

## What is understanding?

### An overview of recent debates in epistemology and philosophy of science

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#### 1. Introduction

Human beings strive for understanding of what is going on in the world. They want to understand why the planets take their specific orbits, how life came about, why some actions are morally wrong and so on. No wonder then that curricula at schools and universities often list understanding as one of the primary goals of education and training. And no surprise that the sciences and humanities, but also art and religion promise a better understanding of the world or at least of some aspects of it.

But what exactly is understanding? What type of intellectual achievement does it constitute? What does it mean to understand why something is the case or how something has come about? These questions are at the center of recent debates in epistemology and philosophy of science. The aim of this chapter is to systematically overview the related research about understanding.

In some sense, the preoccupation of philosophers with understanding is not new. The very name of the philosophical discipline of epistemology derives from the ancient Greek word “episteme”, which may be translated as “understanding”, and episteme was already scrutinized by ancient philosophers. As a classic work in epistemology, Plato’s dialogue *Theaetetus* is devoted to the question of what episteme is and Theaetetus proposes that episteme is justified true belief (*Theaetetus*, 201c–d). Locke’s *Essay Concerning Human Understanding* and other important philosophical books refer to understanding in their titles. However, most of these works focus on knowledge (where “knowledge” is another translation of “episteme”) and not so much on what we now call understanding. Locke’s *Essay*, for instance, is about “the Original, Certainty, and Extent of humane Knowledge; together, with the Grounds and Degrees of Belief, Opinion, and Assent” (I.1.2). In the second half of the 20<sup>th</sup> century, epistemology was mainly concerned with the question of whether *knowledge* may be analyzed as justified true belief. The debate was sparked and shaped by counterexamples that Gettier (1963) raised against this account of knowledge.

What we call understanding has thus not been a prominent topic in modern epistemology until very recently. However, understanding (in particular in its German translation, *Verstehen*) did play a crucial role in a philosophical discussion of how the humanities (*Geisteswissenschaften*) differ from the sciences. Historian Droysen contrasted what he called *Erklären* (explanation) with *Verstehen* (understanding) and suggested that history calls for understanding while the physical sciences explain (Droysen 1868, Par. 8 and 14). In Dilthey’s works about the foundations of the humanities, understanding is taken as their characteristic

achievement (e.g. Dilthey 1910, 98–100; see Kögler and Stueber 2000 and Martin 2000 for the views of different classic *Verstehen* theorists). The logical positivists, by contrast, rejected a strict dichotomy between the sciences and humanities, and thus between explanation and understanding (e.g. Hempel 1942; see von Wright 1971 and Stueber 2012 for more recent contributions). It does not come as a surprise then that understanding surfaced in analytic philosophy of science in debates about scientific *explanation*. Explanation was taken to be primary and analyzed e.g. in terms of valid argument (Hempel and Oppenheim 1948), while understanding was merely regarded as a psychological byproduct or a pragmatic aspect of explanation (e.g. Hempel 1965, 413; see De Regt 2009 for a survey about views concerning the relationship between understanding and explanation).

Only recently, some epistemologists and philosophers of science have come to think that understanding is a cognitive achievement that needs to be addressed for its own sake. Works that pioneered this turn to understanding include Zagzebski (1996), Elgin (1996), and Kvanvig (2003) in epistemology, and Friedman (1974), Schurz and Lambert (1994), and De Regt and Dieks (2005) in philosophy of science. So far though, epistemologists have not much taken into account the works of philosophers of science, and vice versa.

In this survey, we focus on the nature of understanding and bracket related topics, such as the value of understanding. Like most authors in the debate, we are interested in understanding in general, rather than in a restricted or qualified form of understanding, such as moral understanding.

## **2. Why is understanding important?**

But why bother about what understanding is? And why have so many philosophers turned their attention to understanding? There are at least three reasons for this trend, which partly turn on the general importance of understanding, but partly also on developments within philosophy.

First, understanding seems a central good that we try to realize when we think about the world. More specifically, the value of understanding seems to surpass that of knowledge (Kvanvig 2003, 2009a; Pritchard 2008; Gardiner 2012; Carter and Gordon 2014; see Whiting 2012 for a critical voice and Grimm 2012 for an overview). We can know something without understanding it. So achieving understanding seems an additional step forward, and we would not take this step if it did not have some additional value. Furthermore, knowledge may easily be acquired through the testimony of experts; understanding, by contrast, seems more demanding and requires that an epistemic agent herself puts together several pieces of information, grasps connections, can reason about causes, and this too suggests an added value.<sup>1</sup>

If the value of understanding surpasses that of knowledge, then epistemology's traditional focus on knowledge lacks legitimacy. In fact, philosophers have found it difficult to spell out why knowledge has a value that warrants an exclusive preoccupation with it (e.g. Kvanvig 2003). The problem of accounting for a supposed special value of knowledge is now called

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<sup>1</sup> That knowledge and understanding differ in their ease of transmission has often been noted, e.g. by Cooper (1994), Hills (2009; 2015), and Gordon (2016); see Sliwa (2015) for a different view.

*the value problem for knowledge* (Pritchard 2010, ch. 1). Epistemology escapes this problem if it turns to understanding.

The second reason for devoting attention to understanding is that understanding is a central goal of the sciences. String theorist Greene (2008) goes as far as to characterize science in terms of understanding: “Science is the process that takes us from confusion to understanding in a manner that’s precise, predictive and reliable.” Likewise, De Regt and Dieks (2005, 142) claim that “[u]nderstanding is an inextricable element of the aims of science”. If these voices get it right, any attempt to account for science and its achievements has to take understanding seriously, as has been explicitly urged by Elgin (2007, 34) and Kosso (2007, 173–4).

Even if understanding is not as central to science as some think, science is certainly concerned with explanations, and there seems to be a conceptual link between explanation and understanding: Explanations provide understanding, the latter being the goal of the former (Friedman 1974; Lipton 2004, 23; Grimm 2010). Any account of explanation has to account for this link (Friedman 1974), thus understanding should at least be of some interest to philosophers of science.

The third reason to look at understanding derives from developments within epistemology. According to the traditional account, knowledge requires justification. There are strong intuitions that the justification is internal to the epistemic agent, i.e. that it is accessible to her, as so-called internalists have it (e.g. BonJour 1980). Likewise, there are strong intuitions that justification proceeds in a coherentist manner, i.e. that a belief is justified by embedding it into a coherent web of beliefs, as so-called coherentists have it (e.g. BonJour 1985). Although the intuitions supporting internalism and coherentism seem deep-seated, it has proven difficult to save them in an account of knowledge. Internalism about epistemic justification is threatened by a regress problem (e.g. Bergmann 2006, ch. 1). Coherentists have a hard time to show how coherence is related to truth, which is supposed to be the aim of belief and a central feature of knowledge (see, e.g. BonJour 1985, ch. 8). However, an immediate access to the reasons for a belief and the ability to connect a belief with others seem to be central to understanding (Kvanvig 2003, 192). This suggests that internalist and coherentist intuitions have been misplaced: while being inappropriate in an account of knowledge, they spell out important features of understanding. Thus, an epistemology that does not restrict itself to knowledge, but takes into account understanding too can do better to accommodate our intuitions about our epistemic achievements in a broad sense (Greco 2010, 7–8). Likewise, it may also provide a home for intuitions that are articulated in virtue epistemology (Zagzebski 2001, 248). Nevertheless, the idea that an account of understanding may provide a better home for internalist, coherentist, and virtue-related intuitions has been challenged recently (e.g. by Greco 2014, Grimm 2016, and Khalifa 2016).

