



# Understanding Human Action. Integrating Meanings, Mechanisms, Causes, and Contexts<sup>1</sup>

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Humans are capable of understanding an incredible variety of actions performed by other humans. Even though these range from primary biological actions, like eating and fleeing, to acts in parliament or in poetry, humans generally can make sense of each other's actions. Action understanding is the cognitive ability to make sense of another person's action by integrating perceptual information about the behavior with knowledge about the immediate and sociocultural contexts of the action, understanding of relevant meanings and one's own experience. Given the importance of action understanding in every domain of human life and society, and in light of the complexities that surround it, a comprehensive scientific understanding of this capacity is needed. Scholars are increasingly dissatisfied with monodisciplinary approaches to understanding human action, like when an action is interpreted only in sociocultural terms while overlooking cognitive constraints, or when an action is understood in biological terms while neglecting its psychological impact on the agent.

Recent interdisciplinary endeavors demonstrate how an interdisciplinary approach is possible when investigating complex functions like action understanding. Ever more insight is gained in the mutual influences between biological, cognitive and sociocultural processes that together contribute to action and action understanding. The purpose of this paper is to describe how a 'mechanistic explanation', or a 'mechanism-based explanation' of action understanding provides a theoretical framework for integrating various and often conflicting disciplinary insights. By applying the heuristics of 'definition', 'decomposition' and 'localization', researchers can determine the phenomenon that they collaboratively investigate while at the same time dividing this task into smaller component tasks of which the results must eventually be put together. Some researchers, for example, can apply a hermeneutic approach to the sociocultural environment in which action understanding takes place, while others aim to specify the cognitive processes or the neuro-electrical pathways that are activated under those conditions.

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After having presented a step-by-step analysis of an interdisciplinary investigation of action understanding by way of developing a mechanistic explanation the chapter closes with some suggestions for testing its result and mentions some limitations of this approach.

*Keywords: action understanding, cognitive ability, mechanistic explanation, decomposition, localization, interdisciplinary research, transdisciplinary research, multilevel phenomenon*

## **Понимание природы человеческого действия. Интеграция смыслов, механизмов, причин и контекстов**

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Каждый из людей обладает способностью понимать все то невероятное разнообразие видов деятельности, на которое способны другие люди, пусть даже спектр таких действий варьируется от базовых биологических действий по самосохранению — питание, бегство от опасности — до деятельности парламентариев и поэтического творчества: каковы бы ни были действия одного человека, любой другой, как правило, может понять их смысл. Понимание деятельности есть когнитивная способность, которая состоит в установлении смысла действий другого; эта способность реализуется в результате интегрирования чувственных данных об индивидуальном поведении в наличный контекст деятельности — равно как и в более общий социокультурный контекст — а также в результате выявления релевантных этому действию смыслов и смыслов, заключенных в собственных действиях. Важность и трудноосуществимость задачи понимания человеческой деятельности в любых сферах индивидуальной и общественной жизни предполагает необходимость всестороннего научного осмысления указанной человеческой способности. В академических кругах усиливается неудовлетворенность результатами применения монодисциплинарных подходов к пониманию человеческой деятельности; так, например, каким-то действиям может быть дано социокультурное освещение, а их когнитивные рамки будут оставлены без внимания; или же действиям будет придан биологический смысл — в ущерб пониманию того, какое психологическое воздействие оказали они на субъект действия.

Новейшими трансдисциплинарными исследованиями демонстрируется возможность осуществления трансдисциплинарного подхода в исследовании таких сложных функций, как понимание деятельности. Еще более плодотворным оказалось изучение взаимного влияния биологических, когнитивных и социокультурных процессов, сочетание которых важно как для деятельности, так и для ее понимания. Задача данной работы — представить описание «механического объяснения» или объяснения действия «в терминах задействованных механизмов»

в качестве теоретического основания соединения разных, порой взаимно противоречивых, дисциплинарных позиций. Благодаря привлечению таких эвристических приемов, как «дефиниция», «декомпозиция» и «локализация», исследователи получают возможность вычленить феномен, являющийся объектом совместного исследования, и одновременно подразделить общую задачу на компоненты, которые возможно реализовывать по отдельности — так чтобы, в конечном счете, снова составить из них целое. Например, одна часть исследователей может исследовать герменевтическими методами социокультурную среду, в которой осуществлялась деятельность, а другие одновременно сосредоточатся на уточнении характера когнитивных процессах этой деятельности или на активированных в ходе ее нервно-электрических проводящих путях.

Вслед за описанием постадийного анализа трансдисциплинарного исследования понимания деятельности, основанного на интерпретации в терминах задействованных в ней механизмов, в данной статье приводятся некоторые предложения, касающиеся проверки результатов этого анализа, а также затрагивается тема ограниченности предложенного подхода.

*Ключевые слова: процесс понимания смысла деятельности, когнитивная способность, задействованные механизмы, декомпозиция, локализация, междисциплинарное исследование, трансдисциплинарное исследование, многоуровневое явление*

## Introduction

Humans are capable of understanding an incredible variety of actions performed by other humans. Even though these range from primary biological actions, like eating and fleeing, to acts in parliament or in poetry, humans generally can make sense of each other's actions. Understanding other people's actions is called *action understanding*, and it can transcend differences in race, gender, culture, age, and social and historical circumstances. Action understanding is the cognitive ability to make sense of another person's action by integrating perceptual information about the behavior with knowledge about the immediate and sociocultural contexts of the action and with one's own experience.

Because it is necessary to integrate multiple sources of information, it is not surprising that failures to understand a person's behavior are also common. Well known is the case of the autistic professor who compares herself to an "anthropologist from Mars." Incapable of spontaneously understanding why someone cries, she has learned rules that help her to infer that people who rub their eyes while tears are running down their cheeks are weeping and probably feel unhappy (Sacks, 1995). By contrast, normal individuals automatically allow stereotypes, prejudices, self-interests, and the like to influence their understanding of a person's behavior (Bargh & Chartrand, 1999). More generally still, humans can easily misunderstand unfamiliar symbolic actions or rituals if they rely too much on their own sociocultural expertise (Gadamer, 2004). Given the importance of action understanding in every domain of human life and society, and in

light of the complexities that surround it, a comprehensive scientific understanding of this capacity is needed. Apart from satisfying intellectual curiosity, such insight would serve to improve our action understanding and mitigate several forms of misunderstanding. Indeed, in studying action understanding, “we as scientists are engaged in the very process that is central to our concerns” (Gergen & Semin, 1990, P. 1).

Scholars are increasingly dissatisfied with monodisciplinary approaches to understanding human action. Such one-sidedness can rest upon various motives. For example, “hermeneutic interpretations” of action understanding tend to emphasize historical and cultural influences while overlooking that ultimately such influences depend upon individual cognitive processes<sup>2</sup>. This has provoked criticism of the corresponding assumption that humans are born as a “blank slate” and that culture is solely responsible for all cognitive contents. However, such critique in turn easily slides into an overemphasis on the biology of human nature and a denial of sociocultural influences on cognition (Pinker, 2003).

Fortunately, recent endeavors have shown that an interdisciplinary approach is preferable when investigating complex functions like action understanding. Such research often involves developing a new “interdiscipline,” such as cultural psychology (Bruner, 1990), or combining insights from the social sciences and psychology (Shore, 1996; Sperber, 1996). Evidence shows that throughout human evolution there have been mutual influences between biological and cognitive processes that shape human capacities and the sociocultural influences on those processes (Bogdan, 2003; Donald, 1991; Tomasello, 1999). In addition to these interdisciplinary investigations, computational sciences and artificial intelligence research are developing computer models of human understanding that enable new types of experiments and simulations (Churchland, 1995). Such insights underscore the necessity and fruitfulness of disciplinary boundary crossing and require that various disciplinary methods, concepts, and theories be combined in innovative ways.

At present, there is a need for a theoretical framework that is capable of explaining a phenomenon as complex as human action. Such a framework requires integrating insights from multiple disciplines. The purpose of this chapter is to propose a “mechanistic explanation”<sup>3</sup> of action understanding that will provide a theoretical framework for integrating various and often conflicting disciplinary insights. Proposing an integrative

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- <sup>2</sup> There is little room for evidence from the natural and social sciences in the hermeneutics as proposed by the influential Gadamer (2004). A theory of interpretation that gives scientific explanation a role in interpretation is proposed in Ricoeur (2008). In the social sciences, an influential approach considers human functions as stemming from actor-network interactions, without specific interest in biological and psychological conditions (Bourdieu, 1990).
  - <sup>3</sup> Such an explanation is called “mechanistic” in the philosophy of science literature, referring to the explanatory mechanism as an epistemic device, playing a role in the organization of knowledge. If our knowledge of a phenomenon changes, the mechanism needs adjustments accordingly (Machamer, Darden, & Craver, 2000). ‘Mechanism’ should not be taken in an ontological sense, which would imply that scientists merely have to ‘uncover’ it.

