

Individuation of Cross-Cutting Causal Systems in Cognitive Science and Behavioral Ecology

Marie I. Kaiser, Beate Krickel

Abstract: For many causal endeavors, such as measuring, predicting, and explaining, individuating causal systems plays a crucial role. In this chapter, we focus on the individuation of a specific type of causal systems, what we call *cross-cutting systems*. These are systems that lack natural boundaries and that are not restricted to the spatiotemporal region of the individuals to which they belong. Based on examples taken from cognitive science and behavioral ecology, we explore how scientists individuate such cross-cutting causal systems.

1 Introduction

Studying a particular causal system requires singling the system out (see also Beisbart, this volume; El-Hani et al., this volume). This in turn requires knowing what the system is responsible for, knowing its boundaries, knowing what is part of the system and what is not, and knowing how the system can be distinguished from other systems (e.g., non-causal systems or neighboring systems). For example, studying the mammalian digestive system requires knowing that the system is responsible for the breakdown of food so that nutrients can be absorbed by the body; and that, say, the stomach is a part of it, but the kidney is not, and so on. All these questions concern the *individuation* (or *identification*)¹ of a causal system.

Causality enters the picture at two points: First, causal system individuation is relevant for many scientific endeavors, such as measurement, intervention, and explanation that are themselves causal. One can intervene into a system and evaluate the impact of an intervention only if one knows where to intervene (i.e., the parts of the system) and if one knows what the typical behaviors or outputs of a system are. The same holds for measurement and explanation: Many empirical studies involve quantifying causal systems, which requires demarcating them from other systems; mechanistically explaining the behavior of a causal system requires knowing what this behavior is and which parts of the system are involved in bringing about the behavior. Second, the criteria for individuating causal systems are causal. We will elaborate on and explain this second aspect in this chapter.

¹ In line with Kaiser & Trappes (2021), we use the two terms synonymously. We acknowledge that there might be interesting ways of distinguishing individuation and identification. For instance, one might think that identification is only about singling out/demarcating and counting, whereas individuation is more demanding and requires, e.g., assigning the causal system to a kind (see e.g., Lowe (2005)). However, intuitions about the meaning of these terms differ and there exists no established, non-controversial distinction between these two concepts.

Individuation has an epistemic and a metaphysical component (see also the causal mosaic in Illari and Russo 2014; introduction, this volume). Individuation, on the one hand, is a practical issue requiring the right kinds of methods and epistemic practices in order to single out a system. On the other hand, individuation concerns the relations between entities (Lowe 2005) and specifies what makes an entity the entity it is. Clearly, both components of individuation are related: to practically individuate a system one needs to know what makes it the system that it is (see also Andersen, this volume). In this chapter, we will mainly be concerned with the metaphysical aspects of individuation. However, we adopt a “metaphysics of biological practice” (Kaiser 2018b, 29) approach. That is, we develop our metaphysical claims on the basis of an analysis of how scientists actually individuate causal systems when they measure, intervene in, reason about, explain, and theorize about them. We thus address epistemological, methodological, and semantic questions about individuation as well, but only as means to derive metaphysical conclusions from the answers.

In this chapter we focus on examples of causal systems prominently studied in cognitive science and behavioral ecology: cognitive systems and individualized niches (which are a special type of ecological niches à la Hutchinson 1957). We analyze how these causal systems are individuated and which role causality plays in determining the parts and boundaries of these systems. These two kinds of causal systems – cognitive systems and individualized niches – differ in many respects but have many features in common that make it philosophically interesting to discuss them together. The two most relevant ones are: they do not have *natural boundaries*, and they are what we call *cross-cutting systems*. We explain these two features in more detail in the next section.

In Section 2 we introduce what cognitive systems (Section 2.1) and individualized niches (Section 2.2) are and provide some examples. In Section 2.3 we point to some differences between these two kinds of causal systems, and we reveal five features that they have in common: they are causal, they do not have natural boundaries, they are responsible for a phenomenon, they are systems of a focal individual, and they are cross-cutting. In Section 3 we argue that the individuation of causal systems in cognitive science and behavioral ecology requires, first, to identify the phenomenon that the system is responsible for, and second, to identify the parts of the system that are relevant to the phenomenon. We develop some preliminary ideas about specifying these two conditions in general by spelling out what the phenomena (Section 3.1) and relevance (Section 3.2) are in the case of cognitive systems and individualized niches.

2 Cognitive Systems and Individualized Niches: Cross-cutting without Natural Boundaries

In the present chapter, we discuss the individuation of two types of causal systems that play a central role in cognitive science and behavioral ecology: cognitive systems and ecological niches. We first briefly present the two examples and then explain what they have in common that makes these two examples especially challenging and philosophically interesting when it comes to causal system individuation.

2.1 Cognitive systems

A central question in cognitive science as well as philosophy of cognition is: What are the boundaries of cognitive systems? This question is especially hotly debated in the context of the research program of 4E cognition (i.e., extended, embodied, enacted, embedded cognition) (Shapiro 2007). Up for debate is the question of whether cognition takes place only in the brain, or whether it involves the body or even elements of the external world as well.