### **3. What types of understanding are there?**

There are good reasons then that philosophers scrutinize what understanding is. Before we can discuss accounts of understanding though, we have to ask whether there is one such thing named “understanding” or rather several types of understanding that each need their own analysis.

Everyday talk provides first hints about this question. At least the following epistemically relevant types of uses of the verb “to understand” can be distinguished:

- (1) *S* understands *X* [e.g. another person, a language, ...]
- (2) *S* understands that something is the case
- (3) *S* understands how something is the case [e.g. how something came about, how a tool functions]
- (4) *S* understands why something is the case
- (5) *S* understands what is the case [e.g. what somebody said]
- (6) *S* understands how something is of a certain quality [e.g. how something feels for somebody]

Further qualifications may specify e.g. a *means/vehicle* of understanding (*S* understands *X* by means of theory *Y*) or express that the understanding has a certain quality (*S* well understands that ...). Note also that “understand” is sometimes used as an intransitive verb, but this use seems derivative and presupposes that there is something that is understood (Kvanvig 2003, 189).

Thus, in all relevant uses, “understanding” relates a subject of understanding (*S*) to an object that is understood. In everyday attributions of understanding, *S* typically denotes an individual human being. It is an interesting question whether groups, institutions, or non-human animals may have understanding too, but since this question has hardly been addressed in the literature, we will leave it aside and assume that subjects of understanding are individual human beings. Classifications of understanding thus turn on the question of what is understood.

In this respect, (1)–(6) suggest three types of understanding, namely objectual (1), propositional (2), and interrogative understanding (3–6) (Baumberger 2011, 70–1; cf. Carter and Gordon 2014, 3). However, this distinction does not run very deep. For instance, understanding how a certain clock works (which would count as interrogative understanding) is the same as understanding the mode of operation of the clock (which would count as objectual understanding).

Even though language does not dictate a useful distinction of different types of understanding, we have to decide how we deal with the different uses of the word “to understand”, which give rise to what one may call “objectual”, “propositional”, and “interrogative” understanding. Things would certainly be simpler, if we could explain some types in terms of others. We will discuss proposals to this effect in Section 5, but our impression is that the question of how the different uses of “understanding” hang together has not yet been settled. For the remainder of this survey we will concentrate on two specific uses, namely:

- (OU) *S* understands some subject matter or domain of things;
- (EU) *S* understands why something is the case.

Understanding referred to in the first type of use will be called “objectual”, while understanding referred to in the second type of use will be called “explanatory”. When we

speak of understanding without qualification we refer to both objectual and explanatory understanding.

For a more refined typology of understanding, note first that there is a kind of understanding that is targeted at what is meant by linguistic expressions or by other symbols, e.g. mathematical formulae or tube maps. We call this “symbolic understanding”. Understanding why something is the case, e.g. why there was a volcanic eruption in Iceland in 2010, typically relies on symbolic understanding because it presumes the competent use of language or other symbols. But it is clearly not exhausted by symbolic understanding because it is concerned with how some part of the world is, independently of how we symbolize it. In recent debates about understanding, symbolic understanding is usually bracketed because it is supposed to be a topic of its own, which is best handled in a theory of symbols.<sup>2</sup>

Closely related to symbolic understanding is the understanding of representations such as theories and models. The understanding of quantum theory is a point in case. It partly turns on the use of symbols, e.g. the symbol for the wave function, but clearly goes beyond this. Arguably, to understand quantum theory, you have to be able to apply it to simple examples. The understanding of models and theories has recently attracted some attention by philosophers of science (see Section 4.2.2). In particular, De Regt and Dieks (2005, 151) have given an account of what they call the “intelligibility” of theories.

What has obtained much more attention though and will thus be our focus is an understanding that goes beyond representations and stretches out to facts, to phenomena of the world. Of course, we often need models and theories to understand the world, but when we use a theory to understand a phenomenon, the theory is merely a means or a vehicle of our understanding.<sup>3</sup>

#### **4. Conditions for Understanding**

Ideally, an account of understanding provides necessary and sufficient conditions for someone understanding something. As it happens, most conditions that have been proposed resemble the well-known traditional conditions of knowledge: belief, truth, and justification. This is no accident. Like knowledge, understanding is a cognitive achievement or success that can be ascribed to an agent. Now, if understanding is to be of an agent, the latter has to possess a representation of what is understood. It is further plausible that the representation must in some way be accepted by the agent, and so we get a condition that parallels the belief condition for knowledge (Section 4.2). Moreover, since understanding is a cognitive success, the representation needs to reflect the relevant facts adequately. This calls for a condition that parallels the truth condition for knowledge (Section 4.1). Finally, it seems that understanding would not be a cognitive success *of the agent* if the agent could not provide good reasons for the representation that underlies her understanding or if her understanding did not result from

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<sup>2</sup> There is a rich literature about linguistic understanding (e.g. Barber 2003) and whether understanding a language amounts to some kind of knowledge or not (e.g. Pettit 2002 and Longworth 2008).

<sup>3</sup> This is not to deny that theories and models are part of the world. Consequently, our understanding of the world can address models and theories too, e.g. when we ask how Einstein developed his General Theory of Relativity. But such questions about the development of theories are neither aiming at understanding the theories nor need the theories be used as a vehicle to answer the question.

a reliable process. This motivates a condition that parallels the justification condition for knowledge (Section 4.3).

There are good reasons then to expect that the conditions of understanding parallel those from the traditional account of knowledge. Nevertheless, since understanding may differ considerably from propositional knowledge, its conditions may need different construals. And it may be disputed whether understanding does indeed require conditions of all three types and whether additional conditions are needed (Section 4.4).

#### **4.1. Understanding and the facts**

There is widespread agreement that a representation must somehow answer to the facts to enable genuine understanding.<sup>4</sup> It is controversial though how to spell out this idea.

##### **4.1.1. Factivity conditions**

A natural idea is to require factivity – truth of a suitable proposition – as a condition of understanding. Understanding that  $p$  is the case is indeed factive in exactly the same way as knowledge: if someone understands that  $p$ , then “ $p$ ” is true. This suggests that explanatory and objectual understanding fulfill a condition of factivity too. Particularly, if explanatory understanding is taken to be equivalent to understanding that ( $p$  because  $q$ ) (Grimm 2006, 518; Pritchard 2010, 75; Hills 2009, 99), it must be factive. Since explanations are often very complex and involve e.g. initial conditions and generalizations, one may strengthen factivity and require that all propositions constituting the explanation be true. This rather strong condition can easily be adapted to objectual understanding: all propositions constituting one’s representation of the subject matter need be true (cf. Kvanvig 2003, 191).

But at least for objectual understanding, such a strong factivity condition seems too demanding. A few peripheral falsehoods may degrade one’s understanding, but do not undermine it completely. Thus, so-called moderate factivists (or “quasi factivists”; Kvanvig 2009b; Mizrahi 2012) do not require that all propositions constituting the representation of the subject matter be true, but only that the central ones (Carter and Gordon forthcoming) and most of the rest be true (Kvanvig 2003, 201–2). Some authors have gone further and argued that objectual understanding is not even moderately factive; some of their arguments may apply to explanatory understanding too.

