The Ways of Scientific Anticipation: From Guesses to Probabilities and From There to Certainty

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Abstract. Science of anticipation can be distinguished into three kinds, each relying on a different psychological mechanism. Further, these mechanisms – based on everyday conceptual thinking, thinking in logical concepts and thinking in systemic concepts, respectively – are in hierarchical relationships the first being the least developed and the last the most developed form of (scientific) thought. Each of these three sciences has specific to it understanding of what is scientific explanation and by which methods the explanation can be achieved. It is noteworthy that following from the epistemology and methodology of each of the three kinds of sciences, different forms of scientific anticipation can be achieved. The least developed everyday conceptual science grounds anticipation essentially on chance discoveries of patterns in everyday observations. Logical conceptual thought allows formalization of anticipation, mathematical in the first place. Yet formal anticipation is limited, because it does not contain understanding of why, by which mechanisms, certain events – "causes" – are followed by others – "effects." This limitation can be overcome by structural-systemic science, which grounds anticipation on explicit understanding of the structures and the ways they change.

Keywords: Science of anticipation, psychic mechanisms, everyday concepts, logical concepts, structural-systemic concepts

Déjà vu

In 1925, relatively well-known at that time British-American psychologist William McDougall gave a lecture where he introduced his understanding of psychology as follows:

> I seem to be in a position analogous to that of an anatomist called upon to defend the proposition that man is a biped, or that of a physiologist required to prove that man breathes air. That is to say I am expected to support by argument a fact familiar to all men through first-hand experience, a fact so familiar and well established that it has become embodied in the very structure of all languages and is recognized and acted upon by all men in all the practical conduct of daily life. This is a strange and embarrassing position for any man of science. ([1], p. 273)

What was this so obvious idea that for some reason he had to defend as novel? In 1930, he wrote on this subject referring back to a little earlier time – time that today is almost exactly a century ago:

> Fifteen years ago American psychologists displayed almost without exception a complete blindness to the most peculiar, characteristic, and important feature of human and animal activity, namely, *its goal seeking*. ([2], p. 3, my emphasis)

McDougall was indeed talking about his so-called Purposive or Hormic Psychology which essentially proposes that "man's acting and thinking are purposive" ([1], p. 273). If human behavior is purposive – and it is – then obviously it involves anticipation. Purpose is a description of the future state of affairs that is achieved if behavior leads to expected results. Thus purpose can be understood as a prediction of the changes of the environment and organism-environment relationships. So it seems to be rather naïve – if not to say self-obvious – to prove that anticipation is useful. And yet the books, conferences and workshops dedicated to anticipation began slowly to emerge in Anglo-American science during last three decades only.

We are slowly rediscovering the obvious; just a decade ago a conference summary proposed – "it is no overstatement to suggest that humanity's future will be shaped by its capacity to anticipate, prepare for, respond to, and, when possible, even prevent extreme events" [3]. Reading this statement the feeling of *déjà vu* should be strong for anybody with some knowledge of the history of life sciences beyond Anglo-American. Russian neurophysiologist Piotr Anokhin, for example, proved already almost a century ago that anticipation and based on it purposeful action is not just about making life better – there would be no life without anticipation and corresponding result-oriented action. It is so because to be alive means to survive in environments that can change beyond tolerance limits of a living organism at any given moment ([4, 5], see also [6]). Such survival is possible only when an organism is able to anticipate potentially harmful changes of the environment – only then it can act by changing either the environment or itself so that environmental change does not lead to destruction of its integrity.

These thoughts I just expressed are rather deconstructive – what good can come out from the statement that "all this has been here before"? I think understanding the situation where we are at the moment with our science of anticipation is necessary for defining its future. If there seem to be difficulties or problems now, these must be discussed. Furthermore, our whole Study Group – Anticipation Across Disciplines – is defined in a way, which actually supports the conclusions I just arrived at and also shows what constructive can come out of this. One of the three areas of work is dedicated to ... Learning from the Past.

Science is usually supposed to be cumulative; later developments are thought to surpass the earlier. Yet it is not always true. There are periods in science history where the opposite turns out to be correct – past is ahead of the most recent. There are all the reasons to suggest that this is exactly where psychology is standing at the very moment: last 60 years of research have not contributed much to better understanding of the (human) mind. In fact, psychology of the first half of the 20th century is ahead of today's mainstream psychology [7-12]. This is the idea I wanted to arrive at with my introduction. The ideas I am going to develop in this chapter are directly rooted in "old" pre-WWII Continental European psychology. I do not see much use of modern mainstream psychology (see for definition of it, [13]) for this direction of thought; path to future seems to lie through going back to past and continuing from where they stopped.