For example, some researchers argue that the human working/short term memory system extends the brain as eye movements play a crucial role for the successful execution of different working memory tasks. It could be shown, for example, that when subjects are asked to make a copy of a pattern of colored blocks, they will perform repeated eye saccades between the original and the copy. If eye saccades are prohibited, e.g., by asking subjects to look at a fixation cross, performance in these tasks severely decreases. Some argue that this shows that the working memory system includes the eyes and their saccadic movements (Ballard, Hayhoe, and Pelz 1995; Clark 2008; Kaplan 2012).

Similarly, the biologists Hilton F. Japyassú and Kevin N. Laland (2017) argue that the cognitive system of spiders is not only located inside the spider's nervous system. Rather, the spider's web and the spider's interactions with the web are parts of the spider's cognitive system as well. Spiders flexibly change their webs to improve their food intake depending on their current nutrition state (i.e., hunger) and on features such as how profitable different areas of the web are. For example, spiders manipulate thread tension of specific portions of their webs. By doing so, these portions of the web become more sensitive to perturbations, e.g., due to trapped insects. This will increase the spider's attention to these web portions as increased vibrations travel from the perturbed web portion to the spider's body. Japyassú and Laland argue that this shows that the spider's web is part of the spider's cognitive (here: attentional) system.

2.2 Behavioral Ecology: Individualized Niches

An important kind of causal system studied in behavioral ecology are individualized (ecological) niches (for other types of causal systems in ecology see El-Hani et al., this volume; Poliseli, this volume). *Individualized* niches differ from ecological niches (Hutchinson 1957) in that they are the niches of (types of) individuals, not of populations or species. Biologists use the concept of an individualized niche to capture the fact that each type of organism is not only unique in its phenotypic traits and in the behavior that it shows; it is also unique in the way it interacts with specific parts of the environment – including abiotic factors, such as temperature, and other individuals (Kaiser & Trappes 2021; Trappes 2022). How biologists study and think about individualized niches suggests that they take them to be real entities in nature, rather than abstract entities. Even though the term ‘individualized niche’ suggests that it is the niche of a particular individual, biologists often study *types* of focal individuals and *types* of individualized niches (e.g., the niche of a Guinea pig male or the niche of a bold beetle) for reasons of statistical power and to develop generalizations. The niche of an individual—the “focal individual”—consists of all factors that are relevant to the fitness of the individual. Among these are various environmental factors including abiotic factors and other individuals, and the interactions between the focal individual and those environmental factors that influence its fitness. Interestingly, biologists regard the focal individual (together with its behaviors, other phenotypic traits, and internal states, such as hormones) as a part of the individualized niche to emphasize the complex interactions and entanglement between individual and environment.

One example of an individualized niche is the individualized social niche of adult Guinea pig males.² Biologists investigate, for instance, how adult Guinea pig males adjust their hormonal and behavioral phenotype to conform to a new social environment (Mutwill et al. 2020). This is a niche-changing process called ‘niche conformance’. Adult Guinea pig males who have been, for instance, housed together with a single female (pair-housed) and are then placed in a colony housing adjust their behavior and underlying hormonal phenotype to the new social environment. They engage in more social interactions, particularly courtship and agonistic encounters, but also aggression towards other individuals. Because of the high frequency of social interactions, the adult Guinea pig males also show increased baseline testosterone levels and decreased cortisol responsiveness (Mutwill et al. 2020).

² Social niches are special types of individualized niches that focus on the interactions of the focal individual with other individuals (often of the same species).

Another example are the two sorts of individualized niches that Antarctic fur seal females can choose for breeding on Bird Island, South Georgia (Nagel et al. 2021). On the one hand, there is a breeding site showing a high population density, resulting, for instance, in a higher availability of mates, more competition for resources, more social stress (including possible traumatic injuries of pups), but a lower risk of predation. This is the high-density niche. On the other hand, there is a breeding site exhibiting a low population density, resulting, for instance, in a higher risk of predation, but a lower availability of mates, less competition for resources, and less social stress (including possible traumatic injuries of pups). This is the low-density niche. Biologists seek to elucidate the mechanism of how female fur seals interact with their environment to make this choice and how and why different individuals choose differently.

The individuation of ecological niches has not been an object of philosophical analysis so far. In their research practice, biologists are confronted with certain individuation challenges, which now and then provoke reflections on how to define the niche concept and how to identify the boundaries of individualized niches. Among the individuation challenges that biologists face are the difficulty to measure fitness effects and to clearly find out that certain environmental factors do or do not affect the fitness of an individual. Moreover, biologists often study more than one individualized niche at the same time (sometimes of different focal individuals) and do not clearly separate between them.

2.3 What cognitive systems and ecological niches have in common

Cognitive systems and ecological niches share interesting features that make their individuation challenging and philosophically interesting. First, they are *causal* systems. Cognitive systems, such as the working memory system, are composed of parts, e.g., activity in specific brain regions, eye movements, that causally interact such that the cognitive system does what it does. Similarly, ecological niches consist of parts, such as environmental items or con-specifics, that causally influence the fitness of the focal individual.

Second, they do not have natural boundaries. A widespread assumption is that entities are individuated based on their “natural boundaries” (Kaiser 2018a, 71) or “physical barriers” (Kaplan 2012, 552; Sterelny 2005, 31), such as the cell membrane, the skin of a mammal or the exoskeleton of an insect. Natural boundaries often involve structural differences and material discontinuities, and they function as selective barriers (Kaiser 2018a, 71-73). Reference to natural boundaries specifies the idea of spatial parthood: parts of an object (or system or mechanism) must be *spatially included* in the object in the sense that they must be located within the natural boundary of the object. Many cognitive systems and individualized niches

do not seem to possess such natural boundaries. Some of their parts (e.g., the brain, organisms) may have such natural boundaries but typically there is no natural boundary that surrounds a cognitive system or an individualized niche as a whole. Accordingly, the individuation of these sorts of causal systems cannot be based on the criterion of spatial inclusion.

