Chapter 15
A Structural Systemic Theory of Causality and Catalysis

Aaro Toomela

This book intends to explore the basic concept of catalysis in philosophy, chemistry, and psychology, with the aim of developing the concept further in (cultural) psychology. This aim implies that the concept is, in principle, useful and the only question is how to use it most efficiently for advancing psychology as a science. In the context of modern mainstream psychology (see Toomela in press-c, for the definition of 'mainstream psychology'), indeed, any step further from linear cause–effect theory of causality is a significant advancement; yet it does not follow that the concept in the proposed form should be used.

Why the Notion of Causality Matters?

Though science aims to explain and understand, not all kinds of explanations can be considered scientific. For instance, it is hard for many Christians to understand how God created the world, both in six days and instantaneously—both versions are suggested in the Book of Genesis. These two views may seem absolutely contradictory to anybody with reasonably developed intellect. Yet the brightest minds have proposed brilliant solutions to this contradiction. Among many wonderful ideas derived from discussing the time of creation, we find, for example, a suggestion by St. Augustine, according to whom, "God finished all his works in six days *because* six is a perfect number." It was also made clear by others that "The creation of things is *explained* by the number of six, the parts of which, one, two, and three, assume the form of a triangle" (White 1896, p. 7, my emphasis; see also many other explanations for this contradiction *ibid.*). Here we find not only an explanation as to why it took exactly six days to create the universe but also a causal explanation as to why it took six and not any other number of days. Indeed, as the number six assumes the form of a

A. Toomela (✉)
Institute of Psychology, Tallinn University,
Narva Rd. 29, 10120 Tallinn, Estonia
e-mail: aaro.toomela@ut.ee

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triangle; obviously it took six days to create the universe, and, as a triangle is one, the creation was also instantaneous. This causal explanation, however, would not be considered scientific today, at least by scientists. Thus, we can conclude that even though all scientific knowledge is knowledge, not all knowledge is scientific.

So far I have written only a few lines and already introduced confusion that needs to be cleared up: I use the terms 'explanation,' 'science,' 'scientific,' and 'causality' as if it is clear what these terms mean; yet this is not the case. Next, I will discuss why causality matters for science.

Scientific Explanation and Causality

Detailed discussion regarding the essence of scientific explanation and understanding goes beyond the scope of this chapter. I will give only a brief outline of the issue here (see Toomela 1996, 2009, 2010a, e, 2012, in press-a for more details). Shortly following Aristotle (e.g., 1941d), scientific knowledge could be defined as knowledge of causes. In mainstream psychology today, the issue seems to be solved—everybody seems to know what 'cause' and 'causality' mean. It seems to be universally accepted that causality refers to linear cause–effect relationships. Therefore, the whole science of psychology should also be concerned with discovering 'causes,' i.e., events that make 'effects' happen.

Understanding causality as a chain of cause–effect relationships, however, becomes questionable when it turns out that many other theories of causality exist. In this case a metatheory is needed to justify why this and not some other theory of causality has been chosen. In order to proceed, I provide one alternative (though there are several more). I have called this theory of causality structural–systemic (e.g., Toomela 2010e, 2012), to distinguish it from systems theories that are not structural and structural theories that are not systemic. According to structural–systemic view, followed by many continental European psychologists before World War II, three individually necessary, but only collectively sufficient aspects of causality must be distinguished. A studied thing or phenomenon is understood, i.e., explained causally, when, first, its constituent parts or elements are identified. Second, specific relationships between these parts are described and, third, qualities of the whole that emerge during the synthesis of parts are discovered. Structural–systemic causality requires methodologically, fourth, a developmental approach to the scientific study. This is because qualities of elements change when they are synthesized into an emergent whole; therefore, the identification of elements is possible only before synthesis takes place. On the other hand, it must also be demonstrated that the hypothetical elements truly belong to the studied whole Thus, the actual process of synthesis—development—must be studied.

An example of this kind of explanation was repeatedly described by Gestalt psychologists as well as by cultural–historical psychologists, originally Vygotsky. The example is that of water. Koffka, for instance (see also Vygotsky 1926, 1983 for usage of the same example), discussed this example in the following way:

> Let us take the simplest example we can find: water is explained by atomic theory as a compound of two elements, hydrogen and oxygen, in such a way that it consists of molecules, each of which is composed of three atoms, two of hydrogen and one of oxygen. [...] This sounds like a straight molecular theory, but it is not anything of the kind. For H, H_2, and H_2O have all different properties which cannot be derived by *adding* properties of H's and O's. [...] In the simple water molecule, what a complexity and what a difference of structure from the H and the O atoms! It is wrong to say that this system consists of two hydrogen atoms and one oxygen atom. For where are they to be found in it (Koffka 1935, p. 57)?

I am going to elaborate on this example to demonstrate all four principles of structural–systemic causality. First, there is the question of elements; we know that a molecule of water is composed of—but does not 'consist,' as we learned from Koffka—the elements hydrogen and oxygen. Among other qualities, one element burns and the other is a necessary component of chemical burning.

Second, these elements can be combined into different wholes. Chemical bonds can be established between these two elements. For instance, we can get water, H_2O, but can also get many other substances, such as hydrogen peroxide, H_2O_2, or hydrogen superoxide, H_2O_4. All of these compounds are distinguished by the number of same elements, hydrogen and oxygen, as well as the kinds of relationships between these elements: H–O–H, H–O–O–H, and H–O–O–O–O–H, respectively. Furthermore, we can get oxyhydrogen by just mixing the two gases hydrogen and oxygen; in oxyhydrogen, the relationships between the elements are those of physical proximity without chemical bonds between them. Usually we would have a mix of two kinds of molecules, H_2 and O_2, or H–H and O = O, where the bonds are formed between the atoms of hydrogen and atoms of oxygen, respectively, but not between H and O.

Third, all of these compounds as wholes are characterized with remarkably different properties: water can be used for extinguishing fire, whereas oxyhydrogen is highly explosive. Hydrogen peroxide and hydrogen superoxide are also distinguished by many properties from other compounds as well as from each other. Hydrogen superoxide, for example, can exist only at very low temperatures (Marshall and Rutledge 1959). On the other hand, the wholes also have properties that do not characterize the individual elements. Water can be used for extinguishing fire, whereas hydrogen burns and oxygen is necessary for burning. Thus, properties of elements change when included in an emergent whole. Additionally, the properties of a whole depend not only on its constituent elements but also on the specific relationships between the elements.