Why we must have psychology of anticipation

Readers of this chapter may feel that my comments on the state of psychology are not related to anticipation research in other fields of science; state of psychology may seem to be irrelevant for them. Yet it is not so. Let us go back to a short quote by McDougall, I brought above: "man's acting and thinking are purposive" ([1], p. 273). All studies in all fields of sciences are cases of purposive acts based on purposive thinking. Let me add here one more idea, a little older. Plato, through the mouth of Socrates, made in his *Phaedrus* an interesting statement:

> I am still unable, as the Delphic inscription orders, to know myself; and it really seems to me ridiculous to look into other things before I have understood that. [14], p. 510, 230a1-3)

I think this statement has more in it than it superficially may seem. If we would like to improve our ways of anticipation in particular or any scientific study in general, it is necessary to know ourselves as mental beings. Why so? The reason is that there is more than one way in which our mind can operate. There are different ways of thinking that can be arranged into a hierarchy of development beginning from the most primitive mechanisms of noticing associations between sensory events to most complex ways of organizing knowledge structural-systemically (see Russian psychologist Lev Vygotsky's grounding works on the hierarchy of thinking mechanisms [15-18] and [6, 19-21] for recent developments of this theory). Developmentally later and more complex ways of thinking are also more efficient in making sense of the world.

Psychology cannot formulate principles of the most advanced form of thinking before it has emerged and is used – psychology can only discover it. But after discovering, psychology can describe this form and, through this, allow to decide rationally, which mechanism of thinking to apply in solving the problems ahead or to discover which form of thinking was used in creating what we already know. Here lies exactly the potential use and power of psychology – if it can describe the mechanisms of thinking, it brings them under our control and helps to avoid moving inconsistently between more and less developed forms of thought without ever noticing it. I think psychology – especially a non-mainstream branch of it that explicitly grounds itself on past theories skipping the present – is ready to provide that ground.

We do not need all the theory of thought at this point. In the following I am going to describe three developmentally latest forms of thinking. This can be done in different ways. For our purposes – to advance anticipation studies – the best way, I believe, is to take a look at these forms of thought from the perspective of science methodology. Before going further, I think it is necessary to mention that methodology is not sum of scientific methods. Methodology is a theory of scientific methods – it answers the question, why we think [sic!] our methods provide us path to answers we as scientists are looking for. Why, for instance, we think that mathematical data analysis can reveal hidden from direct observation mechanisms that underlie observed phenomena. After asking this question we discover that – it cannot [22-26]. Other similar questions about our scientific methods of study – which include the choice of the things or phenomena we study, tools and tasks we use in our studies, "data" we construct on the basis of our observations, and data interpretation methods – must be asked and answered in the same way.

Methodology is not the most fundamental area of questions for scientists to ask. Methodology is grounded on understanding – explicit or implicit – of what is scientific explanation. Without going into details on this point, I think it is justified to equate scientific explanation with description of causes of studied things and phenomena (see, e.g., [11, 27, 28]).[1] Here it is important to realize that causality can be defined in more than one way. Thus the question about scientific explanation can be also formulated as a question about what "cause" means. Without answering that question we are not able to ground methodologically our decisions about choice of methods. Overall, three qualitatively different definitions of scientific

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[1] It should be also mentioned that there are many theories of (scientific) explanation as well as of causality. The theory of scientific causal explanation I am describing here is based on a developmental theory of human thought operations. It is beyond the scope of this chapter to discuss why it is feasible to follow this and not some other theory of scientific explanation.

explanation can be distinguished in modern sciences. Research methodology and methods correspond to the views on scientific explanation. Each of the stages of thought development is also related to different ways of (scientific) anticipation. At the same time, these three views correspond to three last stages of thought development. First I introduce very shortly these stages of thought development.