Third, they are causal systems that are responsible for something. This insight is known from the mechanistic literature: a mechanism is always a mechanism *for* a specific phenomenon (e.g., Glennan 1996; Craver and Darden 2013; Illari and Williamson 2012). Niches and cognitive systems are causal systems that share this feature. Like the digestive system is a system that does digestion, cognitive systems are systems that enable cognition, and ecological niches are systems that influence fitness.

Fourth, cognitive systems as well as individualized niches are systems *of* an individual. Cognitive systems as investigated by cognitive scientists and cognitive neuroscientists are the cognitive systems of humans or, to a lesser extent, the cognitive systems of non-human animals. A niche is always the niche of a specific (type of) organism, the focal individual.

Fifth, cognitive systems and individualized niches are what we call *cross-cutting* (see Figure 1). They can be cross-cutting in two ways. First, even though cognitive systems and individualized niches belong to biological individuals they cut across them in interesting ways (cognitive systems do so often, niches always). Second, they are cross-cutting in the sense that they are bigger than the system that was traditionally identified as a cognitive system or niche. Figure 1 summarizes the ways in which niches and cognitive systems are cross-cutting systems.

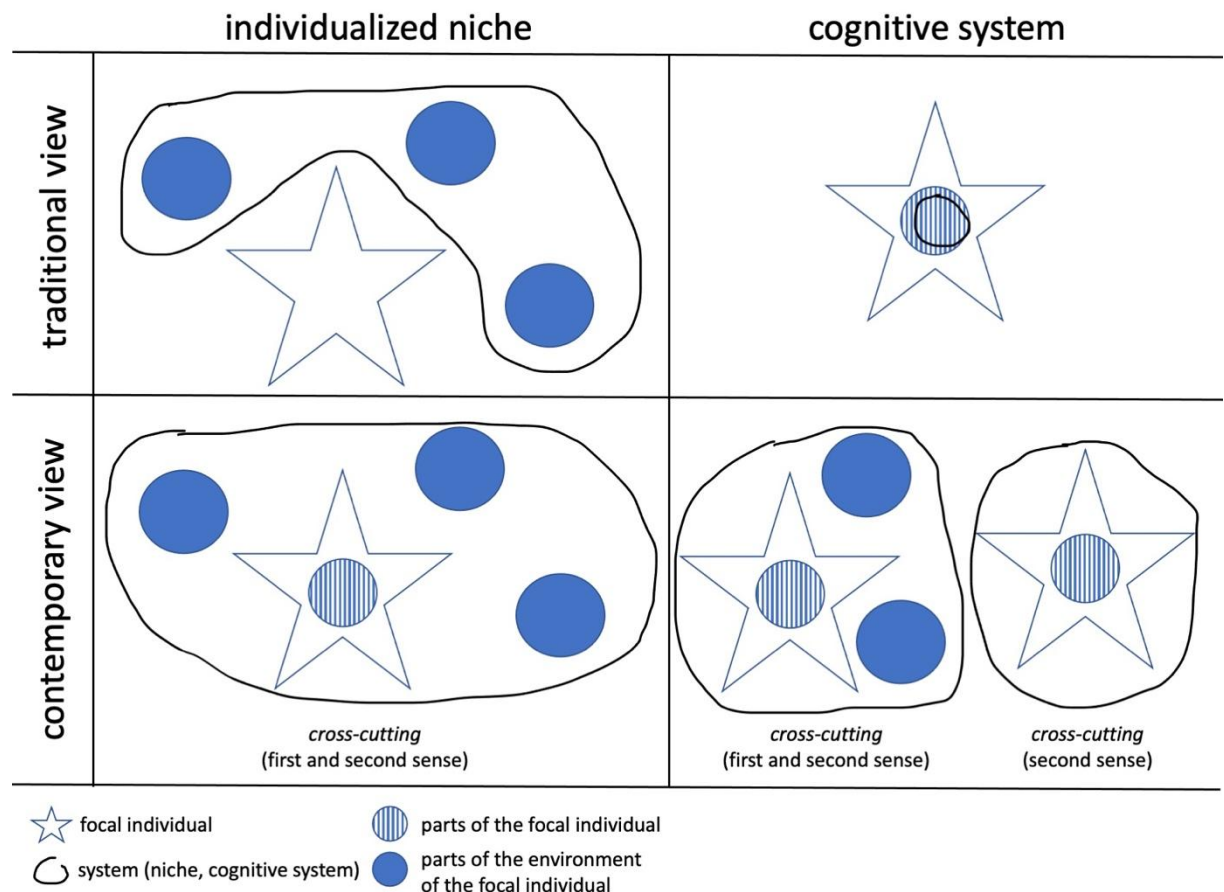


Figure 1 Ecological niches and cognitive systems are cross-cutting systems. Top-left: Traditionally, individualized niches were thought to only comprise elements of the environment of the focal individual. Bottom-left: Today, biologists agree that niches are cross-cutting systems, i.e., they comprise the focal individual itself as well as specific parts of it and thereby cut across between systems. Top-right: Cognitive systems were traditionally thought to be located only with the brain or parts thereof. Bottom-right: There is a growing consensus that some cognitive systems extend the boundaries of the brain and comprise parts of the extracranial body and/or parts of the environments of the focal individual.