Finally, in order to demonstrate that water is, indeed, composed of hydrogen and oxygen, it is necessary to demonstrate that a molecule of water breaks up into hydrogen and oxygen; this can be done with the electrolysis of water, for example. On the other hand, it is also necessary to demonstrate that a molecule of water emerges via the synthesis of hydrogen and oxygen; among other ways, this can be done by heating a mix of two gases, H_2 and O_2, until the hydrogen burns, i.e., the bonds between hydrogen and oxygen atoms emerge.

Glimpse into the History of Causality Theories

So far we have seen that there is more than one theory of causality and, for some reason, one of them—that of the cause–effect chain—has been accepted almost universally by psychologists today. There should be reasons as to why this particular choice was made. Today, there is practically no discussion on the nature of scientific knowledge in psychology. Therefore, we need to look back into history with the aim of discovering when and why the choice among causality theories was made. I think it is necessary to go far into the past to find answers to these questions.

Causes and causality were mentioned and discussed to some degree by several philosophers of antiquity. The most advanced theory of causality was proposed by Aristotle, who distinguished four kinds of causes; now referred to as material cause, formal cause, efficient cause, and final cause, respectively (see, e.g., Aristotle 1941a). Material cause is a description of what a thing is made of, formal cause is the statement of essence of a thing as a whole, efficient cause is a description of the source of a change, and final cause is a reason or that for the sake of which a thing is.

This view is very similar, though not identical, with the structural–systemic causality theory. Particularly, material cause for Aristotle was not just the material from which something was made; it was also explicitly defined as parts. Formal cause, in turn, was that of the whole and synthesis. So, what we do not find there is the idea of specific relationships only.

It is also important to take into account that *efficient cause* as part of the more complex theory does not have the same meaning as it does when taken as the only kind of cause. Today, it is understood that cause is some event that precedes an effect and makes the effect happen; therefore, it has temporal characteristics and ontological consequences. Cause in this simplified theory is, in other words, something occurring *earlier* than effects and is also the beginning of the consequence, a reason why the result emerges. In the Aristotelian account, however, efficient cause is *not* the beginning of the result; according to Aristotle, all four kinds of causes are beginnings simultaneously:

> [. . .] all causes are beginnings. [. . .] 'Cause' means (1) that from which, as immanent material, a thing comes into being, [. . .] (2) The form or pattern, i.e., the definition of the essence [. . .] (3) That from which the change or the resting from change first begins; [. . .] (4) The end, i.e., that for the sake of which a thing is; e.g., health is the cause of walking (Aristotle 1941a, p. 752, Bk. V, 1013a).

Indeed, no "effect" would emerge if there were no parts, no material from which the effect was made. There must be something already existing that changes when the efficient cause is added. In that sense, thus, efficient cause loses both of its characteristics—it is not the only kind of cause that precedes the effect, and it is not the sole kind of cause that has ontological consequences. A new thing or phenomenon emerges when all four kinds of causes act simultaneously; their effect, thus, is systemic, i.e., a process of emergence is possible only if individually necessary kinds of causes are also collectively present.

Today, however, 'efficient cause' is the kind of cause that is considered, by the majority, to be the theory of causality without other kinds of causes necessary. In some point in history, thus, the Aristotelian complex theory of causality was replaced with only part of it, that of efficient causality, which became an all-inclusive theory. Why was a more complex theory of causality abandoned and when? Today, efficient causality is almost universally accepted as the theory of causality. Perhaps there are very good theoretical arguments for this choice—a choice that may otherwise look ridiculous because an elaborate set of established principles has been replaced with one principle that does not cover all aspects of the earlier, complex theory.

Metatheories that reject all kinds of causes but efficient cause, can be found, indeed. There are two philosophers, Descartes and Hume, who can be "blamed" for abandoning Aristotelian thinking. Both of them suggested that only efficient causality should be considered as the theory of causality. It is especially interesting to understand, why only efficient causality? Descartes seems not to give explicit reasons for this idea, but if we take his works as a whole, we find that he had no other choice. Namely, a large part of Cartesian philosophy is to give proof to the existence of God—the background was not whether there is any doubt about God's existence, for Descartes, there was none; the background was to logically prove to nonbelievers that God does exist.

Causality was also discussed in this context by Descartes. For Descartes, God was "infinite, eternal, immutable, omniscient, omnipotent" (Descartes 1985, p. 128). God was also the first (efficient) cause "of everything that exists or can exist in the world" (Descartes 1985, p. 143). If God is the cause of everything and is also all-powerful, then, logically, there can be no other kinds of causes. For other causes are constraints, they put limits on what can happen in principle and what cannot. Not everything can be built from the same material; therefore, material cause is a constraint. It follows that the same form, formal cause, cannot be achieved in an unlimited number of ways. Thus, formal cause is also a constraint. As to final cause, it may seem to fit with the notion of God, which was also mentioned by Descartes, but the problem is that for Aristotle final cause was a far more complex concept. According to him (cf. Aristotle 1941a, c), only some things are for the sake of something, and from these only some are in accordance with deliberate intention. In other cases final cause emerges from the 'nature' of things, and 'nature' means the matter and the form. Hence, final cause is in many cases actually a retrospective concept, which means that there is only one way a particular form from specific material came into existence. Finally, there is also a kind of final cause, in the case of which the thing in question has in itself, by nature, a source of becoming or changing. So a seed, for example, is a thing that becomes, determined by final cause as its essence, something else, a plant. Thus, final cause is also a constraint, and God, being all-powerful, cannot be constrained in any way. Therefore, there is only one kind of cause, that is efficient cause. Hume, in turn, followed a very different path (cf. Hume 1999, esp. pp. 101–115). He, in principle, did not deny that other causes can be operative. Yet he assumed that humans are not able to discover any other kind of cause because they are not capable of knowing the world beyond the appearance of things, and other kinds of causes are not apparent.

Therefore, it is possible to know only connections among ideas that emerge on the basis of observed associations between events.

Despite extensive literature searches, I have not been able to find any other justification for limiting causality theory to efficient causality. I also think that science today cannot accept the idea that there are no constraints on the world (this would exclude all principles, laws, and regularities). It also cannot accept the idea that the world beyond appearances is unknowable in principle. It follows that constraining causality theory to efficient cause alone is not justified by scientific principles and should be discarded.