Everyday concepts, logical concepts, and structural-systemic concepts

All living organisms have receptors that react to certain set of physical-chemical events in their environment. Developmentally the earliest way to anticipate events in the environment and act accordingly is based on purely biotic mechanisms. Living organisms relate to their environment on the basis of species experiences. Next in phylogenesis, psychic ways of organism-environment relationships emerge. Psyche is based on individual experiences (see for definitions of life and psyche, [6, 29, 30]). Even though more complex ways of representing world on the basis of individual experience develop (cf. [18, 19]), these all are constrained by the senses; nothing beyond sensory-based regularities of the world can be represented. Human world is different. Over the history of human race, knowledge about the world beyond senses has been accumulated. How is it possible to have reliable and valid knowledge about the world we have no sensory contact with? Roots of the answer to this question lie in Vygotsky's theory, according to which humans have developed unique way of thought – thought, in the structure of which a linguistic sign is an essential element (e.g., [15, 17, 18, 31]). I have shown elsewhere, how semiotically mediated thought is the mechanism by which limits of the senses can be overcome [32, 33].

For us it is important that structure of linguistic sign – or 'word' in generalized sense, as Vygotsky used – develops over a hierarchy of stages. Thus there are, according to him, three consecutive stages of word meaning structure development, which correspond to three general stages of cognitive development [15]. Vygotsky called the stages syncrets, complexes or everyday concepts and scientific concepts, respectively. Based on vast amount of knowledge accumulated after his death, it is now possible to distinguish not three but five stages [20]. Last three of them are of particular importance in the context of anticipation science as the two earliest stages of word meaning development – those of syncretic concepts and object concepts – are not differentiated enough to ground organized search for knowledge as the last three stages allow.

So, first, so-called *everyday concepts*. Everyday concepts allow to describe in language all the sensory-based world, it properties, objects, and relationships between objects. Categories, referred to by the words are with fuzzy boundaries. Language, being a medium where symbols can be used differently from their referents [33], allows to construct expressions and narratives, which content refers to the world beyond senses. Fairy-tales, myths, and religions belong to this class of creations. Yet there is no way to distinguish reliable and valid inferences about the world beyond senses from imaginary. Another side of these imaginary worlds is that they all can be "translated" into sensory-based experiences. Angels are just people with wings and a god is an old man sitting on a cloud.

Reliable and valid inferences about the world beyond senses can be achieved relying on *logical concepts* (akin to Vygotsky's "scientific" concepts). At this stage, it becomes possible to evaluate the structure of one's own thought – logical forms of inference are clearly distinguished from those that are not logical. Among other attributes of logical-conceptual thought, the words refer to categories with clear yes-or-no boundaries. Logical clear-cut structure of concepts, in turn, grounds the ability to distinguish imaginary worlds from realistic worlds beyond senses.

Science in the modern sense emerged at this stage of thought development. Logical concepts are also limited in their use. The main problem lies in the weakness of all logical inferences – formally correct inferences are also realistically correct if and only if the premises of them are correct. Thought in logical concepts does not ground basis for selecting premises of inferences.

At the final stage of thought development, that of *structural-systemic concepts*, the whole process of sense-making is made conscious. The clear-cut logical structures are contextualized both in terms of the world described by them as well in terms of the thought processes that underlie sense-making of the world. Now not only inferences but also their premises and sources of the latter can be explicitly studied. From scientific activity point of view, I would suggest, the main characteristic of this stage of thought is an ability to distinguish and define all relevant for scientific enterprise ideas from most abstract epistemological and ontological principles to most specific concrete aspects of scientific methods. Knowledge formulated in this way can develop into a coherent whole where each element is clearly positioned in respect of others in the whole of scientific thought.

Next we see, how these different mechanisms of thought are related to views on scientific explanation and corresponding methodology and methods. Each of the stages is also characterized by the specific form of (scientific) anticipation that can be achieved at that stage. In this chapter I look at the development of thought from the anticipation science perspective. This I have not done before. The overall idea of relationships between word meaning structure development and scientific methodology, nevertheless, has been discussed elsewhere [11, 27, 34, 35].

Everyday concepts and phenomenological qualitative science

Scientific explanation

Thinking in everyday concepts is characterized by fuzzy boundaries of categories referred to by words. This way of thinking, thus, does not distinguish clearly and unequivocally neither qualitatively different phenomena one from another nor the researcher and his or her way of thinking from what is studied. One consequence of that kind of limit on thinking is expressed in understanding, what is (scientific) explanation and causality – there is no understanding of it. In an unbounded world everything seems to be constantly changing; therefore instead of studying what things are and in which ways they lawfully change, everyday conceptual science focusses on process, on change.