##### **4.1.2. Arguments against moderate factivity**

Cases from scientific education and from past science suggest that even central falsehoods can be compatible with understanding, minimal as it might be. A central element in a second grader’s view of human descent may be that humans descended from apes, although, on a more sophisticated account, humans and great apes descended from a common hominid ancestor who was not, strictly speaking, an ape. Nonetheless, the child’s view displays some understanding and is certainly better than thinking that humans and apes are not relatives of any sort. Likewise, even though Copernicus thought that the Earth orbits around the sun in a

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<sup>4</sup> Zagzebski (2001) is an exception if she is interpreted as claiming that understanding has exclusively internally accessible criteria of success (cf. Pritchard 2010, 75).

circle (and not in an ellipse), his theory constitutes a major advance in understanding the motion of the planets if compared to Ptolemaic theories (Elgin 2007, 37–8).

It can further be argued that certain superseded theories (e.g. Newton's theory of gravitation) did not only afford some understanding in the past, but still do so today, and not just in educational contexts. In fact, the "pessimistic induction" (Laudan 1981) suggests that even our current best theories may be false not merely at the periphery. Consequently, current science displays some degree of understanding only if understanding is not even moderately factive (Elgin 2007; De Regt 2015).

Scientific practice provides further candidates for counterexamples to moderate factivity. Idealized models, which are acknowledged not to be true, figure centrally and ineliminably in scientific understanding. The model underlying the ideal gas law accounts for the behavior of real gases by assuming that the latter consist of perfectly elastic point masses that do not interact with each other. This is plainly wrong, but there are conditions under which a real gas behaves in some respects as if the model were true, and the behavior of the gas then is understood in terms of the idealized model (Elgin 2007, 38). If such idealizations are the best science can currently do or preferable to representations closer to the truth, then lack of factivity is compatible with a significant degree of understanding. Note also that scientists use incompatible models for understanding different aspects of the same subject matter (e.g. representations of water as a collection of molecules and as a fluid; see De Regt 2015, 3791–2). But if contradictory propositions figure centrally in the respective models, at least one of the models cannot even provide moderately factive understanding (Zagzebski 2001, 244).

Finally, understanding can also be gained by means of non-propositional representations, such as diagrams, maps, graphs, and three-dimensional models. If the content of such representations is not fully explicable in terms of propositions, the resulting understanding cannot be even moderately factive (Riggs 2003a, 218).

#### **4.1.3. Defenses of moderate factivity**

Proponents of moderate factivity have not been swept away by these objections though.

A first strategy to save factivity is to argue that the alleged counterexamples do not instantiate genuine understanding. When we talk of understanding even though moderate factivity is not strictly satisfied, this can often be explained without denying moderate factivity. The idea is that epistemic terms are sometimes used honorifically, for instance, when we speak of "the current state of scientific knowledge" while conceding that some part of it may be false. Likewise, we sometimes talk of understanding, although we do not think that the condition of factivity is satisfied (Kvanvig 2009b, 341–2; Greco 2014, 297–8).

But is it really true that non-factive uses of "understanding" are merely honorific? In ordinary language, "understanding" as applied to domains seems more flexible than "knowledge" as applied to isolated propositions (Baumberger 2011, 82). We readily agree that Copernicus did not know the Earth's orbit to be circular, but it seems inappropriate to entirely deny him understanding of the planets' motion. It is also quite a stretch to say that idealized models do not provide understanding, strictly speaking.

Kvanvig (2009b, 342–3) and Greco (2014, 296–7) therefore turn to a second strategy and argue that moderate factivity is not really violated in the examples, at least as long as they

display genuine understanding. Understanding a target system in terms of an idealized model requires that one knows what the model is like and how it relates to the target. This, in turn, involves knowing to what extent the model is an idealization, which aspects of the target it is intended to capture, and under which conditions the target approximately behaves as the model. But if a scientist knows all this, her central beliefs about the target are true. Recall the example of the scientists who model the behavior of gases in terms of non-interacting point particles. According to Mizrahi (2012), we need to distinguish between the ideal gas law, the conditions under which it applies, and the idealizing assumptions necessary to derive the ideal gas law. These assumptions, e.g. that the molecules do not interact with each other, are indeed false, but they are at the periphery of the model because they can be distinguished from descriptions of the behavior of real gases. This behavior is characterized using the ideal gas law. This law and its conditions of applicability constitute the central propositions of the model. In successful applications of the model, these conditions hold true, and the law is at least approximately true too. Hence, moderate factivity seems to hold.

This strategy is not waterproof though. Note first that Mizrahi relaxes factivity further by allowing central propositions to be only approximately true. There may also be examples from economy or ecology, in which scientists gain understanding by using idealized models whose central propositions are not even approximately true. Furthermore, non-factivists could point out that, in some cases, scientists do not exactly know how their models diverge from reality or under which conditions exactly their models get it approximately right; but it is implausible to say that in such cases scientists at most understand their models and not the systems represented by their models (Baumberger 2011, 83).

Kelp (2016) pursues a third strategy to defend moderate factivity. He defines maximal understanding of a phenomenon  $P$  as fully comprehensive and maximally well-connected knowledge about  $P$ , and introduces degrees of understanding  $P$  in terms of the distance from maximal understanding of  $P$ . Outright understanding then may be attributed to a person if the distance from maximal understanding is smaller than a contextually fixed threshold (Kelp 2015). This context dependency explains why we attribute some understanding of human descent to the second grader, but not to a biologist with the same beliefs. However, Kelp's account implies that striving for maximal understanding calls for fully realistic models, and non-factivists could object that, for cognitively limited beings like humans, representations closer to the truth are typically harder to apply and accordingly less useful for achieving understanding (De Regt 2015).

#### **4.1.4. Challenges for factivists and non-factivists**

Where then do we stand? And what are the challenges for the most prominent positions regarding factivity?

*Moderate* factivists need to explain more precisely what it means that a proposition figures *centrally* in a theory or explanation, or that a proposition is *approximately* true. But the core problem for factivists of any flavor is to explain how idealized models and flawed theories can as such make a positive difference for understanding. To meet this challenge, Strevens (2016) argues that, in contrast to realistic models, idealizations enhance understanding by indicating more efficiently that certain factors make no difference to the explanandum (cf.



Strevens 2008, ch. 8); he also submits that manipulating idealized models can more readily provide insight into why some causal factors are difference-makers and help grasp the nature of explanatory connections.

Non-factivists have no problem acknowledging that idealized models and false theories can contribute to understanding. The challenge for them is to provide a non-factivist version of an external rightness condition, which explains why we cannot gain understanding by any kind of just-so story or false theory.<sup>5</sup>

To meet this challenge, De Regt and Gijssbers (2016) propose that representations afford understanding only if they reliably lead to scientific success, i.e. to true predictions, successful practical applications, and fruitful ideas for further research. Newtonian physics can thus be used to understand certain phenomena because the theory is very successful in a broad range of applications. Truth does play a role for De Regt and Gijssbers, but understanding does not presuppose that the theories themselves are true.