Structural–systemic causality, which developed on the basis of the Aristotelian account, in turn, is free from unscientific theological limitations or assumptions about limits of the human mind that were reasonable a few centuries ago but turned out to be erroneous with the development of the sciences. Structural–systemic epistemology is also nothing new in psychology; it was a grounding principle for many powerful theories more than a century ago. As I have discussed elsewhere (see references above), there are many reasons to agree with Wilhelm Wundt, who suggested that scientific explanation in psychology should contain descriptions of attributes of psychical causality, which are discovered by studying psychical elements, psychical compounds, interconnections of psychical compounds, and psychical developments (Wundt 1897). Knowing the elements, their compounds, and the process of the emergence of novel wholes, the causes of studied phenomena are scientifically explained:

> There is only *one* kind of causal explanation in psychology, and that is the derivation of more complex psychical processes from simpler ones (Wundt 1897, p. 24).

This quotation should not be taken out of context from where it was originally written. Wundt did not mean that more complex cause–effect relationships derived from studies of many simpler cause–effect chains would be causal explanations. For 'complex,' in this regard, refers to organization, the synthesis of elements that comprise the whole. Thus, causal explanation for Wundt was understanding how novel wholes emerge in the synthesis of elements. Altogether, there seem to be reasons to revise the current dominant theory of causality and go beyond oversimplified efficient causality. One such development is proposed by the introduction of systemic and catalytic causalities into psychology.

Catalytic Causality in Psychology

Linear, or efficient, causality is the most primitive view on causal relationships. This model assumes that there are unitary entities, called causes, which necessarily and unconditionally lead to outcomes or effects. This model does not correspond to the context dependent and complex phenomenon studied in psychology, the (human) mind. In order to go beyond the limitations of efficient causality, Valsiner (2000) proposed using another theory of causality in psychology. He added to linear causality theory a systemic causality theory, according to which any outcome is a result of mutually interdependent relationships between the parts of the causal system. Specific outcomes emerge only when all the necessary causes in systematic interaction act together. Furthermore, in order to introduce context into theories, especially theories of development, Valsiner suggested introducing the notion of catalytic or catalyzed causality. 'Catalyzed' refers to the contextual conditions that need to be present for a particular causal linkage to occur. In the absence of these conditions, the causal processes cannot lead to an outcome. At first glance, catalytic causality may look similar to structural–systemic causality. These two views, as I am going to show below, differ in several important aspects, however.

In his later work, Valsiner elaborated the model further (Valsiner 2007). He showed that the idea of systemic causality leads inevitably to hierarchically different levels of generality so that the causal cycle can work between adjacent levels. In systemic catalytic causal processes, new, hierarchically higher levels of forms emerge in the synthesis of elements. Together with the possibility of relationships between hierarchically different levels of causal processes, the causal chains will not remain unidirectional. In linear primitive models of causality only 'upward' causality is discovered; in this way it is expected to explain more complex hierarchically higher-order forms with lower-level causal entities. Multilevel causal system view, however, also entails the idea of 'downward' causality where lower-level entities are causally affected by higher-level forms (see on 'downward causation' also Andersen et al. 2000).

Catalytic Causality Theory (CCT) vs. Structural–Systemic Causality Theory (SSCT)

So far three theories of causality have been described, efficient causality, structural–systemic, and systemic–catalytic. Even though there are other options, I will not discuss the others, which are neither more elaborate nor more popular. Also, I think that there is no need to further discuss whether the efficient causality theory should be taken seriously. The reasons for accepting it are irrelevant for science and reliance on it as the theory of scientific explanation leads to oversimplification and loss of even the possibility of explaining studied things and phenomena. The next question—the question to be answered in this chapter—is understanding which of the two remaining theories are more promising as an epistemological ground for scientific understanding—not only in psychology but in all sciences—and explanation.

No doubt, there are similarities between the two theories. Both assume that more than one kind of cause needs to be identified for full understanding of the studied thing. Next, both distinguish hierarchical levels of development. Further, in both theories the term 'system' is used. Yet there are also fundamental differences between the theories. These differences are not easy to discover because the language used to describe the theories overlaps more than their actual content. It is because the same terms—'system,' in the first place—do not consistently refer to the same idea. Next, I am going to show that CCT, even though it represents a significant advancement when compared to the efficient causality theory, is not sufficiently elaborated and does not allow us to make all the theoretically important distinctions that follow from SSCT.

What is 'System'?

First, fundamental differences emerge when the notion of 'system' is analyzed in the theories. In SSCT, 'system' is a structure, i.e., organized whole, that is composed of (developmentally) distinguishable (but never separable) parts or elements in specific relationships. In the synthesis of elements, a whole emerges, which has properties that do not characterize the parts before they are synthesized. In the same process of synthesis, properties of elements also change; some properties of the emergent whole become properties of the parts simultaneously.

I have used a clumsy term, 'structural–systemic,' because there is more than one theory of what 'system' means. Relatively well-known today is, for example, dynamic systems theory (DST). This theory is in several principal ways different from SSCT (see for more details, Toomela 2009). First, DST studies processes and often explicitly denies the existence of, to some degree, stable structures underlying them. Second, as a rule, DST is applied by encoding the observations of studied processes into numerical variables. These variables are then analyzed as if they represent the elements of the system—whose structural nature is denied. In the process of encoding observations into numerical variables, however, the essential characteristics of the studied structures are irreversibly lost (see on the epistemological problems related to numerical variables, Toomela 2008). Third, DST studies non-linear changes without realizing that truly hierarchical changes are not only non-linear but also non-continuous; entirely novel qualities emerge in synthetic processes. Discontinuity is excluded in DST. In addition, DST is characterized by many vague terms, such as attractor, self-organization, and even the basic notion of 'process' is used in ambiguous ways. In DST, processes can 'cause' other processes, but process is essentially a change in a system that unfolds in time, and "unfolding in time" cannot cause anything.

'System' is also not unequivocally a structure of the thing or phenomenon in the General Systems Theory compiled by Bertalanffy (von Bertalanffy 1968). Bertalanffy believed that systems theory in its advanced form is a mathematical theory; he suggested, for example, that systems problems are "problems of interrelations of a great number of "variables" (von Bertalanffy 1968, p. xx). No mathematical theory, however, can be a comprehensive theory of any real structure of a thing because mathematics studies associations but not discontinuous qualitative changes in the world (see more on the limits of mathematical theories, Toomela 2010d).