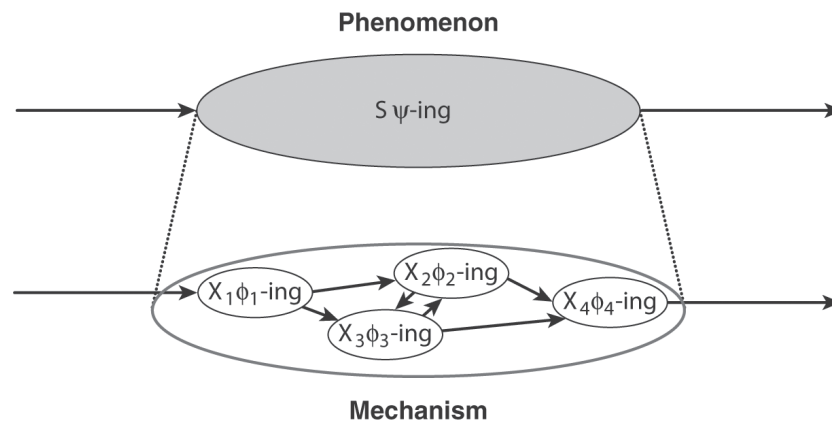
theoretical frame is a common practice in the sciences. Such a frame enables scientists to explain many facts that have been observed while predicting others. In the life and cognitive sciences, a specific integrative device that is often applied is this *mechanistic explanation*<sup>4</sup>. As used here, *mechanism* means “an organized system of component parts and component operations. The mechanism’s components and their organization produce its behavior, thereby instantiating a phenomenon” (Bechtel, 2005, P. 314).

In explaining action understanding, scientists assume that there is a complex cognitive mechanism that is responsible for this phenomenon. Such a cognitive mechanism can “produce” action understanding as it processes multiple sources of external information. Moreover, external influences can modulate or affect the mechanism itself, as is the case with sociocultural information. For instance, neuroimaging experiments in which Western and Chinese students were asked to think about themselves and then think about their mothers showed that differences in family relations are correlated with differences between the neural processes. In Western students, self-related thought activated different processes than mother-related thought, while in Chinese students the two processes were rather similar (Han & Northoff, 2008). Because action understanding involves many more different sources of information, a mechanistic explanatory approach should be prepared to integrate insights such as these, stemming from various disciplines. This chapter will describe how such a mechanistic explanation can be developed, while distinguishing between different steps of the interdisciplinary research process. Although distinguishing such steps of the interdisciplinary process has been shown to be useful, it is important to realize that a research process will probably involve some iterativity (Repko 2008; Repko, Newell & Szostak, 2011). For example, a researcher may be forced to reconsider the initial problem definition due to insights from other disciplines in the problem. The linear description offered here is therefore not representative of the often rather messy research process as it occurs in the lab or behind the desk.

### **Mechanistic Explanation in Brief**

A simple and familiar example of a mechanism is a clock with components like gears and shafts and operations like turning and oscillating. If made properly and provided with external inputs such as energy and correct initial settings, the clock will establish time accurately. However, we cannot identify the mechanism that makes the clock work just by observing its external pattern of behavior. To do that requires going *inside* the clock and investigating its various components and operations. Complex mechanisms may be analyzed at various levels. The human body, for example, is a far more complex mechanism than a clock and must be analyzed at various levels — anatomical, physi-

<sup>4</sup> Because it proved to be extremely rare to demonstrate analogues of Newton’s mechanical laws for biological or cognitive systems, an alternative scientific device is considered more apt for these fields (Bechtel & Richardson, 1993; Machamer et al., 2000). Meanwhile, social scientists are discussing the fruitfulness of a mechanistic approach as well— see Hedstrom and Swedberg (1996), for example.



**Figure 1**

*A Phenomenon and Its Mechanism*

SOURCE: Craver (2007, P. 7)

ological, or biochemical — to be fully understood. Each of these levels refers to the hierarchy of the body's organization, not to the physical size of the parts that exist at each level. Given the many and often nonlinear interactions between, for example, chemical substances, organ functions, and sociocultural meanings that together can produce specific hallucinations, biological phenomena are very complex. Compared to the human body, a mechanical clock is not complex: Underneath the observable level of shafts and gears is the unobservable level of molecules. Note that molecular differences between clocks made from steel or from silver do not affect the way they establish time, whereas changing molecules in blood will affect human bodily functions. Biological and cognitive mechanisms are also far more complex than engineered mechanisms because of the nonlinearity of many intrinsic activities and their responsiveness to environmental factors, including the meanings of sociocultural settings and symbols.

Two strategies are used to develop a mechanistic explanation of a phenomenon: decomposition and localization (Bechtel & Richardson, 1993). *Decomposition* means that we first analyze a given phenomenon—whether establishing time or action understanding—into components or smaller tasks that in concert are responsible for it. *Localization* means that we then try to locate these components of the phenomenon somewhere in the object or organism that displays the phenomenon. In easy cases, such as the clock, we can localize the components of our phenomenon (e.g., pointing the hours or the minutes) in separate component parts and activities of the clock. However, these parts and activities are not completely separable because they rely on the same energy source and initial settings and share many other parts and activities. Typically, therefore, our research leads to increasing specification and revision of the decomposition and localization of the phenomenon with which we started. For readers who may be unfamiliar with this approach, some clarifications are in order.

The first is that a mechanistic explanation is *not* a complete description of a clock, an animal, or a brain. Rather, it is an explanation of a specific phenomenon, event, or behavior that is produced by the organized interaction of components and operations. A mechanistic explanation of action understanding as performed by the brain will, therefore, contribute only in a limited sense to explanations of other functions of the brain. Because a mechanistic explanation could be given for each function and for its components, a complete description would consist of an unmanageable multitude of mechanisms, many of which would overlap and modulate each other. Fortunately, explaining a specific phenomenon does not require this.

The second clarification is that a phenomenon may appear singular and opaque, but if we are to give a (mechanistic) explanation of it, we must establish that it is produced by different components and operations. Cognitive operations are often called *computations*. These can be very simple, like addition, or more complex, like face recognition. **Figure 1** above shows a schema of a phenomenon, the activity of S -ing<sup>5</sup>. It also shows components X 1–4 that, by interacting in response to an external input, produce the phenomenon. The arrows indicate the interactions that connect the components, consisting mostly of simple activation or inhibition signals. These interactions often include feedback and feedforward interactions between the components and their operations. However, note that merely observing the phenomenon (from the top down) does not reveal the complex mechanism and its operation that produce the phenomenon. What appears on the surface to be a single phenomenon is, in fact, a “distributed network” of smaller actions. Note also that the phenomenon receives input (left-side arrow) and produces output, as do the components and operations at a lower level. Explaining action understanding means that we examine the cognitive processes that the human brain performs at various levels and that together form the person’s capacity to understand the action or behavior of another person.

The third clarification is that such a mechanism usually is a multilevel system and can accordingly be examined at different levels. Obviously, we can study action understanding while remaining at the personal level, where we observe which types of action a person can and cannot understand, and examine the conditions that influence his action understanding. Going into the brain to a first subpersonal level, we can investigate which neural networks must cooperate to perform this function appropriately. Going down to a second level, we can investigate isolated components and activities in a particular neural area: its neurons, their interactions, and their connections to neurons in other locations. If we need to be even more specific about these neuronal activities, we can focus at a third level and describe the neurochemical activities by which neurons pass on information to each other. Going in the other direction, we can also climb one level upward and consider the

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<sup>5</sup> If the phenomenon is complex, it is useful to decompose it into in subtasks, as we will do with action understanding (see **Figure 2** at the end of the article).

person as a component; that is, consider him or her as a member of various social groups. At that supra-personal level, we are interested in the interactions between individuals and how they influence each other's action understanding, for example. For reasons discussed later, we don't need always to descend or ascend many levels when we explain a phenomenon like action understanding. The study of neurochemical interactions at the third level may still be relevant, but it is implausible that going as deep as the quantum mechanic level of the human brain yields useful insights into action understanding.

The fourth clarification, and one that is particularly relevant to all cognitive processes, is that mechanisms do not operate in complete isolation but are responsive to various factors, including contextual factors. Organisms are open to external information via their senses, but not always equally so because their motivation state, attention, and other internal processes influence this openness. Thus, the mechanism governing action understanding will be influenced by a host of contextual variables.

The fifth is that organismic mechanisms are much more flexible systems than other mechanisms. In organisms, we may observe that over time and due to learning or development or to injuries, mechanisms responsible for a particular behavior have changed or have been adapted—something a clock cannot do<sup>6</sup>. Strikingly, an organism may even develop different ways to produce the same behavior or phenomenon. Automatization of a skill leads, for instance, to diminished involvement of conscious control of movements, making it possible to perform other cognitive tasks simultaneously. This can be made visible with the help of brain imaging techniques, which reveal that experts and novices in a particular skill display strikingly different brain activation patterns when performing similar tasks (Poldrack et al., 2005).

A mechanistic explanatory approach, then, is particularly useful to interdisciplinarians because it allows them to achieve a more comprehensive understanding of phenomena such as action understanding. In applying this approach, interdisciplinarians can connect the monodisciplinary insights in specific components and operations at multiple levels and their intricate interactions that contribute to human action understanding. How this works is the subject of the next section.

### **Drawing on Disciplinary Insights (Steps 1 to 6)**

Generally speaking, scientific efforts enable us to represent reality and intervene in it (Hacking, 1983). Scientists represent reality by using mathematical formulas, graphs, charts, mechanistic and verbal explanations, and the like. Scientists intervene to test the adequacy of their representation or the predictions they derive from it. Depending on the

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<sup>6</sup> In my 'Sculpting the space of actions. Explaining human action by integrating intentions and mechanisms' (2014) it is shown how development and learning can have lasting effects on a mechanism that underlies human capacities. These changes can have an impact on relevant perceptual, cognitive and behavioral components of such a capacity. As a result, the performance of a particular function or action by an expert can be in many ways be different from a novice's performance.



discipline and the representations, such interventions range from digging for fossils in geological strata, sending particles through a cyclotron, subjecting people to experimental conditions, to adjusting variables in computational programs used for simulations of phenomena. Choosing an adequate type of representation of our insight into a phenomenon is an important matter, as is the choice of an appropriate intervention to test it.