A different non-factivist condition of rightness is proposed by Elgin. She requires exemplification to establish the necessary tie to the facts, at least in cases of idealizations, fictions, and competing theories (Elgin 2004; 2007; 2009; 2016).<sup>6</sup> The latter can provide understanding if they exemplify important features that they share with their target systems. If a real gas is understood in terms of an ideal gas, for instance, the ideal gas exemplifies the relationship between pressure, volume, and temperature expressed by the ideal gas law; under certain conditions, this relationship is (approximately) instantiated by real gases; in this way, the ideal-gas representation refers to the real gas and provides some understanding of its behavior. This proposal raises the question of how a fictional entity or representation may exemplify the features it is supposed to share with the target. Elgin's (2016) answer invokes abstract properties, which can be exemplified by fictional entities and representations just as well as by material objects.

## **4.2. Understanding and the epistemic agent**

A representation – an explanation or a theory – can only afford an epistemic agent with understanding if it is somehow hers or otherwise connected to her. But exactly what connection is required?

### **4.2.1. Belief and commitment**

A natural suggestion is that the explanation or theory needs to be believed by the understanding subject. This suggestion follows immediately if understanding is a species of knowledge (as e.g. Grimm 2006, Greco 2014, Kelp 2015, and Khalifa 2011 hold). But many authors who do not regard understanding as a species of knowledge agree with a belief

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<sup>5</sup> Wilkenfeld (2015) suggests that representational accuracy is a *good-making* feature of understanding. This allows him to make understanding answerable to the facts without posing a necessary condition. How accurate a representation must be for outright understanding is then supposed to be a matter of the context.

<sup>6</sup> Elgin's original account of understanding (1996) had no external rightness condition and identified understanding with having a system of commitments in reflective equilibrium. A similar account is defended by Ammon (2009; 2016).

condition too (e.g. Kvanvig 2003; 2009a; Hills 2009; 2015; Pritchard 2010). Here, belief cannot be restricted to those propositions that constitute the explanation. One also needs to believe that the explanans explains the explanandum; i.e. that the propositions from the explanation instantiate, or refer to, the right kind of deductive, statistical, or causal structure. For objectual understanding, a plausible belief condition requires that the agent believes the propositions constituting her theory (or other kinds of representation) and that these propositions stand in an appropriate structural relationships to each other.

A belief condition along these lines faces worries that parallel worries from Section 4.1. It seems possible to gain some understanding by means of idealized models and superseded theories one knows to be false and thus does not believe. And some non-propositional representations, such as diagrams, graphs, and material models, seem to afford understanding, although it seems impossible to explicate the content of the propositions in terms of beliefs attributable to the agent (cf. Elgin 1996, 123; Riggs 2003a, 218).

Both worries may be avoided if the agent need not believe the explanation, theory, or other kind of representation itself, but rather that the explanation etc. is, in the present context, sufficiently good or even the best available. Khalifa (2011, 100) has proposed such a condition for “full” explanatory understanding.

An alternative suggestion is to replace the notion of belief by a broader notion of acceptance or commitment. Here, commitment comes in degrees and aims not only at truth (as does belief), but also at various other epistemic aims, e.g. simplicity, fruitfulness, and scope; and it applies to non-propositional and even non-verbal representations too (see Elgin 1996; 2004; Ammon 2016; Baumberger and Brun 2016).

#### **4.2.2. Grasping**

In the literature about understanding, it is a commonplace that the understanding requires more than believing or accepting or even knowing isolated pieces of information. Additionally, it is claimed, the agent must “grasp” or “see” how they hang together: understanding requires “seeing the way things fit together” (Riggs 2003a, 218), “grasping of explanatory and other coherence-making relationships in a large and comprehensive body of information” (Kvanvig 2003, 192), or to “‘grasp’ or ‘see’ how the various parts of the model relate to one another” (Grimm 2011, 88).

But what is grasping? A simple example suggests two possible answers:<sup>7</sup> Suppose that a climate scientist explains to her young son that the global mean surface temperature has massively increased since the middle of the 20<sup>th</sup> century because of increasing greenhouse gas concentrations. Since she is right and her son has good reasons to believe her explanation, he may be said to know why the global mean temperature has increased. But he does not seem to understand why. When asked why this is so, all he can do is to repeat his mother’s explanation. The problem seems to be that he does not really grasp the explanation. But what exactly is he lacking?

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<sup>7</sup> Similar testimonial cases have been discussed by Grimm (2006, 531–2; 2014, 31–2), Pritchard (2010, 81; 2014, 316), and Newman (2014, 60–3).

According to a first suggestion, the problem is that the boy has no conception of how increasing concentrations of greenhouse gases cause global warming, i.e. no conception of the underlying causal mechanism (called “greenhouse effect”). Grasping the explanation then requires beliefs about what it is about  $q$  that makes it a cause of  $p$  or beliefs about the mechanism that leads from  $q$  to  $p$  (Grimm 2006, 531–2; Pritchard 2010, 81; 2014; Newman 2012, 15–6; cf. Salmon 1984, 260). The second suggestion points out that the boy cannot tell what would have been the case if greenhouse-gas concentrations had developed differently or if volcanic eruptions had caused a massive increase in aerosol concentrations. Grasping the explanation then requires the ability to infer correct descriptions of similar, possibly counterfactual, cases (Grimm 2006, 531-2; 2014; Hills 2009, 100; 2015). The two suggestions may be viewed as complementary, and both can be adapted to objectual understanding. According to the first, grasping would not only involve beliefs about relationships between certain units, but also insights about why the elements stand in these relationships. Under the second, grasping would involve the ability to apply a representation to actual and counterfactual cases.

If only the first suggestion is correct, the necessity of grasping may be included in a suitable belief or commitment condition. Understanding why then requires that the agent believes a comprehensive explanation that not only identifies the causal factors, but also shows how the explanandum depends on these factors and what the underlying causal mechanism is.<sup>8</sup> However, it has been questioned whether a causal-mechanical explanation is necessary for explanatory understanding. Such explanations fail at the deepest level of physical reality and in domains in which causal explanations are not available or not what we are primarily interested in as e.g. in mathematics, logic, and ethics. Moreover, in domains in which causal-mechanical explanations are in principle applicable, scientists do not always use them (De Regt and Dieks 2005, 145–6). It seems implausible to say that there is no understanding in these examples. Indeed, in everyday life, we often ascribe understanding to an agent even if she cannot give any causal-mechanical story.<sup>9</sup>

If the second suggestion is correct, it is more likely that an additional condition of grasping is needed.<sup>10</sup> But what may this grasping of connections consist in on top of correctly believing that they hold?

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<sup>8</sup> It is arguable though that mere belief can only account for grasping if it is suitably qualified, e.g. as thick belief (i.e. explicit assent) or as occurrent belief (i.e. consciously endorsed thought).

<sup>9</sup> Grimm (2014, 337) argues that the difference between having a causal-mechanical explanation and having an explanation which merely specifies the cause is a difference in degree rather than in kind. Pritchard (2014, 322) offers a defense of the necessity of an at least rudimentary causal-mechanical explanation for explanatory understanding.

<sup>10</sup> Whether this is indeed the case depends on whether grasping can ultimately be explicated in terms of having additional beliefs or knowledge. We come back to this question below. Even if grasping an explanation cannot be reduced to belief or knowledge, grasping may conversely imply belief or commitment (Grimm 2006, 530–4, e.g. conceives of grasping as belief in a thick sense). If this is so, then grasping suffices as a condition that binds understanding to the epistemic agent.