The definition of the term 'system' is not unequivocally clear in CCT. In some places it may appear that understanding the 'system' is similar in CCT and SSCT. For example, in CCT it has been stated: "The system cannot be studied unless the aggregate of the qualitative whole is observed as a system—as interrelated parts functioning in relation to one another" (Beckstead et al. 2009, p. 71). Thus, in a system there seems to be parts, their relationships, and the whole. Yet it is not a system in the SSCT sense. The differences are related to conceptualization of the three basic notions of systems theory—'whole,' 'part,' and 'relationship'—that are understood differently in CCT and SSCT.

Notion of 'whole' in the CCT When talking about the whole, the authors are talking about an *aggregate*, which is usually defined as a collection of items that are gathered together to form a total *quantity*! In SSCT, instead of 'aggregate,' 'organization' would be used to refer to interrelated parts with the qualitatively novel whole emerging in the process of synthesis. Even though all theoretical principles are reflected in the ways language is specifically used, one unfortunate term does not necessarily indicate the whole essence of the theory. However, there are many other expressions that indicate the same—'system' in CCT is not a structure of distinguishable parts in specific relationships, rather it seems to be something vaguely defined. In some places, indeed, we find that the phenomena should be understood as qualitative wholes (Beckstead et al. 2009, p. 73). The meaning of 'whole' becomes unclear when we learn (see next section for details) that a system is in a context. This context is not a set of other systems that have the potential to interact with the particular whole but context is, rather, some 'condition,' 'mediator,' or 'catalyst.' None of them has been understood as a system or whole by itself in CCT.

For SSCT, in turn, all wholes, all systems or structures, are embedded into higher-order wholes. 'Context,' for example, means other systems can potentially interact with the particular distinguished system being studied. In that sense, thing-in-context becomes a higher-order whole with novel qualities that do not characterize the particular whole in some other context.

Notion of 'part' in the CCT The notion of 'part' or 'element' is also quite ambiguously defined in CCT. In some places we find that "parts and their relationships to each other as well as to the whole [. . .] cannot be treated as separate *variables*" (Beckstead et al. 2009, p. 71, my emphasis). In other places it is not variables but some *systemic conditions*, under which something occurs (e.g., Beckstead et al. 2009, p. 72). Other terms are added to that: "[. . .] the catalytic model—showing the dynamic interaction of *individuals, conditions, contexts,* and *catalytic agents* [. . .]" (Beckstead et al. 2009, p. 78). To these terms, other notions, such as *regulator* and *mediator* (Cabell 2010), should be added.

Altogether, it seems that in CCT some whole might be a system but this whole interacts with conditions, contexts, catalysts, regulators, mediators, and maybe with something else as well. So there are systems and there are factors (I have no better name for all these other notions taken together) that interact with systems. Perhaps it is possible to identify what a factor is, but I think it is not clear at all how exactly this or that factor leads to the change of a system.

This problem does not emerge in SSCT. For SSCT there are only structures that are distinguished from other structures; the universe as a whole is a structure that is composed of hierarchically lower-level substructures of different complexity. CCT tries to identify factors that contribute to the change of a particular whole. I do not see any reason why the same notions that define a structure—parts and relationships—should not be used for explaining change and development. In SSCT, any structure as a whole can change only in two ways; either the relationships between the elements change (as in the case of burning oxyhydrogen), or a new element is synthesized into a structure (an atom of oxygen is synthesized with the molecule of hydrogen). In both cases we need "context": oxyhydrogen will not change into water unless the process is ignited by an amount of energy introduced into the system (essentially it means that if properties of the elements of oxyhydrogen change, their energy-level will be different so that the molecules of oxygen and hydrogen can be broken in order to synthesize their atoms into water), and atoms of hydrogen must be in the "context" of oxygen for the synthesis of water to be possible.

Altogether, thus, there are only structures at hierarchically different levels of distinction. All the different terms, 'individual,' 'condition,' context,' 'catalyst,' 'regulator,' and 'mediator,' refer to the same thing—these are the elements of a higher-order system where the 'individual' belongs. This 'individual' interacts with its environment, which is just a set of other structures that may become elements in the individual and some other subsystem of the environment higher order system. Below I will address more details and distinctions related to this issue, in the section on catalytic causality.

Notion of 'relationship' in CCT It is acknowledged in CCT that a system as a whole is different depending on the relationships between the parts: "Two systems with the same parts —A, B, C—but different relationship of the parts will yield different results" (Beckstead et al. 2009, p. 73). Superficially it may seem that the same idea relies under the notion of 'relationship' in both CCT and SSCT; yet this is not the case. Every theoretical notion is fully defined in the context of the theory it belongs to. The same notion in different theories is also different because the whole where it belongs to is different. The same applies in the case of 'relationship.' In CCT, relationship applies to relationships between parts of a system. Yet parts and system as a whole are not defined similarly, as we have seen in previous sections. Thus, 'relationship' also has different meanings. In SSCT, relationships emerge in a distinguished system as a whole as well as between the system and its context, which is a set of other systems. It is not clear at all, however, what 'relationship' means when CCT notions of conditions, contexts, catalysts, etc., are used. If there are no conceptual differences between the relationships between parts and between a system and context, condition, etc., then it is not clear what these other notions mean. But if the relationship with context is conceptually different from the relationship with catalyst or with mediator then it is not clear any more what 'relationship' means.

Parenthetically, it must be mentioned here that I am *not* suggesting that there is only one kind of relationship between elements in SSCT. On the contrary, there are infinitely many kinds of relationships possible. Relationships between atoms, chemical bonds, are not the same as relationships between words or between two human beings. The problem with CCT is that with confusing terminology of parts of a system and contexts, conditions, etc., principally the same kind of relationship can be treated theoretically as if it were different depending on whether we call a part of a system a part, a condition, or whatever else. How so? In hierarchical systems, i.e., in all systems, a part at one level is a whole system at another level of analysis. Thus, what is 'context' at one level is 'another part' of a more complex system at another level of analysis. Therefore, what we describe as 'relationship between parts' at one level of analysis becomes something different, such as a relationship with a condition, for example, at another level of analysis; though it is the same relationship. This confusion does not emerge in SSCT.