Engaging in interdisciplinary research is an even more demanding process. A mechanistic explanation allows us to assign disciplinary insights more or less to particular levels: Neuroscientists will focus on the neuronal and neural level, psychologists at the higher level of action understanding and its components, while sociologists will focus on the interactions between individual persons that influence the properties of this understanding. The challenge for interdisciplinary integration is to demonstrate how the components and activities that occur at different levels interact with those at other levels. However, first we must decide which disciplines are relevant for explaining action understanding. *Relevance* is thus a key term for this first part of the interdisciplinary process, if only to keep it manageable.

### **Defining the Problem: Decomposition of Action Understanding**

Action understanding is the subject of many disciplines. This is partly the result of it being such a general and wide-ranging phenomenon with many different properties. While acknowledging its variability, it is useful to formulate a general definition. In what follows, we will consider action understanding as the result of cognitive processes that an individual—partly unconsciously—performs when making sense of another person's actions. In doing so, one person has not only to recognize the other person is acting, but also to include various sources of information to interpret that action. As a result, the action can be understood and perhaps responded to appropriately.

By putting cognitive processes at the heart of the definition, we will focus on the cognitive information processing that goes on in the brain, for which we will establish a mechanistic explanation. This decision is in line with recent developments in both the cognitive and social sciences. Indeed, we may even speak of a “cognitive turn” in many disciplines. For instance, anthropologist Bradd Shore (1996) argues for a “cognitive view of culture” (p. 39), concurring with his fellow social scientist Sperber (1996), who argues for combining psychology with the study of culture because of our “psychological *susceptibility* to culture” (p. 57). In accordance with that susceptibility, Reyna (2002) analyzes the human mind as a “neurohermeneutic system,” for which “‘interpretation’ is the operation of neurons to represent, and act upon, reality” (p. 112). Finally, and more extreme, is the argument that even “philosophical theories are largely the product of the hidden hand of the cognitive unconscious” (Lakoff & Johnson, 1999, P. 14). Note that putting cognition at the heart of these approaches does not imply that there is no room left for external and sociocultural influences on action understanding. Nor does it imply that the culture-specific meaning of words and symbols doesn't matter. It does, and the study of cultural

determination of meaning is highly relevant. However, for such sociocultural aspects to have an influence on action understanding, they must exert this influence by affecting cognitive processes that go on in the brains of individual persons.

Having defined action understanding and put cognition at its center, we now have to take an important step. I mentioned in the previous section that we must apply two heuristics, decomposition and localization. Ergo, we should first try to decompose action understanding into smaller (sub)phenomena that can be studied more or less separately and subsequently integrate the results. Associated with that decomposition is our localization effort that involves finding responsible cognitive or brain processes that do the work. In fact, we have already localized action understanding very broadly in the individual's cognitive processes.

Having defined action understanding as a cognitive process, we can now decompose it further by classifying it according to its contents<sup>7</sup>. We can follow the lead of hermeneutic philosopher Paul Ricoeur, who has devoted much of his work to the theory and method of interpretation of human narrative and human action. Ricoeur (1992) pointed out that we can approach action with a set of interrelated questions focusing on, respectively, who, what, why, how, where, and when<sup>8</sup>. His analysis prioritizes three of those questions, which offer three different perspectives on action: *What* is the action, *why* is the action being done, and *who* is the agent? Because "Who is the agent?" refers to the agent's identity, social roles, continuous maturation, and the like, this information will generally not be captured by the other perspectives. For that reason, Ricoeur deplores that "the use of 'why?' in the explanation of action . . . became the arbiter of the description of what counts as action" (p. 61). It will become clear that to identify the relevant contexts, we need to know more about the agent "who" performed the action. Ricoeur's emphasis upon the "who" of action does not imply that contexts do not matter, but it is a consequence of the fact that contexts have to make themselves felt via an individual's cognitive processing.

So, following the lead offered by a hermeneutic analysis of understanding actions, we can decompose action understanding into three different, but probably interrelated, component tasks: understanding what an action is, understanding why an action has been performed, and a more thoroughgoing understanding of the "who" behind it. Evidence does indeed confirm the possibility of disentangling these three components of

<sup>7</sup> Even though it is very well known that classifications and taxonomies often need corrections, revisions, or additions, they are extremely helpful in delineating otherwise overwhelming domains (Dupre, 2001). In the case of human capacities like action understanding, our preliminary classification inevitably starts from the use of our common vocabulary. This does not imply that such words that we commonly apply hold up to scientific scrutiny. Indeed, although we may expect that concepts in the domain of human experience are more robust than concepts like «ether» or «vital force,» we may need to revise the former, too (Keestra & Cowley, 2009).

<sup>8</sup> This set of questions has also been proposed in the context of the classification of scientific theories (Szostak, 2004).

action understanding that have to do with, respectively, action recognition, intention understanding, and narrative understanding.

### **Justify Using an Interdisciplinary Approach: Action Understanding as a Multilevel Phenomenon**

Because our mechanistic explanation focuses on cognitive processes, we must first appreciate that cognitive sciences are themselves plural and that the field is interdisciplinary. This has been the case from the start, as one of its pioneers recalls: “I argued that at least six disciplines were involved: psychology, linguistics, neuroscience, computer science, anthropology and philosophy. I saw psychology, linguistics and computer science as central, the other three as peripheral” (Miller, 2003, P. 143). Note that interdisciplinary endeavors may range from a mere borrowing of concepts or tools to the establishment of a new interdisciplinary with its own discipline-like contents, structures, and conventions (Klein, 1990). In our current research, different types of interdisciplinarity will be involved simultaneously.

Somewhat simplifying, I mentioned earlier that there is a link between the contribution of different disciplines and the different levels of a mechanism. This is easier to see in nonorganismic mechanisms, as they are not so complex nor flexible in their organization. From cosmology via molecular physics to quantum physics, we can distinguish different disciplines focusing on particular levels of mechanism. They use their own tools and methods and formulate different theories and hypotheses. Even though the differences between, for example, quantum mechanics, relativity theory, and classical mechanics are considerable, I believe that in the cognitive sciences, the characteristics of the different levels and the associated differences are wider ranging. To connect sociological and psychological observations, brain images, neurochemical interactions, and genetic factors, we need a wide variety of conceptual and methodological tools, whereas in the physical sciences, gaps between levels are largely bridged with mathematics.

Given this complexity and the interdisciplinary nature of our investigations, decomposing action understanding into action recognition, intention understanding, and narrative understanding will make our task more manageable. Our next step is to localize these task components somewhere “in” the individual, or rather in that person’s cognitive apparatus—foremost the brain. The interaction between cognitive processes and their contexts may involve social scientific and humanistic investigations. Applying our mechanistic explanatory perspective to the decomposed task of action understanding, we will once more approach it as a multilevel phenomenon. Of course, we already did that when decomposing the task into three components, but now we are heading for the brain and neural tissue. Indeed, we must try to assign the components and operations of our phenomenon to concrete, localizable, bodily, or neural areas and activities. Generally, if we start from a particular level, we can look both upward and downward. Looking downward “involves describing lower-level mechanisms for a higher-level phenomenon” where these mechanisms are responsible for subtasks of the task or phenomenon (Craver,

2007, p. 257). Conversely, if we look upward, we may be able to see our mechanism interacting with other mechanisms that together realize a new phenomenon at this higher level. For instance, our action understanding will, in interaction with perception, motivation, and motor action, contribute to the agent's response to another person's behavior. At that level, it can be considered a component alongside several other components and operations. So, in looking downward, we can treat action understanding as an independent variable and detect changes in the associated mechanisms. Or, conversely, we can investigate the changes in action understanding due to influences at a higher level. **Figure 2** at the end of this article may illustrate these investigative approaches to the mechanism that we are discovering in association with action understanding.

Interdisciplinary collaborations are involved in the investigations of such a mechanism, bringing different intervention and observation techniques with them. Researchers can experimentally intervene in the components or operations at a particular level and try to detect the consequences at another level—upward or downward. In the cognitive sciences—including neuroscience—such interventions can be distinguished generally as interference, stimulation, or activation experiments (Craver, 2007). Stimulation involves, for example, presenting a stimulus to a subject and detecting correlated activation at lower levels, down to single neurons. Interference implies disturbing the normal mechanism, for instance by electrostimulation of neurons, with subsequent detection of behavioral differences at a higher level. Apart from such “vertically” directed interventions, researchers can try to influence the mechanism “horizontally.” By varying the stimuli, researchers can observe at various levels whether different mechanisms are activated, which subsequently are observable through specific properties of cognitive processing. Activation experiments can also be combined with brain imaging techniques, which allow researchers to observe the associated lower-level activities of the posited mechanism, its components, and its operations. The colorful images of brain activation patterns published in great numbers are the results of such activation experiments. Furthermore, there is also the valuable assistance of comparative work performed by ethologists, developmental psychologists, computer simulation scientists, philosophers, and, again, social scientists and humanists. The latter disciplines can help to investigate, for instance, whether action understanding relies on different mechanisms in subjects from collectivist versus individualist societies, or whether religious and nonreligious subjects display a difference in focus while processing perceptual information. Clearly, limiting the number of disciplines to those that are most relevant to the problem at hand is crucial to make the interdisciplinary research process manageable—even though empirical evidence can lead to the need to include an originally excluded discipline<sup>9</sup>.

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<sup>9</sup> For example, climate change models have only recently included ocean dynamics, after marine scientists proved that it is involved in climate change.