One difference between cognitive systems and individualized niches is that the transition from the traditional view to the contemporary view (see Figure 1) started from opposite directions. Traditionally, cognitive systems were thought to be located inside the brain only. Newer research programs in cognitive science incorporate the idea that cognition is at least sometimes embodied and/or incorporates tool-use or other elements of the organism's environment. On the contrary, biologists thought of ecological niches as solely consisting of the environment of individual organisms. Nowadays, individualized niches are viewed as including non-environmental factors, such as the focal individual, its behavior, and internal states, as well as interactions between the focal individual and its environment.

3 How do we delineate cross-cutting systems without natural boundaries?

A common way to address the question raised in the title of this section is to look at the relationships among the parts of the system and to contrast these relationships with the relationships between the parts and the environment of the system. Let's call such accounts

part-focused accounts of causal system individuation. The idea underlying such accounts is that the relationship between the parts of the system relevantly differs from the relationship between parts and non-parts. Many argue that the relevant relation is *causation*.³ Roughly, the assumption is that the causal interactions among parts are stronger/more frequent than the causal interactions between parts and non-parts. The idea that the intensity of causal interactions determines the decomposition and demarcation of a system goes back to Simon (1962) and has been taken up and revised by several other authors (e.g., Wimsatt 2007; Haugeland 1998; McShea 2000; McShea and Venit 2001; Grush 2003). The general idea of the intensity of causal interactions can be spelled out differently, for instance in terms of interaction bandwidth⁴ profiles (Haugeland 1998; Grush 2003), in terms of causal integration (McShea 2000; McShea and Venit 2001), in terms of “cohesion” (Collier 2004; DiFrisco 2018), or in terms of modularity (El-Hani et al., this volume). The accounts differ in their details, which are not important here. The important aspect is that these accounts take specific relational (causal) properties of the parts of a causal system to provide sufficient grounds for individuating causal systems.

Part-focused accounts are confronted with several challenges (see, e.g., Craver 2007; Grush 2003; Kaplan 2012). One challenge is that they face the difficulty of distinguishing between parts of the system and parts of the environment that are *background factors*. For example, the heart’s beating is a background condition for the memory system to work properly—it is causally necessary for the memory system to work. One would thus assume that the heart’s activity and the memory system are strongly causally coupled. The heart, however, is not part of the memory system. The same holds for what Craver calls “sterile effects” (Craver 2007:143) of system parts. For example, the memory system will reliably activate other systems, such as the language system. However, the language system is not part of the memory system. Insisting that, still, the parts of the memory system are more strongly causally coupled among each other than to background factors and sterile effects seems to be unwarranted. It may well be that there is a part of the system that gets active only, say, to compensate for a malfunctioning of other components. As a consequence, it will be causally coupled with the rest of the system only in rare cases. Based on part-focused accounts, the compensating part, then, will not count as a part of the system.

³ According to other accounts, parts must be *integrated* in order to form a system (e.g., Rupert 2010). For reasons of space, we will not address these accounts here (see El-Hani et al., this volume).

⁴ Note that the bandwidth-criterion, as Grush (2003) named it, is meant to provide a criterion for decomposing a system into parts or sub-systems: sub-systems show more internal causal interactions than there is between sub-systems. Since sub-systems are themselves systems, the criterion can be used for system individuation as well.

Another major problem of part-focused accounts is that they ignore that systems are always systems *for*⁵ something – similar to mechanisms (e.g., Glennan 1996; Craver and Darden 2013; Illari and Williamson 2012) and to causal role functions (Cummins 1975). The working memory system is the system that enables memory; the spider’s attention system is the system that enables quick and efficient reactions to external stimuli; the individualized niche of an adult guinea pig male is the system that affects the fitness of the adult guinea pig male. In the end, we can only reliably identify a system if we have a clear understanding of what it is doing or what it is responsible for (we call this the *phenomenon*). Only then, one can identify those elements that are relevant for whatever the system is doing/is responsible for. In a nutshell, we think that individuating a causal system requires providing answers to two questions: (1) What is the *phenomenon* that the system is responsible for? (2) How are parts of the system *relevant* to the phenomenon, in contrast to non-parts? We use our case studies to provide some preliminary answers to both questions.

3.1 What is the Phenomenon?

What are the phenomena for which the causal systems in our examples are responsible? Cognitive systems are usually taken to be responsible for different cognitive capacities of humans or other animals. The working memory system is responsible for working memory, the spider’s attentional system is responsible for attention, and so on. Individualized niches are individuated relative to and, thus, are responsible for changes in the focal individual’s fitness, such as the inclusive fitness of the Guinea pig male or of the fur seal female. Fitness, thereby, cannot be straightforwardly interpreted as a capacity of the system similar to cognitive capacities. Rather, fitness is usually understood as the total number of offspring that an individual produces during its lifetime and that survives until reproductive age. Fitness, thus, is not the *capacity* to produce offspring but is rather identified with the actual production of offspring—the more offspring an individual de facto produces the fitter it is. A further difference between the phenomena for which cognitive systems are responsible and those for which niches are responsible is that cognitive systems are taken to be responsible for *successful* executions of the relevant capacity. Niches, in contrast, are taken to be responsible for *changes*

⁵ Note that the use of “for” here does not come with any teleological commitments (such as proper functions). In the mechanistic literature, the idea that “mechanisms are always for something” is not meant to imply that all mechanisms have proper functions or some other kind of purpose; it is meant to express that there are no mechanisms *simpliciter* but that mechanisms always do something or bring something about (see also Glennan 2017, 37).

in fitness—independently of whether these changes lead to an increase or a decrease of fitness (Trappes et al. 2022).