Downward Causality

Another questionable concept in CCT is the idea of downward causality. This notion is reflected in statements, such as, "phenomena are qualitatively organized by the whole system" (Beckstead et al. 2009, p. 72) or, "the emergence of higher levels of generalized signs becomes causative in relation to lower levels" (Valsiner 2007, p. 376). So there are two directions of causality, "upward" and "downward." This distinction opens up the possibility for a lot of confusion. In the first place, it creates tension between a whole, "up," and its parts, "down," as if these two can be separated. Also, it becomes unclear in which sense these two forms of causality can be distinguished. For instance, are they simultaneous in time or do they have effects in different times? The distinction of the two forces is attributing "earlier" to upward causality and "later" to "downward" causality. This is because parts exist before the whole but an emergent whole—which "becomes [sic] causative in relation to lower levels"—cannot have its effect before it has emerged. If "downward" causality has its effect after the whole has emerged, then something very strange must be acknowledged—there must be a period of time when elements already become parts of a higher-order whole, but do not form the whole yet because to be in a whole means that they are affected by the whole. Otherwise we would have to say that the whole can be separated from its parts so that the whole, as efficient cause, can affect its parts. This possibility, obviously, would be rejected by CCT.

Hence, there is a contradiction in CCT, and, at the same time, there is hidden an important principle that is fully accepted in SSCT. As I mentioned already above, it is not only the qualitatively novel whole that emerges in the process of the synthesis of elements; the qualities of the elements also change in this process of emergence. Thus, SSCT rejects the idea that there is a direction in the relationship from parts to whole and from whole to parts. Rather, parts change qualitatively during the process of the emergence of the whole; changes in the qualities of parts and the emergence of a whole with new qualities are just different aspects of the very same process. Both changes are also simultaneous. One important notion must be defined in order to explicate this aspect of SSCT in sufficient detail. I am going to discuss this definition in more detail as important consequences follow from it.

Detour: Definition of Quality

In human and social sciences the term ‘quality’ is used abundantly. Yet there seems to be no clear definition of what ‘quality’ means. In common language ‘quality’ is related to ‘good’ or some other value. In psychology ‘quality’ or ‘qualitative’ is often used as the opposite of ‘quantity’ or ‘quantitative.’ So “qualitatively different” becomes “different,” but not in quantity. In this use, the notion is not only circular but also misleading, because quantity and quality are not necessarily opposites. At least since Hegel’s analysis of the notions of quality and quantity, it is questionable whether these notions can be opposed at all (cf. Hegel 1969, esp. Sect. 3: Measure). There are too many phenomena in the world where increases or decreases in quantity are accompanied by change in quality. Even more, I would say that there is no quantitative change possible without concordant qualitative change and vice versa.

Over the history of philosophy, quality has been defined in numerous ways (see for a long list of different definitions, Chambers 1728). While not all definitions fit a theory of systems, ‘quality’ is an essential notion for all systems theories where it is recognized that qualitatively novel wholes emerge in the synthesis of elements (non-continuous accounts, especially mathematical, are implicitly nonqualitative even if, superficially, qualities are mentioned theoretically). Thus, we can constrain the choice of definitions to that which is defined in terms of systems theory. Following principles formulated in continental-European psychology, especially in Gestalt school and cultural–historical school, among others, I have suggested for more than a decade, that it is structural–systemic theory, which should be preferred over other systems theories. Therefore, the definition of quality I propose is defined in terms of SSCT.

The definition follows quite naturally from the basic notions of SSCT. There we have elements, relationships, and wholes, or hierarchical syntheses of elements, which are different from elements, so we need a term that determines what this difference means. Next, we observe that all processes of emergence of higher-order wholes are related to relationships. In the emergence of a whole, certain relationships are formed between the elements, and in the destruction of a whole, relationships are broken. Furthermore, every element is constrained in the process of synthesis; a relationship that has been established cannot be established again before breaking it. (Here it might seem that I am suggesting something self-evident. It might be so, but it is not self-evident that the question—can the same element establish unlimited number of relationships?—needs to be asked. All developments in science begin with discovering new questions; answers are much easier to find than questions worth asking.)

Thus, what actually changes in the emergence of a whole is the establishment of relationships; once established, the strong constraint emerges so that the same relationship cannot be established again. The other side of the same constraint is that before synthesis elements must have the potential to establish a relationship. It follows that in synthesis elements change—they change in the kinds and numbers of relationships they can establish and nothing else. The structural–systemic definition of ‘quality’ jumps out now almost by itself (at least it did it to me about eight years ago; I even remember the exact location where I was riding my bicycle when the definition “came” to me). So I define quality in this way: *Quality is the potential of a structure to become into relationship with another structure*.

I have one example to demonstrate what this abstract definition means. Gold is one of the least reactive chemical elements. It is not soluble—does not enter into a chemical compound with other elements—in nitric acid. So gold does not have a quality that would permit it to enter into this relationship, whereas silver, for example, does. That is why an “acid test” nitric acid can be used to distinguish gold from several other metals. Gold is obviously qualitatively different from other metals. Now we see what “qualitative difference” means in structural–systemic theory. Gold has a unique set of relationships (chemical, mechanical, cultural, etc.) it can enter into with other structures. It is, thus, qualitatively distinguished from other metals, whose unique set of qualities is, at least partly, different from that of gold.

After I defined quality for myself, I found some definitions provided by philosophers that are in many respects similar to the one I propose. The definitions that are relevant were proposed by Aristotle and Hegel, respectively. This is not surprising, rather it shows, again, that structural–systemic thinking emerged from Aristotelian thought and was further elaborated by Hegel—both connections I have discussed elsewhere (e.g., Toomela 2012). I provide both definitions in order to the help the reader connect SSCT with its philosophical roots.

Aristotle gave four very different definitions of quality (Aristotle 1941a, b). Out of the four, the following is relevant in this context:

> [. . .] by Quality I do not here mean a property of substance (in that sense that which constitutes a specific distinction is a quality) but a passive quality in virtue of which a thing is said to be acted on or to be incapable of being acted on (Aristotle 1941c, p. 305, Bk.V, 226[a]; see also Aristotle 1941a, p. 871, Bk.XI, 1068[b] for the same definition).