### 4.2.3. Ability accounts of grasping

The most prominent accounts analyze grasping in terms of suitable abilities. Here are three related accounts of explanatory understanding.<sup>11</sup>

Grimm (2006; 2010; 2011; 2014) draws on Woodward's (2003) idea that understanding should be unpacked in terms of being able to answer "What-if-things-had-been-different?" questions. He suggests that the distinction between believing and grasping an explanation lies in one's ability to answer questions of this sort. This ability, in turn, is the ability to anticipate the sort of change that would result if the factors cited as explanatory were different in various ways.<sup>12</sup>

Elaborating on Grimm's suggestion, Hills (2009, 2015) claims that the distinction between merely believing or even knowing an explanation to the effect that ( $p$  because  $q$ ) and grasping the relation between  $p$  and  $q$  lies in one's ability to engage with the relationship between  $p$  and  $q$  and variations thereof. Understanding requires that, in the right sort of circumstances, you can successfully (Hills 2009, 102–3):

- (i) follow some explanation of why  $p$  given by someone else;
- (ii) explain why  $p$  in your own words;
- (iii) draw the conclusion that  $p$  (or that probably  $p$ ) from the information that  $q$ ;
- (iv) draw the conclusion that  $p^*$  (or that probably  $p^*$ ) from the information that  $q^*$  (where  $p^*$  and  $q^*$  are similar but not identical to  $p$  and  $q$ );
- (v) given the information that  $p$ , give the right explanation,  $q$ ;
- (vi) given the information that  $p^*$ , give the right explanation,  $q^*$ .

(iii) and (v) constitute the ability to apply the explanation to a particular case, (iv) and (vi) the ability to judge similar or counterfactual cases, and (iv) is the ability to answer What-if questions in Woodward's sense. Hills's condition is thus more demanding than Grimm's, who focuses on (iv) (but see Grimm 2010).

De Regt argues that scientific understanding of a phenomenon requires the ability to give an adequate explanation which fits it into a broader theoretical framework (De Regt 2009; based on De Regt and Dieks 2005). Since this presupposes a sufficient understanding of this framework, understanding a scientific theory is a prerequisite for understanding phenomena scientifically. De Regt identifies the understanding or grasp of a theory of a phenomenon with the ability to use the theory to cast predictions and to give explanations about the phenomenon. His account is even more demanding than Hills's, not only because understanding a phenomenon requires that one grasps a theory of the phenomenon, but also because it requires the ability to construct – not merely to comprehend or reformulate –

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<sup>11</sup> So far, there has been little discussion of how an ability account for grasping would look like for objectual understanding. But see Gordon 2016.

<sup>12</sup> Note though that merely believing that ( $p$  because  $q$ ) may already require the ability to answer certain What-if questions (Grimm 2014, 388). On this account of believing an explanation, no distinct grasping condition is necessary over and above a belief (or commitment) condition.

explanations and predictions about the phenomenon; this, in turn, will often involve the ability to construct models that relate the explanandum to a theoretical framework.<sup>13</sup>

It is notable that the accounts of grasping differ in what they take to be the object of grasping. Some identify the object with a system of relations of dependency in the world, others with a representation of such a system. Grimm (2011) considers both options but favors the first in his more recent writings (Grimm 2014), as do Hills (2009; 2015) and Strevens (2013), while De Regt and Dieks (2005), De Regt (2009), Wilkenfeld (2013), and Baumberger and Brun (2016) opt for the second option. If relations of dependency in the world are grasped, “grasping” tends to be simply another word for “understanding”.<sup>14</sup> If what is grasped is a representation, grasping is only a necessary condition for understanding a phenomenon via the representation.

#### **4.2.4. Challenges to prominent accounts of grasping**

The accounts of Grimm, Hills, and De Regt have all been attacked as too demanding. De Regt’s account may be too strong even for scientific understanding, because some explanatory understanding seems possible even if we do not have a theory about the phenomenon to be explained (Kelp 2015). And if a theory is involved, it seems we need not be able to use it and construct a model on its base to understand why something is the case (Newman 2012, 5–7; Strevens 2013, 513). We can gain some understanding, e.g. of global warming, even though we cannot construct a model of the climate system by using physical theories (e.g. fluid dynamics) and empirical assumptions (e.g. about cloud albedo).

Grimm’s and Hills’s conditions are weaker, but they are subject to criticism too. First, Peter Lipton identifies understanding-why with the cognitive benefits that explanations provide and argues that these benefits (knowledge of causes, necessity, possibility, and unification) can be gained by other means than explanation. We may e.g. understand why the acceleration of bodies does not depend on their masses by running through Galileo’s thought experiment, although it does not explain why this independence holds (Lipton 2009, 47). If Lipton’s arguments for understanding without explanation can be defended (against e.g. Khalifa 2012 and Strevens 2013), Grimm’s and Hills’s conditions cannot be necessary for understanding-why.<sup>15</sup>

Second, Newman (2012; 2014) argues that the grasping necessary for understanding does not require the ability to apply explanations to counterfactual cases. In his terminology,

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<sup>13</sup> Other accounts of understanding which assign abilities a central role include the Inferential Accounts of Scientific Understanding by Newman (2012; 2013; 2014) and Ylikoski (2009; 2014), Wilkenfeld’s Representation Manipulability Account of Understanding (Wilkenfeld 2013), Le Bihan’s Model View of Understanding (Le Bihan 2016), and Elgin’s account of objectual understanding (Elgin 2007). Khalifa (2013b) explains grasping in terms of the ability to reliably evaluate explanations and identifies thus a grasping condition with a justification condition.

<sup>14</sup> Strevens (2013) identifies grasping with understanding-that and distinguishes it from understanding-why. This enables him to explicate understanding-why in terms of grasping without circularity.

<sup>15</sup> The idea that understanding can do without explanation may be more promising for objectual understanding. Gijsbers (2013) argues that a merely classificatory theory can provide some understanding of a domain, even if it does not enable us to explain facts about the domain.

understanding requires the ability to make inferences about why the explanans explains the explanandum, but not the ability to assimilate new information and provide solutions to new problems. If someone has problem-solving abilities as well, she is properly said to understand a theory, which she can use to comprehend a whole range of phenomena (Newman 2014, 59–62).

Third, Hills's account requires that the agent can formulate an explanation in her own words, and Grimm's proposal is naturally interpreted as requiring that she can explicitly answer What-if questions. But some agents (e.g. young children) might not possess the necessary linguistic abilities, even though they understand why something is the case. Grimm (2016) proposes to accommodate such cases by adapting a distinction of Sosa (2009, 13): animal understanding only requires an ability to reliably track dependency relations, reflective understanding additionally the ability to articulate these dependencies and explicitly answer What-if questions. Hills (2015) draws a similar distinction between explicit understanding, which is subject to conditions (i)–(vi), and implicit understanding, which merely requires the ability to draw conclusions about current and similar cases (i.e. (iii) and (iv)), where “to draw conclusions” simply means to believe conclusions on the right bases.

Irrespective of their details, all ability accounts of grasping raise some interesting questions. A first, so far largely neglected, issue is: Do the requisite abilities constitute the grasping or are they grounded in it? De Regt (2009) and Hills (2015) presume the former, but do not argue for this view. Strevens (2016) suspects that this gets the order of dependence wrong and suggests that the abilities are grounded in the psychological state of grasping: My grasp of a dependency relation gives me the ability to reason about it and answer related questions.