A reader may feel now that even if that kind of science may have existed in some remote time in the past, it does not exist any more. In fact, this kind of science – which by its essential characteristics is more akin to art than to science [36] – exists today in many areas of social and human sciences (cf. [11, 28, 35]. I am not going to put too much effort into proving that this kind of scienting is increasingly common today; there are too many sources available to prove that (e.g., [37]). So I just provide a quote showing that there is a kind of science, indeed, which is not able to distinguish between who is studying from what is studied:

> We have left the world of naïve realism, knowing now that a text does not mirror the world, it creates the world. Further, there is no external world or final arbiter—lived experience, for example—against which a text can be judged. ([38], p. xiv)

Others have been even clearer. One quite popular approach in modern qualitative science has formulated several assumptions that underlie their methodology; the first of them states:

> Assumption 1. The external world is a symbolic representation, a "symbolic universe." ([39], p. 6)

So it is made clear that the "external" world cannot be distinguished from personal. Further, there is also no clear understanding of what kind of understanding is searched for. It is rather collection of endlessly growing descriptions which basically lead nowhere:

> At some point we [qualitative researchers] ask, 'Did we get the story 'right'?', knowing that there are no 'right' stories, only multiple stories. Perhaps qualitative studies do not have endings, only questions. ([40], pp. 44–45; see also [41], and [42], for similar ideas)

Research methods

Everyday conceptual thinking is not able to go beyond directly perceivable facts about the world. Even though many methods are used in this kind of science – interviewing; direct observation; the analysis of artifacts, such as documents, photos, diaries, etc.; the use of personal experiences etc. – all these methods can be reduced to one: description of directly perceived experiences. Without constraining artificially study conditions it is not possible, however, to go beyond appearances, superficial subjective descriptions of personal experiences. The world beyond senses can be understood only by manipulating environment of the studied things, be them physical, living, or psychic. So the research methods of everyday conceptual science reflect the essence of that stage of thought development.

Scientific anticipation

It might seem that everyday conceptual science can result in no reliable anticipation. Indeed, science that is explicitly based on confusing the world with the semiotic representation of it and relying on methods that cannot do more than just describe what seemed to the researcher to be interesting at the moment, could end up with nothing more than what they claim the world to be – a personal story with no valid connection to the world. Yet it is not entirely so.

Everyday conceptual qualitative science collects observations and finds regularities in them on inductive-intuitive basis. It is important that there are two possible bases for regularities in such a process of data interpretation. As observations that are analyzed are observations of the world, the regularities that are recognized in the data may reflect regularities of the perceived world. Such regularities can lead to beyond-chance level predictions of some events in the world. But there is also another ground for regularities that cannot be distinguished by everyday conceptual thinker from the first. Namely, observed regularities can be purely subjective, intralinguistic. A researcher may observe certain regularities and find further support for them not because there is some regularity in the world but because he or she just selects observations that correspond to the prediction and rejects others that do not correspond. In that case the criterion for regularity is purely subjective: if it is possible to relate certain observations one to another in a certain way then the researcher just does it. As in semiotic systems every sign can be in principle related to any other sign – because all linguistic signs can in principle be used in ways and contexts that are different from the referents of the sign [33] – the researcher is actually unbounded in "discovering" regular patterns in observations. These patterns, however, would be intrapsychical with no necessary connection to the world observed and described.

As the criterion for deciding whether reliable pattern was discovered – a category of observations, for instance – is subjective, then a researcher may end up with interpreting the collected data as "making sense" – because intuitively it feels in this way. Without clearly distinguishing the way of one's thinking from the world thought about, realistic and subjective patterns of observations cannot be distinguished. Paradoxically there is also no way to demonstrate to everyday conceptual thinker that the "results" of this kind of studies are only accidentally reliable and never valid about the world beyond senses. The reason for this impossibility lies in the fact that for that researcher subjectively all may "make sense"; it may "feel" meaningful. No rational argument can refute that kind of feeling.

Logical or "scientific" concepts and Cartesian-Humean science

Scientific explanation

Logical conceptual thinking distinguishes process of thought – logic – from what is studied and made sense of with these thought operations. Correspondingly it becomes possible to specify, what is (scientific) explanation as a form of thought about the world. Further, the form of logical concepts is hierarchical; they comprise intralinguistic hierarchies where higher order words refer to a category of lower-order words, which, in turn, refer to sensory-based experiences. A possibility to reflect on thought processes allows at this stage of thought development to explicate the criteria by which categories are composed. This quality of logical concepts allows to distinguish between kinds or categories of the bases of categorization. One specific category – that of scientific laws – can be distinguished among others.