### Identifying Disciplines Most Relevant to the Mechanistic Approach

In general, deciding which disciplines are most relevant for any given research project can be guided by three questions: Does the discipline have a well-defined *perspective* on the problem? Has the discipline produced a *body of research* (i.e., insights) on the problem of such significance that its published insights and supporting evidence cannot be ignored? Has the discipline generated *one or more theories* to explain the problem (Repko, 2008, P. 169–170)? Although action understanding is instantiated by a multilevel mechanism, it is not surprising to find that disciplines that focus on very low levels—like quantum mechanics—have not delivered useful insights to it. Fortunately, not all events at such low levels make themselves felt at much higher levels in a relevant way. Quantum phenomena do occur in every atom of the brain, but if they affect cognition or behavior, they do so only when they influence functioning of specific neural areas. A cosmological phenomenon like sunspots may impact on human cognition only when it influences earthly temperatures, which have an impact on environmental conditions of humans, which finally can affect human cognitive processes. However, it is rarely the case that a single neuron seriously influences a cognitive process that involves many more neurons, or that human cognition is directly and irrevocably influenced by environmental temperature. Therefore, and in accordance with the observation that everywhere in the universe we find “local maxima of regularity and predictability” (Wimsatt, 2007, P. 209), we can restrict our multilevel system investigations to the nearest levels of our phenomenon<sup>10</sup>. Even though interdisciplinarians must be critical of the traditional division of labor among disciplines and keep an open eye to contributions from unexpected disciplines, the fact that we can conceive of connections between extremely divergent disciplines is never reason enough to overlook differences in relevance and specificity.

Meanwhile, a first estimation of relevant disciplines for our research of action understanding can be made. Although our initial topic of action understanding implies inclusion of the full range of the cognitive sciences, the social sciences, and the humanities to account for all varieties of action understanding, our first delineation and decomposition of it has made the research more manageable. Instead of one broad phenomenon, we are now able to focus on three distinct components (action recognition, intention understanding, and narrative understanding), which will lead to different questions, research methods and results, and theories.

Most straightforward is, arguably, the investigation of the first component, action recognition, which is the capability of “parsing” or sequencing continuous bodily be-

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<sup>10</sup> It is also related to the intriguing phenomenon of emergent properties: properties that occur at a particular level and cannot be explained purely on the basis of our knowledge of lower-level components and operations. We can now say that such emergent properties are likely to depend partly on the systemic interactions between components and operations at the particular level itself, and even that higher-level («top-down») contributions will often be involved, leaving little room for strictly reductionist explanations of higher-level properties (Bechtel & Richardson, 1993).

havior or movements into distinct actions. It is plausible both from a developmental and an evolutionary perspective that this parsing capacity is present in newborns and animals. Consequently, we may at first exclude the humanities and even social sciences from investigations of this component of action understanding. Again, it may turn out that later cognitive or speech developments affect the mechanism that carries out action parsing, but our preliminary hypothesis is that without these developments, action parsing is still being performed. With the exclusion of those sciences, there are still enough candidates for inclusion, such as neurophysiology, developmental psychology, biology, and information science.

For the second component of action understanding, intention understanding, we may need to include social sciences and humanities in our investigations. Note that we cannot straightaway exclude those sciences that assist to explain action parsing. Parsing remains generally a precondition for understanding intention, and it appears in some cases to contribute significantly to understanding the specific intentions of actions. For frequently repeated actions, it has been argued that primates derive the intentional structure of complex actions purely on statistical processing (Byrne, 1999). However, it is implausible that such processing should suffice for all instances of intention understanding. How about discovering the intentions of newly observed actions, or of irregular and complex actions involving tools? There is much evidence of humans taking a so-called “intentional stance,” assigning to the observed agent the possession of mental states such as beliefs, desires, and reasons. This stance is extremely useful for predicting future behavior of relatively autonomous agents (Dennett, 1989). Experimental observations show that even young infants expect that agents are aiming rationally at a particular goal and show surprise if their behavior contradicts this expectation (Gergely, Nádasdy, Csibra, & Bíró, 1995). To explain these mental states, we need to draw in more scientific disciplines because these states involve other types of social information, often mediated by language, symbols, and so on. Social sciences and humanities can systematically investigate the interactions between such influences and action understanding. These influences are even transmitted at lower levels of the mechanism and are correlated with the patterns of activity of so-called mirror neurons, which have turned out to play an important role in this domain. These mirror neurons were discovered some 20 years ago and have surprising properties because they respond both to perception and to observation or imagination of actions. It is interesting that their activation depends partly on prior experiences of the observers, even with socioculturally specific information. Understanding and imitating an action that is within their “vocabulary” or actions is consequently easier than if they observe it for the first time (Rizzolatti & Sinigaglia, 2008). For this component, we can draw on philosophical analysis of intentional action, on behavioral biology and psychology, on the cognitive sciences, and perhaps on social scientific research that focuses on sociocultural specific means and goals of action. In some instances of human ac-

tion, goals, objects, and instruments are perceptually visible, facilitating intention understanding. However, often the action is not or is incompletely visible, or the action is ambivalent or is temporally extended, or the perceptually available information is sparse. Not surprising, therefore, our third component of action understanding, narrative understanding, relies much more on higher cognitive processes and the use of narrative structures. We employ language, concepts, abstraction, temporal and causal relations, and the like when developing narrative structures. These are generally of an abstract nature and cannot be perceived through the senses. With the help of such structures, “we comprehend other people’s minds by creating a coherent narrative or story of their actions, organized around their goals,” including the conditions, the agent’s plans, and possible outcomes (Read & Miller, 2005, P. 125). These coherent narratives are naturally based, in part, upon the observable properties of agents and their actions, but they also depend upon previous expertise and knowledge of the observer, including relevant sociocultural information. While making use of the insights pertaining to intention understanding, for this component we need also insights from the humanities and the social sciences about the construction and use of narratives and theories of meaning in speech and behavior. Moreover, we may want to check for cognitive scientific explanations of these phenomena as well, in order to explain why schizophrenics have difficulties with delivering narratives, for instance.

In sum, simple explanations of action understanding are not to be expected. Even with appropriate neural and cognitive functions, humans will face limitations in their ability to understand each other because of the variability—due to sociocultural influences—in individuals’ cognitive processes. Indeed, social cognitive scientists or cognitive anthropologists argue that sociocultural-specific differences in action understanding have “two distinct moments of birth, one public and conventional and the other a subjective appropriation and integration of a conventional form by a particular person. The links between public models and personal knowledge are contingent relations” (Shore, 1996, P. 371). Such contingency applies less strongly to action recognition, as such statistical and perceptual processes will be more generally present in individuals from different cultures—even though for sociocultural actions we may need specific expertise to be able to parse complex ritual actions. Given the number of disciplines listed above, interdisciplinary research can benefit from prudently leaving out a discipline if it is not relevant to the specific component or operation in which we are interested.

### **Conduct an In-Depth Literature Search**

Having exposed the scope and complexity of action understanding, it is apt to conclude that it is not a research topic but rather a comprehensive field of interdisciplinary research. However, with the help of the mechanistic explanatory approach, we are able to narrow the scope of our research adequately. First, by decomposing the phenomenon, we have helpfully delineated three component tasks: action recognition, intention un-

derstanding, and narrative understanding. Now, we can try to limit ourselves to one of the three component tasks when we engage in behavioral, ethological, developmental psychological, or other studies at the phenomenon level. We can investigate the conditions and results of handling the task and subsequently explain what, in fact, the apparent task consists of. We can also observe whether adults, infants, and animals are doing comparably well and whether their results are correlated with their language capabilities. A more advanced subject would be the relations between the component tasks. For instance, recognition of an action is sometimes facilitated by understanding its intention. Such relations therefore complicate the explanatory mechanism.

Second, after observing the phenomenon “horizontally,” we may then look at it as a multilevel mechanism and view it “vertically.” Earlier I noted that we do not need to go very high or low in the investigations of associated levels. So no quantum mechanics or cosmology, but neurology, perhaps neurophysiology, and cognitive psychology should be our prime domains for the literature search.

Third, science in general and mechanistic explanation in particular is especially interested in behavior, changes, and modifications. If nothing ever happens to a phenomenon, it is difficult to give a representation of its relevant mechanism. When investigating such a mechanism, researchers can induce changes by using the interlevel experiments that make use of the interference, stimulation, and activation techniques referenced earlier. Such experiments are relevant to our research. Literature that refers to exceptional cases or pathologies should be included with caution because the flexibility of the brain hinders generalization from such cases to normal cognitive processes. For instance, even with dysfunctional mirror neuron systems, autistic patients may be able to reach some intention understanding.

Fourth, parallel to these studies and drawing heavily upon them, in the cognitive sciences and elsewhere researchers increasingly use computational simulations of a phenomenon. When focusing on a specific component or operation, comparison with results from such simulations may be informative. For instance, when a specific mechanism is simulated in a neural network program, it can also be used for virtual—or in vitro—interference, stimulation, and activation experiments comparable to those carried out on living subjects. More extravagant still, when building and testing humanoid robots, roboticists use the insights of action understanding research. Such research may provide us with information regarding which cues facilitate humans to understand robot actions. For instance, a form of eye contact and gaze following by a humanoid robot seems to be a prerequisite for effective interaction by humans with them<sup>11</sup>.

Fifth, the social sciences and humanities contribute foremost to the “horizontal” investigation of action understanding itself. For instance, cross-cultural research could deliver insights into differences in action understanding properties. It is implausible that socio-cultural differences have a large impact on the cognitive mechanism itself, even though

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<sup>11</sup> See Breazeal (2004) for more on this.



there is evidence of the coevolution of language and cognition (Donald, 1991). It is plausible, nonetheless, that a singular complex and dynamic organ like the brain can develop highly divergent forms of processing corresponding to the expertise that it gathers under specific sociocultural conditions. Anyone who has observed chess masters, musicians, or hierogram readers perform their exquisite skills may doubt whether they have the same brain and use the same cognitive processes as we all do—but, yes, largely they do. Even if these distinct capabilities are only the consequence of modulations of the mechanism by such individual and external influences, the results are relevant enough to our inquiry.