A second question concerns the phenomenology of grasping. There is something distinctively *like* to grasp (or, at least, to seem to grasp) an explanation: a kind of *Aha!* experience, often referred to as “feeling” or “sense” of understanding. How does this sense of understanding relate to the abilities necessary for understanding and thus to understanding itself? There is widespread agreement that the feeling is neither necessary nor sufficient for understanding (De Regt 2004; 2009; Grimm 2009; 2010; Hills 2009; Lipton 2009; Ylikoski 2009). This implies that the feeling of understanding has no role in an account of the nature of understanding; and that, if grasping is necessary for understanding, it needs to be distinguished from this feeling. This does not imply though that the feeling of understanding cannot serve any epistemic function. If it is sufficiently reliable, it may not only motivate, but also guide our search for understanding. Lipton (2009, 57–61) e.g. proposes that it can guide our choice of the “loveliest” explanation; i.e. the explanation which, if correct, would provide maximal understanding. How reliably the feeling of understanding works, is an empirical question. Examples from the history of science (Trout 2002; 2005) and empirical studies about the illusion of depth of understanding (Ylikoski 2009; Kuorikoski 2012) have been used to question the feeling's reliability (but see Grimm 2009).

There is, finally, the question of whether the abilities required for grasping may ultimately be explicated in terms of belief or propositional knowledge. Khalifa argues that the abilities needed for explanatory understanding amount to having knowledge concerning explanatory details. He identifies understanding why with knowing that (a) the explanans and (b) the

explanandum are true, and (c) what the correct explanatory link is between explanans and explanandum (Khalifa 2012, 26). There is no explicit ability condition here, but (c) may be supposed to imply the relevant abilities. However, it may be argued that (a)–(c) do not guarantee the abilities required for explanatory understanding. Newman claims that knowing that and even why ( $q$  entails  $p$ ) is not the same as being able to infer  $p$  from  $q$ , which is Hills’s condition (iii) (Newman 2014, 59–63; see also Gardiner 2012, 174–9, and Khalifa 2015 for a reply). Grimm could argue that knowledge of (a)–(c) does not guarantee that one is able to answer What-if questions. However, the abilities can, perhaps, be absorbed into knowledge of additional facts. Hills resists such a move by arguing that no amount of knowledge guarantees the ability to draw conclusions in new cases. Furthermore, understanding is open-ended in a way that knowledge is not since one cannot specify in advance which conclusions one would need to draw, in which circumstances, to count as understanding why  $p$  (Hills 2015).

### **4.3. Understanding and its norms**

If the conditions for understanding parallel those of the justified-true-belief account of knowledge, then understanding requires not just faithfulness to the facts and grasping, but also justification. But do we really need justification, and, if so, what sort of justification is required? More generally, what norms and values govern understanding apart from the requirement that it draws on a representation which answers to the facts?

#### **4.3.1. Do we really need a condition of justification?**

Some accounts of understanding seem to do without a justification condition. At least at first sight, e.g. Strevens may be understood in this sense since he holds that scientific understanding “can be analyzed entirely in terms of a mental act of ‘grasping’ and a notion of explanation” (2013, 510). However, he immediately adds that “grasping must be something over and above knowledge” (Strevens 2013, 511), and if this means that grasping implies knowledge, then understanding needs justification since knowledge does.

Hills (2015) is more explicit and argues that understanding can be based on defeated evidence. Suppose, you gain understanding why Napoleon was a great general, but an uncontested authority later tells you that he was not. If you hold to your belief that he was because you still think that Napoleon was tactically astute, etc., you do not know why he was a great general because you have strong evidence that your belief is false, which undermines your justification. According to Hills, you nonetheless understand why Napoleon was a great general. If this is correct, then understanding needs less justification than knowledge. Wilkenfeld (2016) goes further than that by drawing the more radical conclusion that no justification is needed.<sup>16</sup>

#### **4.3.2. Must justification be truth conducive?**

As has already become clear, a number of authors (e.g. Gijsbers, Greco, Grimm, Kelp, Khalifa, Newman, and Strevens) think that understanding is a species of knowledge. If this is

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<sup>16</sup> Moreover, Wilkenfeld (2016) uses Hills’s argument to argue that one can understand why  $p$  in virtue of  $q$ , despite not fully believing that ( $p$  because  $q$ ); see Janvid 2014 for a different argument.

in fact so, then understanding requires *at least* the kind of justification needed for knowledge (and as long as knowledge is not identified with true belief as in Sartwell 1991, this is not an empty requirement). Now, the most widely accepted accounts of knowledge are value-monistic and hold that justification must be truth-conducive, i.e. instrumental in acquiring true and avoiding false beliefs. This would imply that understanding also calls for a truth-conducive justification. Other epistemologists hold that justification also draws on values that do not directly derive from truth (see Alston 2006); such values will then be relevant to understanding as well.

If, by contrast, understanding is not taken to be a species of knowledge, then there are no direct implications for a justification requirement on understanding, and various positions are available. Riggs argues that what provides understanding need not only be assessed for accuracy, but also for explanatory power and coherence (Riggs 2003a, 219), and also that trade-offs between accuracy and such further desiderata may be necessary (Riggs 2003b). Moreover, whereas arguments against classifying understanding as knowledge could have implications for justification, this seems not to be the case for the arguments that have actually been advanced so far. For example, the thought that understanding cannot be gained by testimony, while knowledge can be (Hills 2009; 2015), does not, *by itself*, imply that it is impossible to justify understanding by suitable testimony.

Let us now turn to two further requirements which have been hotly debated: Does justification require coherence? Is it internal, i.e. accessible to the epistemic subject? Whereas coherentism and internalism currently have a hard time in the epistemology of knowledge, many authors think that coherentist and/or internalist intuitions can be vindicated for understanding.

### 4.3.3. Coherence

Kvanvig explicitly refers to coherence when he argues that understanding requires the grasp of explanatory, logical, and probabilistic (and maybe additional) relations in a comprehensive body of information, and that one cannot understand something by means of an inconsistent body of information (Kvanvig 2003, 192–3, 201; see also Elgin 2007; Kosso 2007; Riggs 2003a). Coherence also figures prominently in accounts of objectual understanding that defend far-reaching conditions of justification. Specifically, Elgin (1996; 2007) argues that epistemic justification requires reflective equilibrium and that this includes coherence (although it does not reduce to it). Starting from Elgin's ideas, Baumberger and Brun (2016) develop an account of understanding a subject matter by means of a theory, which requires *inter alia* coherence between the theory, the epistemic subject's commitments, and background theories.<sup>17</sup>

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<sup>17</sup> Note also that coherence may become interesting for the epistemology of understanding for another reason than its role in justification. What needs understanding is often complex, so understanding requires that the complexity is grasped, and this in turn means that the representation that provides the understanding must include representations of complex relations and in this sense be coherent (see, e.g. Grimm's complex systems of dependency relations in Grimm 2016).



However, the literature about understanding still lacks detailed proposals about what coherence really requires. A recent exception is Gijssbers's (2015) application of formal accounts of coherence to explanatory understanding.