So scientific explanation becomes a description of those laws that are discovered in studies of the world. The concept of law is directly related to Cartesian-Humean view of causality. According to that view, causality is defined as a relationship between two events, cause and effect. Cause is an event that precedes and is necessary for the emergence of another – following to cause – event, the effect. Scientific law in this case is formally and exactly – often mathematically – described cause-effect relationship. It should be noted that there is also a weaker in terms of causality version of a scientific law, where cause and effect are not clearly distinguished. This kind of a law formulates exactly the relationship between two events without a requirement of the cause to bring out the effect. Newton's laws are examples of the latter kind.

Research methods

All living organisms have access to the world external to them only through senses. Humans – and scientists among them – are not exceptions. Therefore all knowledge about the world can be based only on observations of sensory-based experiences. It does not follow, however, that all observation-based inferences are in principle the same. There are two sources of fundamental differences between ways of making inferences on the basis of observations. On the one hand, as I have already shown above, there are different psychological mechanisms by which inferences are made. On the other hand, the qualitative difference is introduced by a possibility to manipulate with conditions of observations.

Everyday conceptual science relies on *observations of events in naturally occurring situations*. Such observations are necessary for any kind of science. Yet they are not sufficient for logical conceptual science. The reason is that any event in the world can be described in endlessly many ways. Scientific laws are not really about relationships between specific events. Rather, they are about relationships between categories of events. Depending on in which exact way potential cause-events and effect-events are described, the categories of events that are formed will be different. So a researcher needs in addition to establishing some preliminary hypothetical causal association between events – which can be done on the basis of observations or earlier theory – find out the basis for categorizing the events so that an exact law can be formulated.

Logical conceptual thinking allows to specify exactly the bases of categorizations. Every attribute that is individually necessary for a thing or phenomenon to belong to a certain category is explicitly defined. This allows to choose purposefully for different bases of categorization and discover eventually the best set of attributes that defines the category. A researcher thinking in logical concepts can manipulate with external environment and together with it with the attributes that define the category of events studied. In other words, a researcher can conduct *evocative experiments* – artificially created study-situations where attributes of situations can be explicitly manipulated with the aim to establish, which aspects of a situation are necessary to call or evoke the "effect" into existence. I use the term 'evocative' here to distinguish this kind of experiment from another, what I call *constructive experiment*. The difference is explained in the next section, where structural-systemic science is described.

There is a third class of research methods that is applied in logical-conceptual science. Everyday observations and theory is not always sufficient to formulate a hypothesis about cause-effect relationship that could be tested in experiments. In this case often one step between everyday observations and experiments is introduced – let us call it *constrained observations*. In this case researchers constrain study-situations artificially and search for patterns of relationships between events with no *a priori* hypothesis about the exact structure of the pattern in the data. If some reliable pattern is discovered, it can be further tested by evocative experiments for establishing a cause-effect relationship.

It is also important, *how the results of evocative experiments are interpreted* in logical conceptual science. Namely there is a problem that needs to be solved – no exact law would emerge from experiments, however well controlled and conducted. The reason is that it is impossible to create closed systems; all experimental situations take place in to some degree unpredictable compositions of the open-systemic study-environments. Therefore necessarily the experimentally observed putative cause-effect relationships will never be mathematically exact. This problem is solved by abstracting the studied relationship from all possible contexts. An *exact mathematical law* is formulated that is supposed to be valid only in theoretical situations where the abstracted cause-effect relationship is isolated from the rest of the world. With this move from real situations to abstract, mathematical formulas brings a new problem to be solved – how to apply the formula in real situations.

This problem has two solutions. Informal solution is to accept the discrepancies between formulas and real-life situations. The cause-effect formula just "works well enough." Another solution is formal: it is possible to calculate the chances the law corresponds to real-life observation. In that case an exact theoretical probability is achieved to predict the chances the established law will or will not be observed. This exact probability, obviously, is abstracted from reality and is valid only in theoretical cases of observations that are supposed to correspond to empirical observations without a "noise".

Scientific anticipation and its limits

History of science knows many discoveries based on logical conceptual science – Newton's laws are perhaps the best known examples. These laws also demonstrate the weak points of them. The problem was introduced already millennia before Newton. Science is supposed by many to be mainly if not only about measurement – after measuring, the beautiful language of mathematics allows us to make sense of the whole of all the measures we have collected. Measurement, in turn, is, as Plato wrote through the mouth of the Visitor in his *Statesman*, about

> the association of greatness and smallness with each other [...] all those sorts of expertise that measure the number, lengths, depths, breadths and speeds of things in relation to what is opposed to them ([43], p. 326, 283d7-8 and p. 328, 284e3-5).