Sixth, sometimes researchers have established a specific topic that appears to be representative of the phenomenon under scrutiny. In the case of action understanding, the study of imitation has turned out to be exemplary. Studying imitation, we gain insights in “two relationships that are central to understanding minds in general and human minds in particular: the relationship between perception and action and the relationship between self and other” (Hurley & Chater, 2005, P. 48). Meanwhile, imitation has been studied in various animals, infants, adults, and computer simulations. Such an example facilitates interdisciplinary research and translation efforts enormously.

As it is only after a first acquaintance with the literature that you may be able to decide about these matters, interdisciplinary research truly is “a decision-making process that is heuristic, iterative, and reflexive” (Repko, 2008, P. 137).

### **Develop Adequacy Concerning the Relevant Components, Operations, and Interactions of the Mechanism**

After identifying the relevant disciplines, we must develop adequacy in them. Then we should be able to decide their specific relevance, what kind of knowledge we need, and how much knowledge we need from each (Repko, 2008, P. 189–190). In the case of the component tasks of action understanding, the range of disciplines that are involved differ, leading to narrow or wider—in the case of narrative understanding—interdisciplinarity. This distinction reflects the methodological and conceptual distance between the disciplines (Newell, 1998). Achieving adequacy in research that involves wider interdisciplinarity and that leads to an integration of insights is obviously more difficult.

Fortunately, it is possible to reach adequacy in the case of investigations of a multi-level mechanism and its components and operations. This is due to the aforementioned fact that in such a mechanism, there are “local maxima of regularity and predictability” (Wimsatt, 2007, P. 209) even though these maxima may themselves be produced by complex mechanisms. The regular and predictable properties of atoms, for instance, hide various underlying probabilistic quantum mechanisms. Or, referring to **Figure 2** further below in this article, investigations may focus on the local maxima that are represented by particular components or operations that are included in that Figure without having to cover all the rest. As a consequence, there are many theories that describe and explain quite specific properties of the system, perhaps under specific conditions. Such

“theoretical pluralism” is common in the life and cognitive sciences, granting each theory only a relative significance for its domain regarding the comprehensive/overarching problem (Beatty, 1997). Because we are interested in a particular phenomenon, action understanding or one of its three component tasks, we are permitted or even obliged to select those insights that contribute significantly to our understanding of that phenomenon: its occurrence, the components and operations that instantiate it, the conditions under which it occurs, modulating influences from other processes, and so on. Clearly, these insights will be different in kind. Some will be based upon observations of action understanding in humans, animals, or even computer simulations; others will refer to brain imaging results that suggest correlations between specific components and operations involved in relevant cognitive processes, for example.

Adequacy, in our case, must not imply presenting a complete mechanistic explanation that comprehensively predicts and explains action understanding under all possible circumstances, as this would be extremely difficult. Instead, we have already described how we can limit our research project to just a component or an operation that contributes to it. Having done so, we can subsequently aim first to develop a mechanism sketch that explains how the phenomenon might be constituted. Such a sketch leaves room for other sketches that offer different possible mechanisms for the same phenomenon (Machamer, Darden, & Craver, 2000). Once we provide a sketch—or several sketches—starting from our preliminary definition, decomposition, and localization of action understanding, our investigations should enable us to gradually fill in the details of our mechanistic explanation. Adequacy, then, means that we have included those insights that contribute specifically to the instantiation of our research phenomenon, while leaving out others. Given the complexity and flexibility of cognitive systems and the phenomena they produce, it is likely that future scientific developments will have an impact on what insights need to be included. I will illustrate these remarks pertaining to adequacy with an example of such a delineated phenomenon.

We observed in the previous section that distinguishing “what” an action is in some cases delivers information on “why” it is performed as well. This suggests that adequacy with respect to action recognition would also satisfy requirements for adequate knowledge of disciplinary insights for intention understanding. Because it turned out that animals and human adults and infants recognize the beginning and end of an action by noting that body movements differ unexpectedly, changing in tempo and direction (Baldwin, Baird, Saylor, & Clark, 2001), it seemed that adequacy would be relatively easy to reach. After all, in this context, achieving adequacy implies gaining insight into a relatively simple perceptual mechanism that performs statistical processing. Moreover, the visual stimuli that appear to require processing are only those that are associated with changes of tempo and direction. Consequently, the number of components and operations that are involved in these cognitive processes is limited. Thus, the number of disciplines involved is limited, and we are able to specify the insights that we need from them.

However, action recognition and intention understanding turned out not to be two completely overlapping processes in many cases. Indeed, action recognition is not always dependent upon perceptual processes alone: It is often modulated or assisted by other cognitive components. For example, conceptual knowledge of actions and specific task requirements, like the command to focus attention on specific aspects of a movie, enables subjects to recognize more reliably and faster the precise moments an action begins and ends (Baldwin et al., 2001; Hard, Lozano, & Tversky, 2006; Zacks, Kumar, Abrams, & Mehta, 2009). Apparently, the action recognition mechanism can be modulated by components and operations that subserve other cognitive processes. Consequently, adequacy here requires additional knowledge of the mutual constraints between the originally simple mechanism and the properties of such modulating influences of other cognitive processes.

This insight into the greater complexity of the action recognition mechanism forces us to reconsider our striving for adequacy. At least, it implies that we need to refine or further specify the adequacy requirements with respect to disciplinary insights. For instance, if we aim to keep the explanatory mechanism simple, we probably need to refine more narrowly the action types that can be recognized solely on the basis of this perceptual process of action recognition. Secondary to that, we must investigate whether it is plausible that this process can function in isolation at all. This seems to be the case in primate understanding and imitation of actions, where researchers believe that supplementary understanding of the aims, goals, and intentions of the agent is generally not involved (Byrne & Russon, 1998). In humans, isolating action recognition does not appear to be a plausible way to proceed because action recognition and intention understanding are different, yet more tightly connected, phenomena. Indeed, the former is generally subserving the latter: Such initial, “bottom-up” parsing would provide appropriate units on which to base the additional processing needed to achieve ultimate understanding of the intentions at play. This type of low-level mechanism thus seems likely to be a crucial prerequisite to infants’ developing understanding of the intentions motivating others’ actions. (Baldwin et al., 2001, P. 715)

In the case of human action recognition, *adequacy* means the investigation of whether observers often rely upon previous sociocultural knowledge or other cognitive processes to recognize the borders of an action or between actions. If that is the case, the explanatory mechanism for action recognition must be expanded, and our adequacy requirements will be more comprehensive, too.

Sometimes, an empirical finding suggests that adequacy is within reach. For instance, the discovery of mirror neurons in the Macaque monkey motor system was not just exciting; it appeared also to bring some relief to researchers of action recognition and intention understanding. The peculiar activation of these neurons both during action perception and during action performance suggested to many researchers that action recognition and intention understanding could be adequately explained at once by re-

ferring to these neurons. Even though these mirror neuron systems are already more complex than the earlier proposed, and purely perceptual, action parsing mechanism, they did appear at least to operate in isolation from higher cognitive processes that involve speech. Indeed, they are still held to enable “that modality of understanding which, prior to any form of conceptual and linguistic mediation, gives substance to our experience of others” (Rizzolatti & Sinigaglia, 2008, P. 192). Still, the question remains: Was the promise fulfilled that adequacy with respect to action recognition and intention understanding implied having insights into the action parsing mechanism and mirror neuron systems only?

Unfortunately not, as it turned out that in human intention understanding, still more is needed. Due to the complexity of our actions, humans cannot always recognize action borders even with the additional help of these mirror neuron systems, let alone understand the intentions of complex actions. Especially, intention understanding seems to often rely on a “mentalizing” approach, which is the—silent and unconscious—application of a “folk psychology” or “theory theory” that people use to explain or understand “why” someone acts as he does. Such reasoning includes the use of implicit psychological theories about (human) actions, goals, reasons, desires, and the like (Stich & Nichols, 1993). Even though this process does not yet involve explicit and conscious verbalization, such an explanation of intention understanding does involve many more cognitive processes than are produced by the action parsing mechanism or the mirror neuron systems alone.

Not surprisingly, as soon as we include higher cognitive processes that involve language or reasoning in the explanatory mechanism, adequacy will be increasingly difficult to achieve. For instance, the “theory theory” account of intention understanding has rival theories. One of these is a “simulation” theory that suggests that subjects implicitly project themselves into the place of the agent when observing an action. The simulation theory claims to be supported by mirror neuron research because these neurons allegedly enable such silent and immediate simulation (Gallese & Goldman, 1998). The narrative approach proposes yet another and different take on action recognition and intention understanding in humans. It refers to the fact that in most cases, we ask agents themselves “why” they did “what” they did. It is then “these second-person deliveries—the narratives narrated—that do the heavy lifting in enabling us to understand and make sense of others with confidence” (Hutto, 2007, P. 21). Ricoeur (1992)—who taught us the distinction between the “what,” “why,” and “who” of action—explains that a narrative in fact establishes a sort of “plot” around an action, which includes the character of the agent, the events experienced, and those acted on. Together, these allow us to establish the identity of agents and their actions alike, even if such a narrative will never be complete or definitive. Such contributions of our narrative capacity to our capacity of action understanding—and of acting itself—has only quite recently gained the interest of philosophers and scientists (cf. Bayne & Pacherie, 2007; Gallagher & Hutto, 2008; Hutto,

2007; Ricoeur, 1984; Zwaan, Taylor, & de Boer, 2010). Consequently, it has not yet found definitive inclusion in the explanations of action understanding.