One reason to doubt that coherence is a requirement on understanding is that coherence alone does not seem to be truth conducive, as even some champions of coherence concede (see e.g. Bonjour 1985, ch. 8). Consequently, one may worry that it does not buy much for a justification condition on knowledge and factivists about understanding may want to extend this worry to the justification of understanding. This challenge can be countered by arguing that something other than truth conduciveness might be epistemically desirable about coherence.

Khalifa (2016) raises another objection against a coherence requirement. On his view, explanatory understanding is the better the more closely explanatory beliefs resemble scientific knowledge. Granted his reliabilist account of scientific knowledge, it follows that explanatory, inferential, and probabilistic relations enhance understanding. But all this is still compatible with foundationalism and therefore does not underwrite the coherentist claim that such coherence making relations are necessary for justification.

#### **4.3.4. Internalism and externalism**

Turn now to internalism about understanding. The basic idea is that a subject has understanding only if she has access to at least some reasons which speak in favor of the rightness of the representation by which she seeks to gain understanding.

A strong form of internalism about understanding was defended early on by Zagzebski. According to what she calls transparency, understanding implies understanding that one understands since understanding requires to be "directly aware of the object of [...] understanding" (2001, 246–7). Transparency implies that the epistemic subject can assess whether she understands, but it is not meant to equate seeming to understand with understanding (2001, 246; contra Pritchard 2010, 75).

Elements of internalism and transparency, mostly in more modest forms, can also be found in a range of other accounts. For Elgin e.g. understanding that something is the case is parasitic on objectual understanding, which, in turn, has to meet the standards of reflective equilibrium. This means that we can only understand something by means of a system we can accept *on reflection*, which clearly is an internalist requirement (Elgin 1996, esp.128; Baumberger and Brun 2016). In a similar vein, Pritchard argues that explanatory understanding is internalist because it requires one to "have good reflectively accessible grounds in support of the relevant beliefs that undergird that understanding" (2010, 82). A characteristic consequence of internalist views is that testimony does not suffice for understanding, but they do not imply that there are no additional external norms for understanding.

More recently though, internalism about understanding has been attacked, especially by those who take understanding to be some form of knowledge. For Grimm (2014) understanding is knowledge of dependency relations, e.g. of causal relations, and must therefore meet the justification condition for knowledge (see Greco 2014 for a similar account). But this very condition is spelled out with reference to a reliable process of belief

formation, which is not necessarily accessible to the subject (Grimm 2016). Hence, an agent need not be able to determine on reflection whether her understanding was gained in a reliable way.

Grimm (2016) adds a more direct argument to the effect that no internalist condition is necessary for understanding: young children and animals may understand something by grasping dependency relations, but they cannot provide reasons for why they understand since they cannot articulate what they grasp. To account for internalist intuitions, we may introduce the notion of reflective understanding though (see Section 4.2.4).

Greco suggests an alternative way to account for internalist intuitions. Instead of demanding transparency, he proposes a requirement of subjective justification for knowledge, which is met iff the epistemic subject's belief results from intellectual dispositions she manifests when she is motivated to believe the truth (Greco 2000, 190; 2010, 167). This idea was introduced into the debate about understanding early on by Kvanvig (2003, 103, 200), who argued that understanding is internalist (inter alia) because it requires subjective justification in Greco's sense. Later on, Kvanvig also conceded an externalist aspect of justification by adding a condition of reliability that calls for intellectually virtuous beliefs (2009a, 105).

#### **4.3.5. Epistemic luck**

Externalism about knowledge has much been shaped by attempts to handle so-called Gettier cases (Gettier 1963). In such cases, agents happen to have a true belief for which they can provide reasons, but intuitively, they do not command knowledge because their beliefs are true merely as a matter of luck. Now the question arises: Is understanding compatible with all sorts of epistemic luck?

Kvanvig has used the following example to argue for the compatibility of understanding with epistemic luck:<sup>18</sup> Ismena has read a book on North American history and on this basis she can correctly answer a wide range of questions about the Comanche's dominance of the southern plains from the 17<sup>th</sup> to the 19<sup>th</sup> century. But it is a matter of mere luck that Ismena picked a book that provides a correct account of the topic; most other books get it wrong. According to Kvanvig, Ismena has objectual understanding of the Comanche's dominance because she appreciates the explanatory and other coherence-making relationships in a correct body of information about the Comanche's dominance. Kvanvig concludes that understanding requires factivity and the subject's grasping of "relations between items of information", but not the luck-free etiology required for knowledge (Kvanvig 2003, 197–9; 2009a, 103–9).

Ismena seems to have what has been called "environmental luck": She luckily acquires true beliefs in an epistemically unfavorable environment in which one could easily arrive at false beliefs. This type of luck is often distinguished from "intervening luck", in which a person has true beliefs only due to a lucky intervention "between" the facts and her cognitive abilities (the terms are from Pritchard 2008, 330). With this distinction in mind, some authors have tried to further develop Kvanvig's examples to show that understanding is compatible with both intervening and environmental luck (Hills 2015 for explanatory and Baumberger

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<sup>18</sup> See Rohwer 2014 for a survey of the most prominent cases and positions.

2011 for explanatory and objectual understanding; see also Morris 2012). Provided the common assumption that knowledge is incompatible at least with intervening luck, this implies that understanding is possible without knowledge.

This implication can of course not be agreed upon by people who think that understanding is a variety of knowledge and who must consequently disagree with full compatibility of understanding and epistemic luck. Some disagree moderately because they hold that knowledge is compatible with environmental, but incompatible with intervening epistemic luck, and that the same goes for understanding (e.g. Grimm 2006). A moderate incompatibility view can be defended using the following examples from Pritchard: Brand's house has burned down because some form of faulty wiring caused a short circuit. When Brand arrives at the site, he talks to a fire officer, who is, unbeknown to Brand, surrounded by partygoers dressed as firemen. What Brand learns about the cause of the fire is actually true, but only as a matter of environmental luck. Had Brand asked one of the fake firemen, he would likely have acquired a false belief about the cause of the fire. Brand nonetheless understands why the house has burned down, at least if he knows how a fire can be caused by faulty wiring. This would not be the case, however, if Brand had asked a partygoer and if the latter had luckily guessed that faulty wiring was the cause of the fire. In this case, Brand would have had intervening rather than environmental luck. Thus the intuitive judgments about the examples are in accordance with the moderate view. As an explanation, Pritchard refers to the view that understanding, in contrast to knowledge, is by its nature a cognitive achievement in the sense of a cognitive success due to the epistemic subject's cognitive abilities (Pritchard 2010, 77–80).

A more radical view holds that understanding is incompatible with both kinds of epistemic luck. This view follows if understanding is taken to be a form of knowledge and knowledge to be incompatible with both forms of epistemic luck. But of course, direct arguments for the incompatibility of understanding with environmental luck seem more convincing. Khalifa (2013b) argues that explanatory understanding must result from the exercise of reliable cognitive abilities which include the evaluation of, and discrimination between, explanations. This condition rules out environmentally lucky understanding since, in cases of an unfavorable environment, the agent does not have the resources to exclude alternative explanations.

