity) but difficult to use in practice (predictive validity). One of the missing links, not mentioned by these authors, is that of sub-systems. The authors concerned, focusing mainly on demonstrating the globality of the conduct studied, took little interest in its determinants.

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[3] Which corresponds to austral summer.

They simply stated descriptive "laws," emphasizing the characteristics of the entities to be processed.

At a very early stage, two psychologists [17] demonstrated, from a completely different perspective, the existence of intermediate structures or formations, of different types, between the information present at the input of the processing system and the behaviors or conclusions observed at the output.

These authors point out the intervention of the intermediate systems that operate between these two poles and play a structuring role in processing the message. A fundamental transformation concerns the sensorial inputs, which, from the outset, are assigned a meaning which gives them a cognitive status. For visual perception, for instance, the metaphor of the camera and of the objectivity of the perception proves to be more a post hoc reconstruction than a reality.

7.2 An epistemological breakthrough

Since then, the progress made by research in other disciplines (in particular, meteorology, nonlinear bonds, astrophysics, and thermodynamics) encourages researchers to postulate that these intermediate systems (which are in actual fact sub-systems) determine the characteristics and evolution of the entire system.

The discovery of the underlying dynamics had such an impact that it shook the foundations of epistemological concepts, which had been considered as reliable guides for several decades. It is, particularly, well expressed in the famous assertion of the flap of a butterfly's wing by Lorenz in 1972 which, after a period of cognitive disarray clearly reflected by the term "theory of chaos," led to a new way of building science [18]. The scientific study of these new situations is no longer compatible with the intangible framework of earlier epistemological conceptions (Descartes, Newton, Laplace). In contrast, the notions of system, sub-system, ambient environment, and internal forces will form novel tools, adapted to the study of the underlying dynamics.

7.3 Epistemological theorization

In 1968, as said before [4], a book was published that emphasized the usefulness of the notion of system as an epistemological framework relevant to numerous scientific disciplines (including psychology). A more recent contribution [19] provides a recent update on how the theory of complex systems is (or could be) used in the social sciences.

The initial contribution brings arguments to use a unifying theory of complex systems. Beyond the specificities of each discipline, a common background looms[4].

7.4 Some important methodological features

Very briefly outlined, the selected situations share well-known structural and functional properties.

- A system is a global structure (forming a whole) composed of elements (basic units) interacting in various ways.

- The relations between globality and elements cannot be reduced to the sum of the parts.

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[4] Note the singular used in the title of the first edition of the book: *General System Theory*.

• These interactions are generally nonlinear and may vary over time, which automatically prevents the use of arithmetic proportionality for the inference.

• The system is dynamic. It evolves "spontaneously" (i.e., on its own resources) depending on the conditions it encounters in its environment).

• When human operators want to control or direct the subsequent evolution of the system using "governance" process (i.e., put out a forest fire or reduce a pandemic), the system may "resist." From a behavioral point of view, this results in a failure of the methods implemented by the operators to control the situation.

The temporal dimension, unlike the previous paradigms, the paradigm of complex systems places significant emphasis on the temporal dimension. The initial states of the system, which are essential to determine their subsequent evolution, must be known. It is also useful to specify the mental or cognitive patterns of the decision-makers and, if possible, to know the type of paradigm to which they are initially referring (which is generally not taken into account).

8. The contributions of the paradigm of dynamic systems on the evolution of psychology

8.1 Paradigm of dynamic systems

The psychological decision-making processes do not only provide substantive indications (i.e., specific to each case). By adopting a transverse and, therefore, chronological perspective, the evolution of psychology can be characterized using internal factors that are responsible for its mutations or progress. A first observation shows that evolution is not linear. It is not based on continuous capitalization of knowledge but improves, as pointed out by Kuhn, in successive steps, from one paradigm to the next that has a higher explanatory potential. A second comment concerns the homogeneity versus heterogeneity factor. Homogeneity is a paradigm *infra* quality since each decision conduct, irrespective of its specificities will be built using the concepts and methods present in the paradigm, which, thus proves to be an operational reserve. Heterogeneity is a paradigm *supra* quality. It indicates paradigm changes.