Yet the Visitor would not agree that measurement is only about quantities. He was sure that there is another class of phenomena that also must be measured:

> [...] measurement [...] let's divide it into two parts [...] one part will relate to the association of greatness and smallness with each other, the other to what *coming into being* necessarily is ([43], p. 326, 283d4-9, my emphasis)

I think here lie at least two fundamental limitations of measurement-based formal predictions. Both of them emerge because only first and not the second of the Platonic "measurements" is expressed in formal models. First, establishment of a lawful relationship does not explain, why events are related in this or that particular way. Another – and directly following from the first – problem is that if in real life it is discovered that the exact law did not predict events as expected, there is no understanding, why the prediction failed. Or, in other words, such laws do not contain information about how to get the event we want to happen when the law fails.

Scientific laws discovered in studies and then abstracted from reality and formalized through the thought operations are powerful tools for anticipating future events. This power does not apply in all cases due to the limited epistemology that underlies the logical conceptual thought: efficient causality or the cause → effect relationship between events is detached from the mechanisms by which actual changes of the world take place. The problem is that in efficient causality *events* are related one to another. But event is a change of some observed system with a complex structure. Event is essentially a psychically constructed segment of constantly changing material world. A temporally extended unit, i.e. event of change, cannot force or "cause" something else to happen; change is the process of happening itself. If an event is conceptualized as an entity, as some "cause", then the actual change is transformed into a fixed unit that does not correspond to the original segment of a process. Event as a fixed unit is abstracted from reality entity of thought, not of external reality that referentially matches the thought.

Events as "causes" cannot reveal the mechanisms of change because there is no constraint on how an event is conceptualized. The very same event can be described and interpreted in endlessly many ways and therefore there is never certainty that only causally necessary attributes of it are chosen. Further, causes as events are also defined negatively by lack of usually unknown qualities – causes are abstracted from reality.

Let us take a simple causal series of events: a moving billiard ball hits the other ball, which begins to move after the hit. We may think that we have scientifically understood the event, when we can formally express the causal relationship between the cause – movement of the first ball, and effect – movement of the second ball. We may know that "the acceleration of an object is directly proportional to the net force acting on it and inversely proportional to its mass." Usually the second ball moves after caused to move by the first. The formula – within certain limits of error – explains the change of the movement. But if we for some reason encounter a situation where the second ball does not move after being hit, the formula becomes useless. In the formula we have the mass and the velocity of the balls. If the formula does not predict the reality, we would not constrain ourselves only to studying the mass and velocity of the balls. We would also study the table, the stick we used for hitting, the relationship of the balls to the table and perhaps other things. Maybe somebody just magnetized the second ball and then fixed the position of it by the magnet under the table. In that case not only the mass but also the material of the ball becomes relevant, because only some materials can be magnetized. There is no place in the cause-effect formula where the material of the ball is taken into account.

There is also another aspect that is not represented in cause-effect predictions. Namely, there is no information in the exact formulas about how to restore the state of affairs after a cause has had an effect. Formula would perhaps tell us to take the "cause-ball" back at the speed and direction it hit the "effect-ball". We would discover that it does not restore the situation as it was. This fact reveals from another perspective the same problem of predictive formulas – there is no information in them about what the events and things *are*. So there is probabilistic anticipation but no understanding of what is changing and why – unless "why" is "explained" by essentially empty and circular statement that effect happened *because* there was a cause.

In the previous section I discussed shortly the ways the data are interpreted in logical conceptual science. We saw that formal laws can be formulated only when abstracted from reality. To account for mismatch between the formula and reality it is supposed to reflect, probabilities of the observability of the formal cause-effect or covariative relationship can be estimated. What is not often thought about in such cases is that any way to create a formal formula of probabilities of certain events to be in cause-effect – or any other covariative – relationship suffers from the same problem as the direct formal expression of supposed cause-effect relationships. The formal probabilistic formula is also valid only in theoretical abstract isolated from the real world situations. We would need another probabilistic formula to predict the chances the first formula predicts the probabilities correctly ... and another for the second formula, and another for the third, and so on *ad infinitum*.

Altogether, it can be said that formal prediction can be powerful but yet limited in being necessarily probabilistic. There are two fundamental problems with formal prediction. First lies in the fact that formalization requires abstracting from reality. The second limit of formal prediction stems from the fact that formal models are based on limited efficient causality epistemology, which allows to reveal covariative and asymmetric in time cause-effect relationships between observed events but not the mechanisms of change that underlie the events and their relationships.