Developing adequacy can thus take us in different directions. It can imply revisiting the observations of the phenomenon itself, in order to find out whether we can isolate a specific class of actions that can be recognized by a simple perceptual mechanism alone. Or, adequacy may require us to expand this mechanism with the mirror neuron systems, still fencing out those cognitive processes that include speech. Unfortunately, in humans this may still not yield adequacy because our narrative and intention understanding depend mostly upon modulating factors that lie outside the scope of these perceptual and mirror neuron systems. With respect to the disciplines involved, adequacy requirements are enlarged because additional components and operations need attention. On top of that, new disciplines—such as the social sciences— need to be involved in order to reach adequacy. It is to be expected that in our next step(s) we will feel the impact of this.

### **Analyze the Phenomenon and Evaluate Each Insight Into It**

Because research is never simply the accumulation of factual knowledge, we now need to analyze the problem from the perspective of each relevant discipline and evaluate each insight into it (Repko, 2008, P. 217). A mechanistic explanation allows us to respect the differences between disciplinary perspectives even though we will assign disciplinary insights into a phenomenon only a limited role in the comprehensive explanation. Disciplinary theories, methodologies, and assumptions may hold for the investigation of a component or operation of the phenomenon but may have only limited relevance for the overall phenomenon.

Thinking of a phenomenon as the result of the interaction of a multilevel organization of components and operations has the advantage that those components and operations may be investigated separately. Of course, it is tempting to disciplinary specialists to isolate their domain and to maintain that their domain of study and the insights it delivers are sufficient to explain the phenomenon, leaving the rest aside as irrelevant. In such a case, the assumption is that the phenomenon can be explained with reference to a specific “module” that is relatively isolated and independently responsible for all properties of the phenomenon<sup>12</sup>. Even though I argued earlier that there is relative

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<sup>12</sup> A famous example of such an assumption pertains to language, which has been claimed to rest in a specific mental organ, separate from the other mental organs, and therefore also localizable in specific parts of the brain. These claims are highly implausible, if we take our earlier analysis of mechanistic explanations for functions in complex and dynamic biological systems into account. And indeed, former language modularity proponent Chomsky wrote in an influential review in 2002, «A neuroscientist might ask: What components of the human nervous system are recruited in the use of language in its broadest sense? Because any aspect of cognition appears to be, at least in principle, accessible to language, the broadest answer to this question is, probably, most of it.» (Hauser, Chomsky, & Fitch, 2002, P. 1 570). In that review, the authors engage in a more modest approach, similar to the one I present here for action understanding.

autonomy of levels in a phenomenon, in organisms there are many feedback and feed-forward interactions at a particular level, as well as top-down and bottom-up interactions between levels, that can influence such a “module.” We must remain on the alert for this possibility, indeed.

Analyzing and evaluating the disciplinary perspectives on the phenomenon of action understanding within the mechanistic explanatory approach is a straightforward task. Starting from a mechanism sketch, mentioned in the previous section, researchers will complete and describe the components, their operations, and indeed the interactions within the mechanism in ever more detail. This process consists partly of deciding the relevance of the contribution of different components and operations and the further arrangement of them. In our case, analysis of action understanding was already part of Step 1, where we defined and decomposed it into the three component tasks. Clearly, achieving adequacy and this task of analyzing, evaluating, and arranging insights are intimately related research tasks that need to be carried out repeatedly during the interdisciplinary research process.

The interrelated research tasks of analysis and evaluation as applied to the present case of mirror neuron research can demonstrate that the tight connection between the definition, decomposition, and localization of a phenomenon; the experimental set-up used in investigating it; and the subsequent results require much care. An inadequate definition will hamper research as much as a bad experiment. Take, for instance, the following conclusion drawn on the basis of a mirror neuron activation experiment: “To ascribe an intention is to infer a forthcoming new goal, and this is an operation that the motor system does automatically” (Iacoboni, Molnar-Szakacs, Gallese, Buccino, & Mazziotta, 2005, P. 533). This sweeping conclusion was drawn on the basis of an experiment in which humans were looking at images of a hand taking a cup for drinking or for cleaning and images of a breakfast table. Sure enough, the results suggested that our brain automatically includes context information in its prediction of the likeliness of the subsequent action with the cup. Nevertheless, the authors overstate the relevance of their results by defining intention extremely narrowly, while applying a very broad interpretation of the operation of the mirror neurons in this highly suggestive and restrictive task. This exaggeration is partly due to the lack of a comprehensive, interdisciplinary analysis of the phenomenon of intention understanding and consequently the lack of a rigorous evaluation of the results. As a result, the researchers suggest that these mirror neurons function as a module that, in isolation, fulfills the difficult task of intention understanding. Indeed, one of these investigators still maintains that these mirror neurons “embody the deepest way in which we stand in relation to each other and understand each other” (Iacoboni, 2008). However, in human relations we often experience our mutual deep involvement and attachment through verbal meanings, which will not always activate mirror neuron systems. Such meanings may heighten our sensitivity to some actions over others. In sum, although we know that the evidence is

convincing enough to include mirror neurons in the action understanding mechanism, we still need other components to account for intention understanding.

Such overstated claims are more common than one would expect. Most research into human social action, for example, subscribes to one of two opposed theoretical positions: either “Plastic Man” or “Autonomous Man”: “Whereas Plastic Man, being formed by adaptive response to the interplay of nature and nurture, is only spuriously individual, his rival is to be selfcaused. . . . Where Plastic Man has his causes, Autonomous Man has his reasons” (Hollis, 1977, P. 12). Such extreme positions are often due to overestimation of disciplinary strengths and underestimation of disciplinary limitations with respect to a complex and dynamic, multilevel system. Fortunately, interdisciplinary exchanges may force researchers to integrate their insights in a much more complex, but at the same time more comprehensive, explanation.

### **Integrating Insights (Steps 7 to 10)**

According to the model of the interdisciplinary research process that Repko (2008) presents, we would only now enter the second phase of the research process where the integration of insights takes place. Until now, the focus was accordingly on “drawing on disciplinary insights.” Even though I have already looked ahead at the integration of these insights, I will follow the proposed research process and discuss the model’s next steps with respect to the mechanistic explanatory approach on offer here. Therefore, we need to identify conflicts between insights and locate their sources (Step 7) and then create common ground between these insights (i.e., discover one or more latent commonalities between them; Step 8). Using this common ground, we should be able to integrate as many of the insights as possible (Step 9). Eventually, this should bring us to a more comprehensive understanding of human action (Step 10). The mechanistic explanation will prove a very useful instrument in these steps.

#### **Identify Conflicts Between Insights and Locate Their Sources**

Even though it is often the case that “the possible sources of conflict between insights are concepts, assumptions, and theories” (Repko, 2008, P. 250), all forms of interdisciplinary integration are not dependent upon resolving the conflicts (or differences) stemming from these building blocks of disciplinary perspectives on the phenomenon. In the mechanistic explanatory approach, conflicts of different types can occur. One source of conflict stems from the initial phase of defining and decomposing our phenomenon. In the previous section, we came across researchers who overstated their conclusion based upon an oversimplified definition of intention ascription.

A second source of conflict related to such definition and decomposition mistakes is assuming that the underlying mechanisms for different component tasks are completely separate. For instance, even though we distinguished the three component tasks—action recognition, understanding of intention, and narrative understanding—we noted

that it is likely that these components are intimately related, both functionally and in their neural implementation.

Different from such conceptual conflicts are those that arise from misunderstandings of the internal arrangement of components and operations of the mechanism. For instance, interactions between components or interactions have been neglected or overlooked—as is the case when the component task of action recognition would be forgotten as a prerequisite for intention understanding.

A fourth source of conflict is the underestimation of the role of specific context features on the way an action is being cognitively processed. For instance, under favorable conditions—without time pressure, for instance— and with adequate preparation, people are able to suppress or, rather, overrule the power of stereotypical modes of understanding other people because in such cases other mechanisms are kicking in (Kruglanski & Orehek, 2007).

Fifth, conflicts can arise from the failure to acknowledge and evaluate correctly the alternative processing trajectories that may prevail in specific groups or individuals when engaging in action understanding. For instance, it is still debated whether or not autistic subjects, who have difficulties in spontaneous human action understanding and often use specifically trained theories about human behavior, suffer from disturbances in their mirror neuron systems, forcing them to rely on other trajectories (Blakemore, Winston, & Frith, 2004).

A sixth source is a combination of the latter two sources of conflicts: External, sociocultural information may have become entrenched in the explanatory mechanism and cause observable and regular differences in action understanding processing, as is the case with modulation of mirror neuron activity due to individual experience with sociocultural information (Keestra, 2008). In general, for explanations of the variability of sociocultural influences on individuals' cognitive processes, we need to draw on both cognitive and social scientific insights (Shore, 1996).

This is not an exhaustive list of the possible sources and locations of conflicts in mechanistic explanations, but they are the most prominent. The list also demonstrates that considering a phenomenon from a mechanism-based approach is useful as a heuristic when reflecting on potential conceptual and theoretical failures and conflicts. In our domain of action understanding, such conflicts have arisen predominantly with respect to the component of intention understanding.

In particular, there has been a fierce rivalry between an explanation that is based upon tacit folk psychological theorizing by the individual and an explanation that refers to the silent simulation of the observed actor. Conflicts pertained to the definition and decomposition of intention understanding, explanations of its components' tasks, the underlying mechanisms, and their neural implementations in the brain.