So, for Aristotle quality was a *passive* characteristic of a thing; things either can or cannot be acted on. To be acted on means to come into a relationship with something else because one thing can affect the other only by forming a relationship with it. If a thing can be acted on, it means that something else—that acts on it—comes into a relationship with it. Silver can be acted on by nitric acid but gold cannot. Thus, the first has and the second does not have a quality affected by that acid.

Hegel, whose views on causality were very similar to those of Aristotle, defined quality in relation to properties of a thing, in a way also very similar to Aristotle. According to Hegel:

> *Quality* is the *immediate* determinateness of something, the negative itself through which being is something. Thus property of the thing is the negativity of reflection through which Existence in general is an existent and, as simple self-identity, a thing-in-itself. [. . .] A thing has properties; they are, first, the determinate relations of the thing to *another* thing; property exists only as a mode of relationship between them and is therefore the external reflection and the side of the thing’s positedness. But, secondly, the thing in this positedness is *in itself* [. . .] A thing has the property of effecting this or that in another thing and of expressing itself in a peculiar manner in its relation to it. It demonstrates this property only under the condition that the other thing has a corresponding constitution [. . .] Through its properties

> the thing becomes cause, and cause is this, that it preserves itself as effect (Hegel 1969, pp. 487–488).

In this quote, Hegel's 'property' is conceptually similar to 'quality' as defined here; property is "a mode of relationship." Hegel, in fact, also defined a thing through its properties (qualities, in my terms):

> The determinateness through which one thing is *this* thing only, lies solely in its properties. Through them it distinguishes itself from other things, because property is negative reflection and a distinguishing; the thing therefore contains the difference of itself from other things solely in its property (Hegel 1969, pp. 490–491).

Here we saw that for Hegel properties—qualities, if using my term—are *relations* of a thing with other things. If there would be nothing with which a thing could come into relationship with, that thing would be out of our world; there would even be no way to know that it exists. Hegel also makes it clear that relationship is never determined unidirectionally. A thing can affect another thing only if that other thing has a corresponding quality that makes effects possible. We also find here the understanding that a thing is determined only by its qualities (i.e., Hegelian properties). A thing is what it is through the qualities it has, through its potential to come into relationships with other things. Taken together, a thing, i.e., a system or structure is defined by its qualities, its potential for relating to other structures. What is meant by 'qualitative difference' becomes also unequivocally clear: structures with different potentials for coming into relationships with something else are qualitatively different. On the other hand, we also see that quality is a relational notion; it is not characteristic of an isolated thing in itself. Thus, quality is always a contextual notion.

Let us take an example from psychology. I have a slight problem here finding a good example because the choices are almost endless. Any change in mental development, for example, is a qualitative change in a person. If, for instance, I learn a new word, my qualities change. I can relate to environments in a novel way every time someone uses that word in my presence, and I also can use the word. Yet, again, quality is about relations. So, if I use that new word when talking to a person who does not know the word, the relationship of understanding each other does not emerge. Thus, my qualities are not mine alone; they are simultaneously determined by my qualities and the corresponding qualities of possible environments I may encounter.

Many conceptual problems of science can be solved based on this definition of quality. The discussion of these problems goes beyond the scope of this chapter. Here I only mention that, following the proposed definition, we see that different structures may share some qualities and yet be qualitatively different, as in other qualities they may not be overlapping. Enormously important methodological consequences follow from this observation. One of the most underestimated and, yet, most fundamental problems to be solved in psychology is discovering what mental processes underlie observed behaviors. The problem is that externally similar behaviors may emerge on the basis of different mental processes and vice versa (e.g., Toomela 2008, 2010b). So far there has been no theory that would show how in principle it is possible to distinguish internally different—and directly nonobservable—structures that underlie (mental) processes when the external observable outcomes, behaviors, are identical. SSCT provides the needed methodological principle: different mental structures, even when they share some qualities, must be different in other qualities, in other potentials for establishing relationships between mental elements and with the world. By systematically varying environments of individuals—because it is always environment in relation to which a behavior emerges—it becomes possible to discover which structural, environmental differences correspond to which differences and similarities in observed behaviors. Differences in similar environments and similarities in different environments, thus, give the researcher the ground to distinguish directly nonobservable mental structures underlying observed behaviors.

It is true that most psychological research is based on manipulation with the environment, yet other epistemologies do not permit discovering what particular mental structures underlie studied behaviors. So efficient causality psychology, i.e., the mainstream today, can only establish names for regularities in observed behaviors. There is 'neuroticism' that causes neurotic behavior, and there is 'intelligence' that causes intelligent behavior, etc. Such names are not true scientific explanations. Also, CCT seems to not provide methodological ground for solving the problem of matching similar behaviors to potentially different underlying mental structures and vice versa. Certainly many individual and environmental characteristics that associate with different behaviors can be discovered. Additionally, CCT epistemology is much more powerful than the current mainstream because, in CCT, causal concepts are added to the primitive efficient causality framework. Yet there seems to be no methodological principle in CCT that would follow from it and explicate how exactly correspondence between mind and behavior is established.

Back to Downward Causality

As I showed above, the CCT principle of downward (and upward) causality is contradictory if analyzed in the context of a systems theory. Both CCT and SSCT suggest that with the emergence of a higher-order whole, the elements also change. In CCT it is suggested that it is a causal "effect" of a whole to its parts. According to SSCT, however, nothing like that is, in principle, possible. A whole cannot be separated from its parts and, therefore, it also cannot become a causal agent in relation to its parts. Yet the parts change when synthesized into a whole. After defining quality, it is easy to see how the issue is solved in SSCT.

According to SSCT, a novel whole emerges when qualities of to become a part of a whole is realized in the process of synthesis and potential relationships of elements become actual. In this process, qualities of elements change—they become neither in relationships they have already established nor in other relationships they could have formed before synthesis. For example, a free atom of hydrogen that could form relationships with many other atoms, including another atom of hydrogen to establish a molecule of hydrogen, H_2, cannot establish a connection with another atom of H after becoming part of the whole H_2O. The molecule of water, in turn, acquires new qualities, novel relationships become possible, among them are those that may also be unique to molecules of water and to no other substance in the universe. Parts of the molecule of water, also acquire new qualities *qua* parts of the whole; when the whole molecule forms novel kinds of relationships then its parts are required to participate in these new relations. Thus, parts acquire new qualities together, while losing other qualities, when synthesized into a higher-order whole.