Besides these differences, the phenomena for which cognitive systems as well as individualized niches are responsible share interesting features: First, cognitive systems as well as niches bring about and explain phenomena that are *not directly measurable*. To conduct experiments and to measure the relevant phenomenon, the phenomenon must first be operationalized. For example, to investigate working memory, researchers must specify what exactly they take to be an instance of working memory that can be systematically measured. This can be done by having subjects copy patterns, remember lists of words, recall pictures, etc. Another way to operationalize a phenomenon is to identify “proxies” of it, that is, measurable variables that are assumed to adequately represent the phenomenon because they are closely linked to it. The phenomenon relative to which niches are individuated, the (inclusive) fitness of the focal individual, cannot be measured directly in many species, too, because the lifetime of individuals from many species is too long. Instead, biologists measure fitness proxies, such as body weight, health condition, or number of offspring in one year.

Second, the phenomenon in each case concerns a capacity or feature *of the focal individual*, not of the causal system that is to be individuated (Krickel 2018b makes a similar point about mechanisms). It is not the working memory system that copies patterns, and it is not the niche as a whole whose fitness is affected—in each case it is the focal individual that has a cognitive capacity or whose feature is relevant to individuating the system.

3.2 What is Relevance?

In which sense are the parts of causal systems “relevant to the phenomena” in our examples? Not just any cause of a phenomenon is part of the system that is responsible for the phenomenon. Obviously, an account of causal system individuation must exclude *irrelevant* causal factors.

In the discussion of part-focused accounts, two types of irrelevant causal factors were already identified: *background conditions* and *sterile effects*. Background conditions are factors that enable the system to work properly. The systems discussed here, the digestive system, the memory system, individualized niches, all involve living organisms. Therefore, all factors that are necessary for the organism to be alive, such as oxygen, heartbeat, etc. will be background factors—if they were not in place the digestive system, the memory system, and individualized niches could not exist.

Sterile effects are causal effects of parts of a system that may systematically arise when the system is active but that do not play any role for the proper working of the system. For example, the bodies of the respective individuals produce heat, the spiders catching behavior will lead to changes in the environment in which the web is fixated (e.g., by bending a tree limb). The guinea pig's interaction with the new social environment will lead to changes in the behaviors of other guinea pigs that may not affect its fitness, and also the fur seal female will change its environment in several ways that are irrelevant to its fitness.

One account that is motivated by exactly these considerations is the *mutual manipulability account* for individuating mechanisms (Craver 2007). Here, we want to take this account as a starting point to develop a preliminary account of causal system individuation for cross-cutting systems. According to the mutual manipulability account, something is a part of a causal mechanism for a phenomenon P only if (i) it is a spatiotemporal part⁶ of P and (ii) the part and P are mutually manipulable. Phenomena, here, are behaving systems, such as a cell synthesizing proteins (Kaiser and Krickel 2017; Krickel 2018b). According to Craver's account, ribosomes, for instance, are parts of the mechanism for protein synthesis because (i) they are spatially located inside the cell (and their reading off the mRNA temporally occurs during the cell's protein synthesis) and (ii) because the cell synthesizing proteins and the ribosomes reading off the mRNA are mutually manipulable, that is, there is a way to change the cell synthesizing proteins (phenomenon) by changing the ribosomes reading off mRNA (parts) and there is a way to change the part by changing the phenomenon.

Craver's presentation of the mutual manipulability account has stimulated an extensive debate on the details of this account (e.g., Couch 2011; Leuridan 2012; Romero 2015; Baumgartner and Gebharder 2016; Baumgartner and Casini 2017; Kästner 2017; Krickel 2018a; Harinen 2018; Craver, Glennan, and Povich 2021). We will not go into details here, but rather discuss how this account can be used to specify how causal systems in cognitive science and in behavioral ecology are individuated. In particular, we will examine whether the mutual manipulability account provides plausible criteria for identifying those causal factors that are relevant to the phenomenon and thus are parts of the causal system. We will suggest some modifications to suit this account to the individuation of causal systems in cognitive science and in behavioral ecology.

⁶ Many authors, including Craver, distinguish between "parts" and "working parts" or "components", where parts may be arbitrary decompositions of a system or non-functional factors within the boundaries of a system. We will talk about "spatiotemporal parts" instead of "part" in order to be able to keep the formulation of "parts of a system" to refer to what others call "working parts" or "components".

At first sight, the mutual manipulability account seems suitable to specify the relevance of parts of causal systems to the phenomenon that the system is responsible for. Contrary to parts-focused accounts, the mutual manipulability account does not formulate any condition concerning the interrelations between the parts. Rather, both conditions – (i) spatiotemporal parthood and (ii) mutual manipulability – concern the relation between parts and phenomenon. However, two major problems for the mutual manipulability account arise from the peculiarities of causal systems in cognitive science and behavioral ecology.