Structural-systemic concepts and structural-systemic qualitative science

Scientific explanation

Structural-systemic thought distinguishes the thought operations from the things and phenomena studied and, at the same time, defines the way the first is related to the second. Among other consequences to this development of thought, the logical-conceptual scientific laws are not considered satisfactory any more. It is recognized that such laws are essentially human-made abstractions that reflect only limited aspects of reality and are not fully suitable for making sense of open systems. Scientific explanation becomes more complex also. To explain something scientifically becomes a question about structure of a studied thing or phenomenon: what are the elements, in which specific relationship and what characterizes the novel whole that emerges in the synthesis of the elements.

This kind of explanation – even though usually not stated as such – is quite common in many branches of modern sciences. We understand atoms as systems of elementary particles; we understand molecules as systems of atoms; we understand genes as systems of certain acids; we understand living cells as systems of organelles and other distinguishable elements; we understand multicellular organisms as systems of organs, etc. It is noteworthy that none of these theories require mathematics;[2] all the elements, their relationships and qualities of the emergent whole can be defined qualitatively (see for definitions of mathematics [26]).

Research methods

As at previous stage, structural-systemic science uses everyday observations, constrained observations and evocative experiments. Even though superficially similar, the use of these methods is essentially different from previous stages. In addition, a new kind of experiment emerges what I have called *constructive experiment*. Next I characterize briefly each of the methods.

First, *everyday observations* in structural-systemic science can take different forms. First of all, all the observations are explicitly theory-guided as any observation entails selection of aspects that are observed; the only difference is whether the basis of selection is explicit or implicit. Another aspect in structural-systemic observations is that these can be explicitly aimed at searching for situations where either the theory seems to fail or there seems to be no theory to explain subjectively perceived patterns in events. Differently from everyday-conceptual science it is clearly understood that no spontaneous observation without artificially constrained study-situations can lead to scientific explanation but rather only to new questions to be answered. Differently from logical-conceptual science, the observations are used to look for possibilities to falsify existing theories. Logical science is aimed at looking for patterns and treats violations of theoretically predicted patterns as noise or error of observation. In structural-systemic science, theoretically unpredictable situations call for explanation.

Second, *constrained observations* in structural-systemic science have a different aim: the aim is not to look for relationships between events but rather for changes in the ways the studied thing relates to its environment with changes of the context. Another possibility is to look for thing-environment relationships when the context is physically the same but the thing has changed – for example, a human child has developed. Thing-environment relations are changing; thus in such observations also events are studied. But the events are studied as structured wholes – with distinguishing the elements of the events, their relationships and changes in the qualities of the elemets of the events. Structural study of observed events allows to develop hypotheses about the structure of the thing studied. Perhaps it is noteworthy that in structural-systemic science it is understood that directly observable structures are usually not in one-to-one correspondence with the structure of the thing that is studied. Sciences, with rare exceptions, aim at understanding the

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[2] I am not suggesting that mathematics is not involved in building such theories; often use of mathematics is useful or even essential at certain stages of theory-construction. Yet the final theory – the explanation of what the studied thing or phenomenon *is* – is not mathematical. So it can also be said that mathematics cannot define what a thing or phenomenon is even though it can reflect certain aspects of relationships between things.

world beyond directly observable. In these cases, as a rule, structure of the observed events where the studied thing is participating is not identical with the structure of the studied thing. Thus, for example, human behavior is not in direct correspondence to psychic structures that underlie the behavior. The structure of the human mind can be revealed only by varying either the context the humans are or the individuals themselves.

Third, *evocative experiments* in structural-systemic science aim explicitly at distinguishing the elements and their relationships in studied structures. In evocative experiments it is attempted to vary either the element or certain relationship between the elements of the whole and observe whether the whole changes in theoretically expected way. In other words – structural-systemic experiments are studies of development. Development, in this context, is defined not as any change but as a hierarchical reorganization of a system. Thus development can take three forms: element is added into a structure, element is taken away from a structure, or relationships between the elements change. In all three cases the whole structure changes qualitatively. In that perspective, structural-systemic experiment requires explicit hypotheses about what qualities of the whole change when certain element or certain relationship is experimentally manipulated. These hypotheses are created on the basis of everyday and constrained observations.