Thus, there is no downward causality; qualities of elements change through the actualization of their potential for relationships on one hand. On the other hand, the same parts that lose their qualities also acquire novel qualities *qua* inseparable parts of the whole they belong to. These two kinds of qualitative change would be misleadingly called downward causality in CCT. In the best case, 'downward causality' is just an unnecessary metaphor.

Catalytic Causality

In Valsiner's account, a general scheme of systemic causality, that involves catalytic causality, is described as follows:

> The process of synthesizing two separate substrates (A, B) into a new compound (AB) is made possible through a catalyst (C) which temporarily binds to the input substrates – first to A (arriving at intermediate compound (CA), then to B (arriving at intermediate compound CAB, binding A and B into one whole). The catalyst then releases the newly synthesized compound AB and recreates itself (C). Without the binding role of the catalyst the synthesis need not be possible; the direct, unmediated synthesis $\{A + B \rightarrow AB\}$ cannot proceed (Valsiner 2007, p. 373).

Valsiner's account given in this form can be accepted in SSCT: a catalyst is understood as a substrate, which becomes a part of an intermediate system in a chain of systemic transformations. Later, however, the idea of catalytic causality, as applied to psychology, was modified. The concept of catalysis seems to move away from a systemic account and comes closer to the primitive efficient causality view. First, instead of being understood as a (potential) part of a system in a chain of systemic transformations, catalyst becomes 'conditions.' Another important aspect of modifying the concept of catalysis is separating it from the notion of causality. Both ideas are expressed in the following quote:

> The microgenesis of sense-making is a catalyzed, not directly causal, process. The use of the notion of catalysis—study of conditions under which something happens, rather than asserting causality—is still not widespread in psychology (Salvatore and Valsiner 2010, p. 13).

Here CCT moves closer to the efficient causality view, but is still considerably more advanced if compared with the latter. It happens when bringing in the concept of "conditions under which something happens." With this concept, elements of a system become separate from conditions even though they are essentially the same. If "conditions" are not conceptualized as elements of a system, the efficient linear causality intrudes back to the concept of catalytic causality:

> Because the phenomena is a result of interacting and exchanging parts within a system, the catalyst has an important function of changing the relationships and interactions between one or more parts within the system. [. . .] system causality implies the change of one relationship within the system will yield a different result. Therefore, the catalytic overcoming of a barrier, resulting in the changing of a relationship not usually changed, alters the system as a whole, causing some novel (sometimes rare) phenomena (Beckstead et al. 2009, p. 73).

We see that "catalyst . . . has an important function of changing the relationships . . . catalytic overcoming of a barrier . . . causing . . . phenomena" is presented with notions very similar to efficient causality. It seems as if catalyst is just another efficient cause with effects on relationships. The relation of catalysis to causality becomes more confusing, however, because in other places it is directly stated that catalysis is not causal: "phenomena are not caused, but rather, are catalyzed" (Beckstead et al. 2009, p. 77).

Further, as catalysis in some cases is not necessary for a process to emerge, and causality implies necessity in CCT, catalysis is not strictly causal:

> The catalyst does not *cause* in the strict sense of *A—{causes}* → *B*, or "if preceding cause, then following effect". For example, in some cases, and across both disciplines, the product can still form without the conditions presented by the catalyst. Although this may require a long period of time or other necessary conditions, it is still possible. Therefore the catalyst is not a causal concept.If not causal then what? The catalyst has the same abstract function in both disciplines—functioning as a helper in the reaction process. The way in which the catalyst helps in the reaction process is by activation (Cabell 2011a, p. 7).

So instead of causing events to take place, a catalyst "helps" and help is given "by activation." Yet in other descriptions of CCT principles, we find that catalysts are necessary:

> Semiotic catalysis refers to a process that provides the conditions necessary—but not by themselves sufficient—to produce a particular qualitative change in a system. [. . .] A theory of semiotic catalysis, then, is a theory of enablement—one that activates the functions and mechanisms of other signs within the cultural psychological system (Cabell 2011b, p. 10).

In the quotation above, again, efficient causality language is used; it can be implied that changes in a system can be "produced" by other processes, among them is—necessary but not sufficient—catalysis. Also, catalysis "activates;" this term also implies the cause/ before → effect/ after linear efficient causality principle. Considering many contradictory and confusing ideas in descriptions of CCT, it is not surprising that in the end the concept of catalysis has turned from an explanatory principle to a metaphor: "I propose using the metaphor of the catalyst and of catalysis" (Cabell 2011b, p. 7). The concept of catalytic causality turned into a metaphor loses all explanatory content, however—because metaphors are false. Metaphors can be used as heuristic devices but not as theories (cf. Dooremalen and Borsboom 2010).

Catalysis According to SSCT

The principle of catalysis is fully concordant with SSCT and can be explained using its principles without involving vague terms, such as 'help,' 'activation,' 'condition,' etc. I will cite an example from chemistry, where the mechanisms of catalysis are increasingly understood and explained scientifically (i.e., in terms of structural–systemic causality according to the terminology used in this chapter).

I provide an example of ammonia, which was described in detail by Swathi and Sebastian (2008). Ammonia is, among other ways, produced from nitrogen and hydrogen according to the following formula:

$$3H_2 + N_2 \rightarrow 2NH_3$$

When mixing the two gases at room temperature, however, the reaction does not occur because the bond between the two nitrogen atoms is very strong and, for the reaction to occur, this bond needs to be broken first. In terms of SSCT, thus, the qualities of N have changed when the higher order molecule, N_2, has been synthesized. In order to make the reaction possible, the qualities of N need to be changed; it must have a quality to come into a relationship with H (I will reiterate that, according to SSCT, quality is the potential of a structure to come into a relationship with another structure). The reaction presented in the formula occurs, however, if an iron catalyst is used.