The first major problem is the following. As we have argued in Section 2.3, causal systems such as cognitive systems and individualized niches do not have natural boundaries that determine what is spatially included in the system and what is not. Hence, it remains unclear under which conditions the criterion of spatiotemporal parthood is fulfilled. How should we determine whether something is a spatiotemporal part of a system if the system has no natural boundaries? Are the eyes spatiotemporal parts of the working memory system? Is the spider's web a spatiotemporal part of the spider's attention system? Are the mating partners or the wind speed spatial parts of the individualized niche of fur seal females? The absence of natural boundaries of these systems motivated us to look for alternative accounts.

This first problem cannot be solved by simply dropping the first condition of the mutual manipulability account, as Kaplan (2012) does in his discussion of cognitive system individuation. Many systems are causally coupled with other systems without one system being a part of the other. For example, the memory system and the language system are plausibly causally coupled: remembering activates language production (e.g., an inner monologue) and language production activates memory (e.g., by means of association). However, the memory system is neither a part of the language system, nor is the language system a part of the memory system.

A more promising solution is to *replace* the parthood condition by combining the phenomenon-relativity of the mutual manipulability account with the insights of the part-focused accounts discussed in Section 3. Instead of requiring that the system's parts must be spatiotemporal parts of a larger whole, one could require that the parts of a system must causally interact with each other more intensively than with non-parts in a sense specified by one of the part-focused accounts. This idea seems to be promising as it could help to exclude the memory system-language system counterexample above: while these systems are clearly mutually manipulable, they plausibly do not interact with each other *intensively*. How convincing this combination of mutual manipulability with part-focused accounts is, of course, will depend on

whether a clear and convincing specification of “more intensively” can be found. At this point, we refer the reader to the literature on the part-focused accounts mentioned in Section 3.

On a general level, the idea of combining mutual manipulability with an intensity-of-interactions requirement is in line with our examples introduced in section 2. When people solve copying tasks there is a strong causal interaction between the eye movements and arm movements (Ballard et al. 1995) and this causal interaction is plausibly much stronger than, say, the interaction between eye movements and leg movements or any other part of the body. Other examples, however, show that we need to refine the intensity-of-interactions requirement in two ways. First, cross-cutting systems where the focal individual is itself considered to be a part of the system pose a challenge. For such causal systems it is simply not true that *all* of their parts interact with *each other* intensively. In the case of individualized niches and in the spider cognition case, the system’s parts mainly interact *with the focal individual*, and it is the intensity of only those interactions with the focal individual that matter to individuating the system. For example, colony-housed adult Guinea pigs engage in various different social interactions (e.g., courtship, agonistic encounters, aggression). However, for individuating the individualized niche of, say, the previously pair-housed adult Guinea pig male only the interactions of other individuals with this focal individual are relevant, not the interactions between the other, non-focal individuals. Hence, in these cases we should restrict the intensity-of-interactions demand and require only intensive causal interactions of the system’s parts *with the focal individual*.

Second, in the case of individuating individualized niches there is an additional constraint at work in biological practice that the intensity-of-interactions requirement does not capture. Biologists restrict the individualized niche to *direct causes* of the focal individual, more precisely, to direct causes of changes in the behavior or internal states of the focal individual that are causally relevant to its fitness. For instance, the individualized niche of Antarctic fur seal females consists of the availability of mates because this is a direct cause of mating behavior, which affects the females’ fitness. In contrast, the niche does not include factors affecting the availability of mates (e.g., competition among males) which do not affect the focal individual directly. Hence, only intensive interactions between the focal individual and the direct causes of its fitness-relevant behavior/internal states matter to the individuation of individualized niches.

There is a second major problem for the mutual manipulability account. The main motivation for introducing mutual manipulability is to exclude background factors and sterile effects. Still, some authors have raised the worry that some background factors might still come out as part of a system (Craver 2007; Hewitson, Kaplan, and Sutton 2018). For example, the

heart's beating will still come out as a part of the system for a memory task, say, word stem completion if, e.g., the words to be completed are highly emotional. In that case, mutual manipulability is satisfied: if you stop the heart, word stem completion will stop as well; and if you change the words such that they are less emotionally arousing, this will slow down the heartbeat. To solve that problem, some authors suggest adding the criterion of *causal specificity*: the manipulation of the part relative to the phenomenon and the manipulation of the phenomenon relative to the parts must be specific. It must be possible to induce specific changes and not merely turn an on/off switch. This is not true for the heart relative to word-stem completion.

Mutual manipulability revised in this way is straightforwardly applicable to cross-cutting cognitive systems. Eye movements are parts of the memory system of humans, if—on the assumption that they satisfy the first condition—it is possible to intervene into the eyes (by, say, prohibiting movements of the eyes) and thereby change the outcome of the copying behavior; and it is possible to intervene into the copying behavior (by, say, making the pattern-to-be-copied more complex) and thereby change the eye movements. Both seem to be the case in the given example (Kaplan 2012). The same holds for the spider's web and the spider's interactions with it: it is possible to change the web (e.g., by changing the density of the web at some location) and thereby change in the spider's preying success; and it is possible to change the spider's preying success (e.g., by feeding it) and thereby change properties of the web (the spider is saturated and, thus, will change the web to be less sensitive/less dense).