8.2 The decisionmaker's cognitive activities

The succession of decision-making paradigms is indicative of a double concern experienced by researchers. Firstly, avoid any form of extreme reductionism or simplification of the problems. Secondly, the need to build a satisfactory and efficient mental representation of the dynamics of phenomena capable of extending beyond the perceived complexity. The decision-maker selects the information according to the properties of the paradigms.

The OEP does not avoid the first obstacle but provides, due to its simplicity, a topographic cognitive map, which, although incomplete, is easy to use. The paradigm of the dynamic systems does not avoid the second obstacle when it attempts to

evaluate functional quantities, in other words momentary landmarks of the operation and not of the structure.

The decision maker's cognitive status and the type of operations to be performed will be different as soon as the initial choice of paradigm has been made. Each researcher initially opts for a school of thought whose opinions or ideas he shares. The choice of processing methods primarily depends on the decision-maker's personal options.

8.3 Overall lessons learned

How can we summarize the quasi-temporal succession of the paradigms described in this chapter?

- The first is organized so as to obtain a quality that is fundamental to the action: its objective nature. To achieve this, the simplification condition is applied.

- The second, probably chosen as a reaction against the outrageous applications that distort the subject of the studies, decides to process it in its natural position and its globality.

- The third is defined by focusing on the notions of organization into systems (at several levels) of dynamism and of forces and insertion in an open, active, and changing context.

8.4 Does negative become positive?

In many respects, the paradigm of complex systems results in making radical changes to the status of some characteristics of the information. A Copernic revolution occurs what was previously considered negatively and, in this respect, controlled and eliminated from OEP-type processing, becomes, in the perspective of dynamic systems, a source of information.

As we have seen, the laboratory used to isolate the situation studied from the outside world becomes a distorting mirror. Similarly, the decision-maker is assumed to be in a position of relative cognitive neutrality. His opinion is not finalized, leading him to examine numerous partial assumptions. In contrast, in situations of recognized complexity, the decision-maker uses a cognitive block from the outset. This knowledge tool consists of the information present in the situation and analysis registers controlled by the decision-maker. The individual and the situation must therefore be considered as a whole, without splitting them.

This type of recommendation involves major epistemological extensions since the specificity of each cognitive block takes priority over its general nature. Based on this observation, we see that, for numerous situations displaying differences initially considered as minor, it is unrealistic or even deceitful to apply exactly the same processing method on the mere grounds of a previous success. Each situation/decision-maker block has its own specificities and we know that, in complex systems, minor differences at the start of the processing may generate fundamental differences in the conclusions. As a result, the decision-making activity in the systems must also look for, in addition to the general aspects, the specificities and variabilities, since they are sources of information.

9. Conclusion

Three key steps can be identified in this chapter. Each one represents a polarization of the research approach toward an organized objective in a paradigm. The first group of researchers [5, 8–10], naturally focused on objectivity, considering the scientific context of their time. Without abandoning the search for this quality, their successors [4, 11, 18, 19] realized that the very high domination of method over subject led to conclusions, which, although correct, were difficult to transpose to the reality of the situations.

The adoption of new investigation approaches is characterized by three options: process the globality, process the conducts in natural environment, consider the forces and the dynamisms of systems (and sub-systems where applicable). Applied to decision-making processes in special situations, these new approaches also have a very strong impact on the overall evolution of psychology and on its mutations toward new boundaries.

Author details

Bernard Cadet[1]* and Isabel Cuadrado Gordillo[2]

1 University of Normandy, Caen, France

2 University of Estremadura, Badajoz, Spain

*Address all correspondence to: bernard.cadet50@gmail.com

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