The opposition between these theorizing and simulation accounts was modified somewhat as soon as tacit theorizing was no longer necessarily associated with propo-



sitions, rules, psychological causal laws, and the like because only then were animals and infants equally able to understand intentions. So when connectionist models were developed and computer tested with some success, theorizing accounts seemed to gain the upper hand in the conflict (Stich & Nichols, 1993). The balance shifted dramatically again the moment the surprising evidence of mirror neurons appeared. Simulation theorists immediately appreciated it as support for their position and took it as evidence for a neural basis for their idea that we employ similar structures to both actively engage in action and passively understand that action. This was clearly stated in a seminal article co-authored by a neuroscientist and a simulation theorist: “Thus [mirror neuron] activity seems to be nature’s way of getting the observer into the same ‘mental shoes’ as the target—exactly what the conjectured simulation heuristic aims to do” (Gallese & Goldman, 1998, P. 497–498).

Extensive analysis of the history of this conflict between theorizing and simulation accounts of intention understanding would show that the conflict alternately received energy from theoretical arguments, from neuroscientific evidence, from behavioral observations, and so on. As I note in the following discussion, we can meanwhile observe that the two formerly opposing positions are being successfully integrated into an overarching explanatory mechanism.

The mechanistic approach allows us to analyze such a conflict and the different sources from which it arises. Similarly, it can function as a heuristic device that enables us to handle the conflict by employing its apparatus of phenomenon analysis, components and operations, levels, and interactions of sorts. Most important for interdisciplinary research is, of course, how the mechanistic explanation can be adapted in such a way that it can integrate those insights or properties that appeared to be in conflict with each other, while both sides can present some evidence in support. For that, we need to take the next step, in which we are asked to create or discover common ground.

### **Create or Discover Common Ground via a Mechanism**

Interdisciplinary investigations of human action understanding aim at the integration of insights into that phenomenon. For such integration to succeed, it is crucial to build upon a common ground that allows the integration of heterogeneous materials. In our case, this common ground should have the form of an explanatory mechanism. Language processing is unlikely to provide such a ground, for instance, as it cannot play a central role in explanations of action understanding in animals and young infants. Nonetheless, given the strong interaction between components of any comprehensive explanatory mechanism of action understanding, the explanatory mechanism that we choose as common ground will be affected by the components and operations that we will add to it. As noted above, language affects many other components of the explanatory mechanism, including action recognition.

In fact, for most interdisciplinarians who use a mechanistic approach, finding common ground for our interdisciplinary understanding involves the identification of the most promising mechanistic explanation among those that have already been proposed in the literature. *It is this mechanistic explanation as a whole that furnishes common ground.* Note that this implies that generally such common ground is already “composed of knowledge that is distributed among or is common to disciplines” (Repko, 2008, P. 273).

After having identified a plausible explanatory mechanism as common ground, interdisciplinarians need to demonstrate how other relevant components and operations are related to it. What is implied in this endeavor is the rejection of claims that a specific explanatory mechanism independently produces the phenomenon. Embracing a mechanism as common ground can mean that it loses the exclusive explanatory force it previously had. We have observed that mirror neuron systems were believed to be the prime candidate for a mechanistic explanation of action understanding and imitation alike. Thanks to their functional properties, these mirror neuron systems have been held responsible for enabling relationships between oneself and another and between action and perception (Hurley & Chater, 2005). Even though this makes these mirror neuron systems workable as common ground, the associated mechanisms have meanwhile been embedded in a more comprehensive mechanism, limiting their role accordingly. It is worth quoting a recent meta-analysis that argues why still other systems or sub-mechanisms must be added to a mechanistic explanation of intention understanding, with a central role for mirror neurons:

“First, an inconsistent or anomalous movement might be outside the perceiver’s repertoire of familiar movements, so the mirror system cannot be of help. To resolve this, inferences of higher-level goals (e.g., “why did the actress fall?”) or other attributes (e.g., “was she depressed?”) seem to be needed, which are outside the scope of the mirror system. Second, when the perceiver reflects on a high-level intention of an action, this might necessarily engage the mentalizing system. It is possible that the mirror system is recruited for automatic lower-level goal interpretation . . . and the mentalizing system for reflection on the higher-level goals (from task goals to more general intentions)” (Van Overwalle & Baetens, 2009, P. 580).

Nonetheless, various mechanistic explanations of action understanding have been presented in which mirror neuron systems function as common ground. These systems offer, then, a common ground to different mechanism sketches or models. Authors are sometimes even updating their own earlier model, such as by introducing a new model of action recognition learning by macaque mirror neurons which addresses data on auditory input, a model for opportunistic planning of sequential behavior, and studies of how to embed a macaque-like mirror system in a larger ape-like or human-like circuit to support “simple imitation” and then “complex imitation.” (Arbib & Bonaiuto, 2008, P. 45)

In this case, the previous model for imitation and understanding, with mirror neuron systems as common ground, was expanded with components and operations that

process speech and symbol use. With that expansion, the authors are able to explain the differences between human and monkey capabilities while leaving the mechanistic explanation of several commonalities largely intact.

What can be derived from this example is that, if possible, newly discovered insights should be integrated into an existing explanatory mechanism. Obviously, proposing a completely new mechanism is a much more demanding task. The various adjustments of an existing explanatory mechanism in order to integrate insights into a mechanistic explanation are the subject of our next section.

### **Integrate Insights Into a Mechanistic Explanation**

This chapter's argument for a central role for mechanistic explanation is in accordance with the general observation that "at the heart of any interdisciplinary integration lies an integrative device—for example, a metaphor, complex explanation, or bridging concept—that brings together disciplinary insights" (Boix-Mansilla, Duraisingh, Wolfe, & Haynes, 2009, P. 344). I hope to have convincingly shown that a mechanistic explanation is a useful device for achieving interdisciplinary integration. After having identified an appropriate explanatory mechanism as the common ground for explaining our phenomenon, the remaining task is to build on this when seeking integration of additional insights.

Disciplinary insights are, in that case, included as explanations of components and operations of the mechanism, or as explanations of the interactions that take place within the mechanism or between the mechanism and external factors. Given the explanatory mechanism that we have identified as common ground, integrating further insights will lead to refining or expanding it. Refining implies that we can specify the mechanism of a subcomponent or suboperation or interaction of the overarching explanatory mechanism. For instance, the action-perception interactions that mirror neurons facilitate are affected both by action-specific experiences of the subject and the task one is performing (Rizzolatti & Sinigaglia, 2008). Expanding the mechanism involves an extension with a component, operation, or interaction that has turned out to influence the mechanism in a relevant way. For instance, investigations of sociocultural influences on the cognitive processes that underlie action understanding are relatively new and may lead to unexpected extensions: Some processes turn out not to be sensitive to these influences; others are strongly affected by them (Han & Northoff, 2008).

Refining or expanding the explanatory mechanism with an additional disciplinary insight requires a careful consideration of the place within the mechanism where the addition could be located. This is especially difficult in the case of a complex and dynamic multilevel mechanism: An addition is likely to have a widespread impact on many components and operations. *Figure 2* below demonstrates the many choices available for assigning a location to the additional insight. For instance, should we consider a sociocultural influence like religious belief as a "sociocultural model" that functions as a specific "computation" for narrative understanding, having only via that route a modulatory influ-

ence on the perceptual mechanisms that produce action recognition? Alternatively, we could investigate whether it is the imitation of religious practices, implying mirror neuron system activations, that modulate perceptual processes. So knowing that religion influences action understanding still leaves undecided where and how this influence should be integrated into the overarching explanatory mechanism. Similarly, we already mentioned that the action understanding deficits in autistic patients may or may not be wide-ranging consequences of their disturbed mirror neuron systems (Blakemore et al., 2004).