When it comes to individualized niches, as a descriptively adequate account, mutual manipulability seems less straightforwardly applicable because biologists do not perform top-down interventions (i.e., changing the phenomenon to change a part of the system) to individuate niches. As a matter of fact, they do not directly intervene into the fitness of individuals (or into fitness proxies) to detect changes in the niche. Still, these interventions into fitness or fitness proxies are conceivable. For example, biologists could perform such top-down interventions by intervening into the health of an individual (a fitness proxy) to see whether this has any influence on factors that qualify as candidates for being parts of the niche of the individual. Interestingly, biologists do perform interventions that are quite similar to such top-down interventions. In so-called *match-mismatch experiments*, they place individuals in a different environment, to which their phenotype does not match well (e.g., brown grasshoppers on green grass). By doing so, the biologists indirectly decrease the fitness of the individuals, and they investigate how this changes the individual's phenotype and their individualized

niches (Trappes et al. 2022). Hence, the modified mutual manipulability account might nevertheless be fruitful in the context of individuating individualized niches.

4 Conclusion

In this chapter, we looked at a certain type of causal system: *cross-cutting systems*. Such systems do not have natural boundaries and are not restricted to the spatiotemporal region of the individuals to which they belong. We focused on two kinds of cross-cutting systems: cognitive systems and individualized niches. Our core question was how scientists individuate such systems (and should individuate them) given the absence of natural boundaries. We argued that two tasks are crucial to individuating these causal systems: identifying the phenomenon that the system is responsible for and identifying the parts of the system that are relevant to the phenomenon. We characterized the type of phenomena that cognitive systems and individualized niches are for, and we made use of Craver's mutual manipulability account to develop some ideas to spell out the notion of relevance in the case of cross-cutting systems.

The discussion has shown that causation enters the picture at two points: first, causal interactions, interventions, and causal knowledge are a necessary condition for the individuation of cross-cutting systems. According to the account we suggested, the parts of the system do causally interact and are mutually manipulable in a causally specific way. Second, based on knowledge about the identity of the cross-cutting system causal hypotheses about the behavior of the system can be derived and tested, interventions into the parts of the cross-cutting system are now possible to allow for, e.g., What-if-things-had-been-different explanations, causal models of the system can be built, and measurements of the properties of the cross-cutting system and its parts can now be based on a clear understanding of the boundaries of the system.

References

- Ballard, Dana H., Mary M. Hayhoe, and Jeff B. Pelz. (1995): "Memory Representations in Natural Tasks." *Journal of Cognitive Neuroscience* 7(1): 66–80.
- Baumgartner, Michael, and Lorenzo Casini (2017): "An Abductive Theory of Constitution." *Philosophy of Science* 84(2): 214–33.
- Baumgartner, Michael, and Alexander Gebharter (2016): "Constitutive Relevance, Mutual Manipulability, and Fat-Handedness." *The British Journal for the Philosophy of Science* 67(3): 731–56.
- Clark, Andy (2008): *Supersizing the Mind - Embodiment, Action, and Cognitive Extension*.

New York: Oxford University Press.

Collier, John (2004): “Self-Organization, Individuation and Identity.” *Revue Internationale de Philosophie* 58(228): 151–72.

Couch, Mark B. (2011): “Mechanisms and Constitutive Relevance.” *Synthese* 183(3): 375–88.

Craver, Carl F. (2007): *Explaining the Brain: Mechanisms and the Mosaic Unity of Neuroscience*. New York: Oxford University Press.

Craver, Carl F., Stuart Glennan, and Mark Povich (2021): “Constitutive Relevance & Mutual Manipulability Revisited.” *Synthese* 199(3-4): 8807–28.

Craver, Carl F., & Darden, Lindley (2013): *In Search of Mechanisms. Discoveries across the Life Sciences*. University of Chicago Press.

Cummins, R. (1975): Functional Analysis. *The Journal of Philosophy* 72(20): 741–765.

DiFrisco, James (2018): “Biological Processes.” In: D. Nicholson, J. Dupré (eds.), *Everything Flows*. Oxford University Press, Oxford, 76–95.

Glennan, Stuart (1996): Mechanisms and the Nature of Causation. *Erkenntnis* 44(1): 49–71.
<https://doi.org/10.1007/BF00172853>

Glennan, Stuart (2017): *The New Mechanical Philosophy*. Oxford University Press.
<https://doi.org/10.1093/oso/9780198779711.001.0001>

Grush, Rick (2003): “In Defense of Some ‘cartesian’ Assumptions Concerning the Brain and Its Operation.” *Biology and Philosophy* 18(1):53–93.

Harinen, Totte (2018): “Mutual Manipulability and Causal Inbetweenness.” *Synthese* 195(1): 35–54.

Haugeland, John (1998): *Having Thought*, Harvard University Press, Cambridge MA.

Hewitson, Christopher L., David M. Kaplan, and John Sutton (2018): “Yesterday the Earwig, Today Man, Tomorrow the Earwig?” *Comparative Cognition & Behavior Reviews* 13: 25–30.

Hutchinson, GE (1957): Concluding remarks. *Cold Spring Harbor Symp Quant Biol* 22: 415-27.