Finally, *constructive experiment* can be conducted. The idea of constructive experiment was born, as far as can tell, for more than a century ago. Friedrich Engels did not agree with many philosophers, according to whom either knowledge of the world is not possible at all or it is possible only about very limited aspects of it. He argued:

> The most telling refutation of this [...] is practice, namely, experiment and industry. If we are able to prove the correctness of our understanding of a natural process by making it ourselves, producing it from its preconditions and making it serve our own purposes into the bargain, then it's all over with the Kantian ungraspable "thing-in-itself." The chemical substances produced in the bodies of plants and animals remained such "things-in-themselves" until organic chemistry began to produce them one after another ... ([44], p. 19)

So, Engels proposes what we can take, I think, as a criterion of truth: if we know how to create a thing we try to understand, we have understood it, we know that our understanding is "true", i.e., it corresponds to reality as it is. We can go further and define, what kind of knowledge in principle is knowledge about how to make a thing or phenomenon – it is knowledge about the structure. If we know, what elements should be put into which kinds of relationships, we know how to make a whole. Thus the ultimate test of a structural theory is *constructive experiment*, where theoretically distinguished elements are synthesized with the aim to create a whole with exactly those qualities, predicted by the theory.

It should be noted here that constructive experiment should be distinguished from logical-conceptual evocative experiment. In the former, the successful result is the creation of the thing or phenomenon with qualities identical to those that characterize the thing studied. In the latter, however, conditions are created, in which the expected event is evoked to take place – but it is not known, how actually the result emerges. I think it is relatively easy to distinguish the two kinds of experiments. The difference becomes especially clear, when experiment fails. In the logical-conceptual evocative experiment, the researcher would try to manipulate with the "cause" of the supposed "effect"; the effect itself, however, would not be studied. When it becomes clear that evocative experiment failed, the researcher returns to everyday and constrained observations for improving the theory about the cause.

In the constructive experiment, on the contrary, the “effect” – the result of the experiment – would be the first to study. It should be made clear, whether indeed all the theoretically necessary elements were synthesized and in which specific relationships they ended up. Also the emergent whole would be studied to reveal, how exactly it is different from the theoretically expected whole. If all the theoretically distinguished elements and their relationships are discovered but the whole came out different from what was expected, then the researcher returns to observations and evocative experiments. These studies would be aimed at undrstanding, what the “effect” is.

Scientific anticipation

Structural-systemic anticipation is the only kind of exact anticipation. If constructive experiments have proved that correct elements and their relationships have been theoretically established, then any time the same elements become into the same kind of relationships, the whole with expected qualities is exactly anticipated. It does not follow, however, that structural anticipations do not fail in reality. They fail, if the elements or their relationships have not been correctly described. Modern industry is an example of structural anticipation: every new car, spaceship, computer, drug, material or whatever produced is anticipated to be with specific qualities. If the result turns out to be unexpected, the product is studied and, as a rule, the ill-defined element or relationship can be revealed. It is noteworthy that despite extreme complexity of many industrial products, the failure rate is remarkably low.

Structural-systemic thinking does not exclude less developed forms of anticipation. These are used, when no structural theory is available yet. When such less developed forms of anticipation are used, the shortcomings of them are explicitly understood – and the possible ways to overcome these shortcomings through structural studies are recognized.

Summary and conclusions

Science of anticipation was born about a century ago. During this century humans have learned more than ever before how to anticipate events in diverse areas of life. Yet the process of anticipation itself – the psychic mechanisms of it – are much less understood. Interestingly, there are all reasons to suggest that the psychology as a whole as well as the psychology of anticipation in particular was far more advanced about six decades ago than it is now. For this reason in this chapter my discussion of psychic processes that underlie anticipation was based on ideas created by continental European psychologists before the WWII.

Science of anticipation can be distinguished into three kinds, each relying on a different psychological mechanism. Further, these mechanisms – based on everyday conceptual thinking, thinking in logical concepts and thinking in systemic concepts, respectively – are in hierarchical relationships the first being the least developed and the last the most developed form of (scientific) thought. Each of these three sciences has specific to it understanding of what is scientific explanation and by which methods the explanation can be achieved. It is noteworthy that following from the epistemology and methodology of each of the three kinds of sciences, different forms of scientific anticipation can be achieved. The least developed everyday conceptual science grounds anticipation essentially on chance discoveries of patterns in everyday observations. Logical conceptual thought allows formalization of anticipation, mathematical in the first place. Yet formal anticipation is limited, because it does not contain understanding of why, by which mechanisms, certain events – “causes” – are followed by others – “effects.” This limitation can be overcome by structural-systemic science, which grounds anticipation on explicit understanding of the structures and the ways they change.

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