The mechanism of how a catalyst is involved in this reaction was revealed by Gerhard Ertl. In order to understand the description of the catalytic process, three terms need to be defined first: *physisorption*, *chemisorption*, and *desorption*. These terms are related to processes that take place on the surface of the catalyst. These three terms are defined as follows:

> When a molecular species approaches a surface, it can undergo several processes near the surface. It may just bind to the surface by van der Waals interactions, a process that is known as *physisorption*. Alternatively, it may form chemical bonds with the surface atoms, leading to *chemisorption*. Sometimes a molecule may undergo dissociation at the surface and the constituent fragments form chemical bonds with the surface. If one of the fragments finds a suitable adsorbed species nearby, it may then react with such a species on the surface and form new products, which leave the surface in a process known as *desorption* (Swathi and Sebastian 2008, p. 552, my emphasis).

The whole process of catalysis is understood in this way:

> The first step is the adsorption of nitrogen and hydrogen molecules on to the iron surface. Nitrogen at first physisorbs as a molecule, and then dissociates into atoms, which remain chemisorbed on the surface. On the other hand, hydrogen molecule chemisorbs dissociatively, to give hydrogen atoms on the surface. The chemisorbed nitrogen atom then immediately picks up three hydrogen atoms, one by one leading to the formation of ammonia. Finally the ammonia molecule desorbs from the surface (Swathi and Sebastian, 2008, p. 555).

This description contains several important ideas about catalysis as understood in SSCT. First, sometimes synthesis of a certain whole is possible only in several steps. Several steps are needed when the elements of to-become-a-novel-whole are parts of other systems. In that case, these other systems need to be dissociated first to change the qualities of the elements needed for the synthesis. Systems change only when they form a relationship with some other system. In this case, this other system is called a catalyst. A catalyst is a system that forms a temporary relationship with a system composed of elements, whose qualities need to change. After the qualities of the elements have changed, the final synthesis can occur. In this synthesis, the relationship with the catalyst is broken and new relationships between elements of the emergent whole are formed.

Is it Possible to Apply the Chemical Principles of Catalysis to Mental and Cultural Processes?

Psychology has suffered—and is suffering—from reductionism, when principles of lower-level organization are used as explanations for higher-order structures. Physical processes, for example, are constrained by certain principles and laws. An attempt to explain living and mental processes by the same laws would be reductionist because living systems are higher-order structures of physical bodies, which laws and principles are specific to the living structures only. In mainstream psychology, reductionism is extremely common; processes of the brain or, even worse, genes, have been used in an attempt to explain almost every mental process.

An anti-reductionist stance, however, can be as misleading as a reductionist stance. In opposition to reductionism, it is easy to slip into denying the role of lower-level principles to higher-order syntheses. Antireductionism of this kind results, for example, in theories of culture that do not take into account an individual and the fact that all cultural individuals are also living organisms. For example, both in semiotics and in certain schools of (cultural) psychology, it is assumed that there are 'signs' or 'symbols' in the environment of an individual. This idea is fundamentally misleading due to biological constraints on the ways an individual can relate to his or her environment. Namely, the only (sic!) way to relate mentally to the environment is through sensory organs. Yet sensory organs dissociate the sensed environment into tens of thousands (in hearing, for example) or even millions of pieces (in vision) (see, e.g., Levine 2000, for biology of sensation). We sense the world only with receptors; the complex and organized perception is the fully individual creation synthesized on the basis of receptor activation or inhibition. Thus, symbols are also not in the environment. In the environment there are certain physical objects and phenomena that have the qualities to become symbols, when an individual constructs the meanings of sensed events.

In the hierarchically organized world, the laws and principles are actually asymmetric: all lower-level principles apply and constrain all higher-order systems, but higher-order systems are organized according to the laws and principles that apply only to this synthetic level and not to lower levels of organization. So all living organisms are subordinated to the principles of physics but only living organisms are subordinated to the principles of life. To understand life, thus, requires understanding both physical and biological principles; otherwise there is always a danger of attributing principles of life to what actually belongs to the realm of physics. Understanding of the mind, in turn, is not possible unless physical and biological principles are taken into account and distinguished from psychological principles.

It follows that the principle of catalysis can be applied to the analysis of mental and cultural systems without modification. Obviously, such application is not identical to the application of the principle in chemistry—qualitatively different kinds of elements and qualitatively different kinds of relationships between elements must be subordinated to the principle of catalysis in chemistry and psychology, respectively.

Thus, catalysis is not a metaphor for psychology. The concept of catalysis should also not be related to terms like ‘help’ or ‘directing,’ which just hide the structural–systemic essence of catalytic processes. There is no need to create theoretical confusion with talk of ‘context,’ ‘condition,’ or ‘mediator.’ There are just systems that are situated among other systems which either are or are not characterized by qualities that come into a relationship with a given system. ‘Catalysis’ is a very useful concept here that helps us to understand the dynamics of systemic changes and refers to the fact that occasionally higher-order wholes can emerge only in a chain of systemic reorganizations where some elements need to be dissociated from other systems before their synthesis into some other system becomes possible.

What the Concept of Catalysis Can Offer to (Cultural) Psychology

Now we can return to the beginning of this chapter. The question was whether the concept of catalytic causality can be useful for (cultural) psychology. I think the discussion above allows us to conclude that the answer is definitely yes, the concept can be very useful. Yet, as I also demonstrated, there are two different theories in the context of which the concept can be used. Structural–systemic causality theory, as I have tried to show, is a powerful metatheory in the context of which the concept of catalysis becomes productive. A discussion regarding the application of SSCT in psychology is also beyond the scope of this chapter. This epistemology has been used by several eminent scholars before, among them Vygotsky and Luria. Both of them were explicitly relying on the theory I call structural–systemic (see also Toomela in press-a, in press-b). As far as I know, catalysis has not been explicitly applied in structural–systemic schools of psychology, yet, Valsiner and his followers have introduced a very valuable idea for developing SSCT.

The situation is more complicated when catalysis is used in the context of a metatheory that I have referred to as CCT. On one hand, in the context of the primitive efficient causality epistemology followed by the majority of psychologists today, the advancement is obvious and enormously important. It only supports the conclusion, achieved in other publications, that during the last 60 years mainstream psychology has produced almost nothing theoretically noteworthy (Toomela 2007a, b, 2010c; Toomela and Valsiner 2010). Obviously there is little hope for mainstream psychology to advance theoretically on the basis of primitive and out-of-date epistemology, as is clearly demonstrated by CCT.

On the other hand, however, I tried to demonstrate in this chapter that CCT is more confusing and less efficient than SSCT. In that perspective, I would suggest not to go further with CCT, as an alternative—SSCT—seems to be more useful.

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