Illari, Phyllis M., Russo, Federica (2014): *Causality*. Philosophical theory meets scientific practice. Oxford: Oxford University Press.

Illari, P. M., & Williamson, J. (2012): What is a mechanism? Thinking about mechanisms across the sciences. *European Journal for Philosophy of Science* 2(1): 119–135.
<https://doi.org/10.1007/s13194-011-0038-2>

Japyassú, Hilton F., and Kevin N. Laland (2017): “Extended Spider Cognition.” *Animal Cognition* 20(3): 375–95.

- Kaiser M. I. (2018a): Individuating Part-whole Relations in the Biological World, in: Bueno O., Chen R.-L., Fagan M. B. (eds.): *Individuation, Process and Scientific Practices*. Oxford: Oxford University Press, 63-87.
- Kaiser M. I. (2018b): ENCODE and the Parts of the Human Genome, *Studies in History and Philosophy of Biological and Biomedical Sciences* 72: 28-37.
- Kaiser, Marie I., and Beate Krickel. 2017. "The Metaphysics of Constitutive Mechanistic Phenomena." *The British Journal for the Philosophy of Science* 68(3): 745–79.
- Kaiser Marie. I., Trappes, Rose. (2021): Broadening the Problem Agenda of Biological Individuality: Individual Differences, Uniqueness, and Temporality. *Biology & Philosophy* 36(2): <https://doi.org/10.1007/s10539-021-09791-5>.
- Kaplan, David M (2012): "How to Demarcate the Boundaries of Cognition." *Biology and Philosophy* 27(4): 545–70.
- Kästner, Lena (2017): *Philosophy of Cognitive Neuroscience: Causal Explanations, Mechanisms and Empirical Manipulations*. Berlin/Boston: De Gruyter.
- Krickel, Beate (2018a): "Saving the Mutual Manipulability Account of Constitutive Relevance." *Studies in History and Philosophy of Science Part A* 68: 58–67.
- Krickel, Beate (2018b): *The Mechanical World*. Vol. 13. Cham: Springer International Publishing.
- Leuridan, Bert (2012): "Three Problems for the Mutual Manipulability Account of Constitutive Relevance in Mechanisms." *British Journal for the Philosophy of Science* 63(2): 399–427.
- Lowe, E. J. (2005): Individuation. In M. J. Loux & D. W. Zimmermann (Eds.), *The Oxford Handbook of Metaphysics* (pp. 75–96). Oxford University Press.
<https://doi.org/10.1093/oxfordhb/9780199284221.003.0004>
- McShea, D. W. (2000): Functional complexity in organisms: Parts as proxies. *Biology and Philosophy* 15(5): 641–668. <https://doi.org/10.1023/A:1006695908715>
- McShea, D. W., & Venit, E. P. (2001): What is a Part? In Wagner, Gunter P. (ed.): *The Character Concept in Evolutionary Biology*. London, Academic Press, 259-284.
- Mutwill AM, Zimmermann TD, Hennicke A, Richter SH, Kaiser S, Sachser N (2020): Adaptive reshaping of the hormonal phenotype after social niche transition in adulthood. *Proceedings of the Royal Society B* 287, 20200667.
- Nagel R, Mews S, Adam T, Stainfield C, Fox-Clarke C, Toscani C, Langrock R, Forcada J, Hoffman JI (2021): "Movement patterns and activity levels are shaped by the neonatal environment in Antarctic fur seal pups". *Scientific Reports*, 11(1): 14323. doi:

10.1038/s41598-021-93253-1.

- Romero, Felipe (2015): “Why There Isn’t Inter-Level Causation in Mechanisms.” *Synthese* 192(11): 3731–55.
- Rupert, Robert D. (2010): “Extended Cognition and the Priority of Cognitive Systems.” *Cognitive Systems Research* 11(4): 343–56.
- Shapiro, Larry (2007): “The Embodied Cognition Research Programme.” *Philosophy Compass* 2(2): 338–46.
- Simon, Herbert A. (1962): “The Architecture of Complexity”, in: *Proceedings of the American Philosophical Society* 106 (6): 467-482.
- Sterelny, Kim (2005): Made By Each Other: Organisms and Their Environment. *Biology and Philosophy* 20: 21-36, DOI 10.1007/s10539-004-0759-0
- Trappes, Rose (2022): Individual differences, uniqueness, and individuality in behavioural ecology. *Studies in History and Philosophy of Science* 96: 18-26.
- Trappes Rose, Nematipour B., Kaiser M. I., Krohs U., van Benthem K. J., Ernst U. R., Gadau J., Korsten P., Kurtz J., Schielzeth H., Schmoll T., Takola E. (2022): How Individualized Niches Arise: Defining Mechanisms of Niche Construction, Niche Choice, and Niche Conformance, *BioScience* 72(6): 538–548, <https://doi.org/10.1093/biosci/biac023>
- Wimsatt, William C. (2007): *Re-Engineering Philosophy for Limited Beings. Piecewise Approximations to Reality*, Cambridge: Harvard University Press.

Notes on Contributors

Marie I. Kaiser is professor for philosophy of science at Bielefeld University, Germany. In 2015, she published the monograph *Reductive Explanation in the Biological Sciences* with Springer.

Beate Krickel is professor for philosophy of cognition at Technical University Berlin in Germany. In 2018, she published the monograph *The Mechanical World* with Springer.