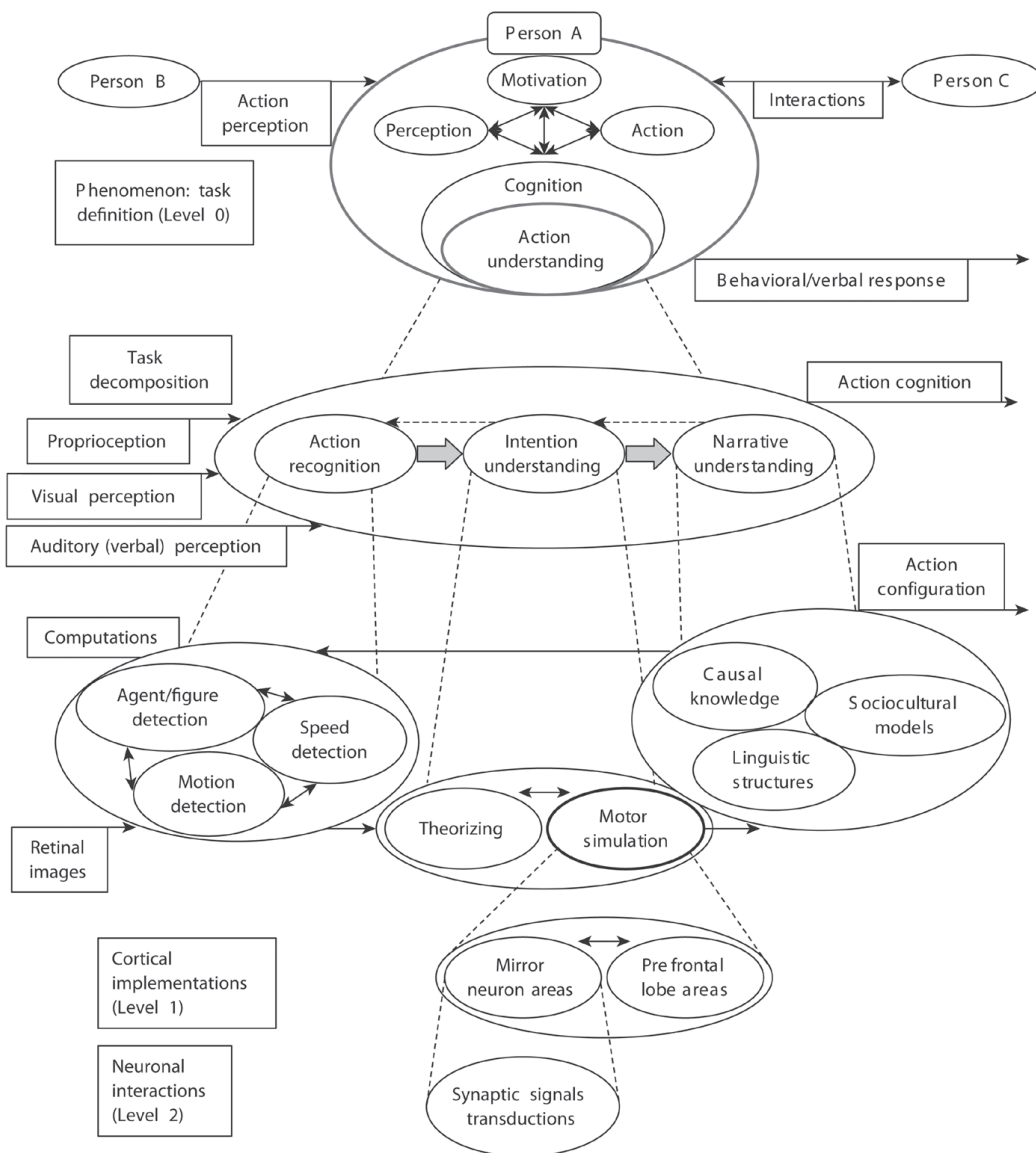
Integrating an additional insight by way of a refinement or expansion of the explanatory mechanism that we chose as common ground, therefore, requires us to specify one or more relations between previously unrelated components or processes. The results of mirror neuron research have, indeed, forced researchers to reconsider explanatory mechanisms for imitation, for action understanding, for empathy, for language processing, and for action learning—to mention the most prominent (Rizzolatti & Sinigaglia, 2008). Obviously, refining or expanding the mechanistic explanations of mirror neuron system activities will, in that case, require a variety of techniques, depending on the specific interactions that the additional component is involved in.

In this context, it may be useful to realize that Repko (2008) mentions four integrative techniques that are commonly used for establishing common ground: (1) *redefinition* of concepts or assumptions to include or exclude phenomena; (2) *extension* of concepts and assumptions or expansion of a theory to cover previously uncovered phenomena, perhaps even beyond their original disciplinary domain; (3) *organization* of previously unrelated concepts or assumptions into a relationship; and (4) the *transformation* of opposing concepts or assumptions into variables of an uncovered factor (cf. Repko, 2008, P. 282–291). Obviously, common ground depends on establishing a relationship between previously unintegrated theories. According to the present approach, it is advisable to identify a given explanatory mechanism as common ground and subsequently to refine or expand this. It is interesting that the four techniques can, in modified form, also be applied to these refinements or expansions, as discussed below.

For instance, the integrative techniques of redefinition and organization are fairly common practice in the life sciences. They are often applied in combination, as can be learnt again from mirror neuron research. Among the many consequences of the discovery of mirror neurons was the following insight:

That rigid divide between perceptive, motor, and cognitive processes is to a great extent artificial; not only does perception appear to be embedded in the dynamics of action, becoming much more composite than used to be thought in the past, but the acting brain is also and above all a brain that understands. (Rizzolatti & Sinigaglia, 2008, P. xi)

Such rigid divides are also at stake when the integration of speech requires various refinements and expansions of the mechanistic explanation of mirror neuron properties, which was proposed as common ground. These refinements and expansions involve a reorganization of components and operations, comparable to the third integrative



**Figure 2**

**Highly Simplified and Incomplete Mechanism Sketch of Human Action Understanding**

*NOTE: Many dynamic (feedforward and feedback, top-down and bottom-up) interactions are left out. Further components and operations, like attention, memory, and awareness, could be added to the sketch as they modulate action understanding. Note that each component and interaction could, in turn, be investigated as a complex phenomenon on its own, requiring a mechanistic explanation. Note, as well, that components may play a role in other mechanisms and contribute to various phenomena simultaneously. This is the case with mirror neurons, for example.*

technique of organization of previously unrelated concepts or assumptions into a relationship. Traditionally, language and action have been treated as separate phenomena. Now that researchers realize that mirror neurons contribute to both these cognitive pro-

cesses, they are better able to explain the subtle and sometimes disturbing interactions of language and action. This requires, however, a redefinition (Technique 1) of some basic assumptions concerning the “modular” processes that were taken to underlie language and action.

Obviously, even when common ground has been established, further integration of insights into the preferred mechanistic explanation demands careful application of various integrative techniques. Also, prudence and modesty are needed with respect to the scope of the theories or explanations that require integration. Researchers must realize that it is most unlikely that it is possible to localize cognitive functions in particular neurons or specific neuronal activities. Talk of neurons that “see” or “feel” or “infer” should, therefore, be taken to mean that these components or operations play a specific and decisive role in the comprehensive mechanism that accounts for that function—no more, and no less (Keestra & Cowley, 2009).

To conclude, a general consequence of the integration of insights should be acknowledged. Even if the focus is not on the assumptions or concepts of the associated theories, integration will have an impact on the scope of these theories. Integration of two theories has the consequence that their scope will become expanded or contracted: expanded when integration demonstrates that a mechanism has also an impact on an additional component or operation; contracted when the converse is true and, for instance, a mechanism turns out to depend on another mechanism for its operation. When the integrated theory has wide-ranging impact on the complex explanatory mechanism, both theory expansion and contraction will obtain, though with respect to different components, operations or interactions and the theories pertaining to these.

### **Produce a Mechanistic Explanation of Human Action Understanding and Test It**

Often, interdisciplinary understanding of a problem will be obtained at the final stage of the research process. In a mechanistic approach to explanation, this is somewhat different. As many—if not most—phenomena in the natural, life, and cognitive sciences do not appear contingently but reflect the behavior of a complex mechanism, there are often already inter-disciplinary mechanistic explanations available of components or operations of the eventual, overarching explanatory mechanism. Remember the definition of a mechanism mentioned earlier: “[A] mechanism is an organized system of component parts and component operations. The mechanism’s components and their organization produce its behavior, thereby instantiating a phenomenon” (Bechtel, 2005, P. 314). When employing the mechanistic approach, researchers are aware of the fact that their specific research of a phenomenon should allow integration of their results into the mechanism in the form of a further specification of a component or operation or one of its interactions.

How we represent the explanatory mechanism is dependent upon its aim. Complex and dynamic mechanisms, with their reciprocal constraints of components and opera-

tions and their feedback and feedforward streams are difficult to represent as a picture. Developing a computer program that includes such components and operations is a more feasible method. However, if our interest is in the neural areas that are involved in the mechanism, we may settle for a neuroanatomical map with designated cortical areas and some broad processing streams. Or, we may focus on a finer grain of single neurons, like mirror neurons, and present the fine distribution of those in a particular area and their connections. Often, researchers present their findings in a relatively abstract “boxology” in which boxes and arrows refer to components and operations. In that case, we can add labels to these that refer broadly to their neural implementations in specific cortical areas. In *Figure 2*, I have presented most of the relevant information on action understanding contained in this chapter in the mixed form of a boxology and the diagram found in *Figure 1*. Clearly, it is far from complete, and much more information could be added to it or integrated with it. Specification of the components and operations would require additional layers and theoretical descriptions, but they are beyond the scope of this chapter.

Finally, it is easy to see that a visual representation of the mechanism can assist further research in many ways, perhaps better than a verbally formulated theory would do. Let me stress that as an integrative device, mechanistic explanation does not exclude formulation of verbal and mathematical theories. Such theories often focus on specific components or operations as we find them in the mechanism. As I noted above, cognitive scientific experiments involve activation, interference, or stimulation of components or operations. The consequences of those can subsequently be detected as changes in components or operations at other levels, or indeed in the behavior of the subject. With the help of a mechanism sketch such as *Figure 2*, we can more specifically engage in the formulation of hypotheses or in thinking of potential interventions in it with experiments or other treatments. We can consider horizontal interactions and their potential effects, or we can reflect on interlevel investigations, using the interference and stimulation techniques mentioned earlier. Such tests should lead to refinements, adjustments, or perhaps even the rejection of the proposed mechanism sketch.

## Conclusion

Action understanding is a complex cognitive capability performed by a complex cognitive mechanism. As we learned above, that mechanism comprises various components and operations that are themselves open to mechanistic explanations. In developing a mechanism-based explanation of action understanding, we need, therefore, to integrate insights from various disciplines by attributing them to components or operations to be found in the mechanism or to specific interactions in which the mechanism participates. Strikingly, although there are many nonlinear processes involved, and notwithstanding the complexity of the overarching mechanism, the phenomenon of action understanding displays relatively stable properties under specific conditions.

The method proposed in this chapter requires application of the heuristics of definition, decomposition, and localization. However, not all phenomena lend themselves to this explanatory approach. If a phenomenon does not appear to behave in an orderly fashion at all, or if it turns out to be impossible—even preliminarily—to localize and identify components or operations, then we may have to look for another approach. Fortunately for us, human action understanding is a phenomenon suitable for this approach. By learning more about the complex and dynamic mechanism that underlies action understanding, we can appreciate even more this crucial capability and cope with its constraints and limitations. Indeed, rather than being satisfied with explanations of its successes, it may be even more important in our global society to acknowledge the fragility of our ability to understand.

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