But what about Kvanvig's Comanche example, in which understanding is supposed to be compatible with environmental luck? According to Greco (2014) Ismena understands a representation, but neither the real system nor the relation between it and the representation. According to Khalifa (2013b), the standard examples (Brand and Ismena) invoke a false analogy to barn-façade cases, but in fact do not instantiate the relevant sort of luck at all. He argues that they are examples of evidential rather than veritic luck, i.e. cases in which it is only due to luck that the agent has evidence in favor of her beliefs, rather than cases in which the truth of the agent's beliefs is due to fortunate circumstances. But in contrast to veritic luck, evidential luck is not supposed to be incompatible with knowledge (see also Khalifa 2011 and Kelp 2016).

#### **4.4. Sufficient conditions**

As we have seen, philosophers debate to what extent understanding has to answer to the facts (Section 4.1), in which way it is tied to an epistemic agent, e.g. via her beliefs or commitments or through her grasping (Section 4.2), and what kind of justification it requires (Section 4.3). While it seems uncontroversial that some condition of external rightness is necessary to explain what understanding is, we have witnessed disagreement about whether the conditions of belief/commitment and justification are needed.

It is of course possible that understanding is also subject to additional conditions. Certain abilities that have been proposed as requirements for understanding may not fit into the categories mentioned so far, e.g. the abilities to assess the limits of the applicability of an account (Elgin 2007, 35), to recognize the need for, and to accommodate, changes in an account (Elgin 2016; Wilkenfeld 2013), to evaluate uncertainties of predictions generated by an account, and to argue against rival accounts (Baumberger 2011, 79). However, it is not so clear whether these abilities are really needed for understanding or whether they merely improve one's understanding, and also whether they are not already contained in what is required by a condition of grasping or of internalist justification.

### **5. Constraints on an account of understanding**

We conclude this overview of recent debates about the nature of understanding with a brief discussion of three questions that are not directly related to the justified-true-belief analogy.

#### **5.1. Can understanding be explicated in terms of knowledge?**

There is widespread agreement that understanding transcends ordinary propositional knowledge insofar as one can know that a fact obtains without understanding why it obtains and without understanding the subject matter to which it belongs. It is also widely assumed that understanding why something is the case moves beyond knowledge why it is the case (an exception being Sliwa 2015). What is typically taken to be additionally necessary for understanding is some kind of grasping which leads to requirements of systematicity (e.g. Elgin 1996; Kvanvig 2003; Riggs 2003a; Greco 2014; Kelp 2015) or of certain abilities (e.g. Grimm 2006; De Regt 2009; Newman 2012; Khalifa 2013b).

But understanding something (e.g. why  $p$ ) may be identified with the corresponding knowledge (e.g. why  $p$ ) if either a demanding notion of knowledge is assumed, according to which knowledge involves the grasping typically associated with understanding (cf. Grimm 2014); or if it is assumed that understanding may be as isolated as knowledge and that it does not require the grasping often associated with it (cf. Sliwa 2015). Both options are neither very plausible nor popular. The first option implies that knowledge cannot be shared through testimony, which is one of its important epistemic social roles and which distinguishes it from more demanding cognitive achievements that involve modal abilities (Hills 2015). The second option leads to a notion of understanding that hardly fulfills the hopes (discussed in Section 2) that spur its rediscovery.

It is more controversial whether knowledge is *necessary* for understanding. After the turn to understanding, many epistemologists first held that understanding does not imply

knowledge (e.g. Ammon 2009; Elgin 1996; 2007; Kvanvig 2003; Pritchard 2008; Riggs 2003a; Roberts and Wood 2007; Zagzebski 2001). But meanwhile, the view that understanding is a form of knowledge and thus implies knowledge has gained ground, even outside philosophy of science where it has always been the dominant view<sup>19</sup> (e.g. Greco 2014; Grimm 2006; 2014, Kelp 2014; 2015; Lipton 2009; Khalifa 2011; Strevens 2013). But the dispute is still undecided (among the more recent defenders of the claim that understanding does not resolve into knowledge are Ammon 2016; Baumberger 2011; Hills 2009; 2015; Janvid 2012; Rohwer 2014; Wilkenfeld 2016).

Given a standard analysis of knowledge as justified non-Gettierized true belief, knowledge does not seem to be necessary for understanding if understanding does not imply justification, if it is compatible with epistemic luck, if it is not factive, and/or if it does not imply belief. But these antecedents are not only highly controversial; it is also not quite clear whether they really imply that understanding does not need knowledge. First of all, there is a weak sense of “knowledge” according to which knowledge is true belief that may be built upon epistemic luck (e.g. Goldman 1999). Hence, if understanding does not imply justification and is insensitive to epistemic luck, understanding may still imply knowledge in the weak sense. Moreover, there is intuitive (Grimm 2006) and empirical (Wilkenfeld, Plunkett and Lombrozo 2016) evidence that understanding and knowledge in the usual sense do not differ with respect to their susceptibility to Gettier concerns, since both are compatible with environmental luck but not with intervening luck. Finally, understanding can imply knowledge even if it is not factive and does not require belief in the explanation which provides the understanding. This is shown by Khalifa’s explanatory knowledge model which explicates understanding why  $p$  as knowledge that  $p$  and that  $q$  is the best available explanation for  $p$  (Khalifa 2011; Khalifa and Gadomski 2013). A subject can have this knowledge even if  $q$  is not an actual explanation of  $p$  and the subject does not believe that  $q$ .

## **5.2. Can some types of understanding be explicated in terms of others?**

We have distinguished between propositional, interrogative, and objectual understanding. Do we need a separate account for each type or can some of them be explicated in terms of others?

Gordon (2012) argues that there is no genuine phenomenon of propositional understanding since attributions of understanding-that are either synonymous with attributions of propositional knowledge, or cases of hedging and thus epistemically irrelevant.

Kvanvig (2003, 189; 2009a, 96) suggests that understanding-why, -when, -where, and -what are explicable in terms of understanding-that. For example, understanding why  $p$  is taken to be equivalent to understanding that  $q$  is a correct answer to the question “Why  $p$ ?”. If epistemically relevant instances of understanding-that are instances of knowing-that, as is widely assumed, it follows that understanding why  $p$  is equivalent to knowing that  $q$  is a correct answer to the why-question. But this is not very plausible in examples in which the relevant knowledge is purely testimonial (such as the global warming example in Section

<sup>19</sup> This claim should be taken with care since when philosophers of science talk about understanding in terms of knowing why or explanatory knowledge, the notion of knowledge is typically not the very demanding notion that is debated in the theory of knowledge (Morris 2012, 14, fn. 11).

4.2). Such examples suggest that a person can come to know that  $q$  is a correct answer to the why-question via testimony while nonetheless falling short of understanding why  $p$ , e.g. because she lacks the requisite grasp or abilities (Grimm 2011, 87; Hills 2009, 100–2; 2015; Pritchard 2010, 81; 2014, 316). This suggests that explanatory understanding cannot be reduced to propositional understanding.

Another question is whether objectual understanding of a subject matter can be explicated in terms of explanatory understanding, e.g. understanding why some significant subset of facts about that subject matter obtain. A strong antireductionism claims that explanatory understanding is not sufficient for objectual understanding since the latter additionally involves grasping non-explanatory (e.g. logical, probabilistic, and similarity) relationships. Elgin (2007) e.g. argues that objectual understanding requires some awareness of how the explanatory understanding fits into, and is justified by reference to, the more comprehensive understanding in which it is embedded. A more modest antireductionism claims that explanatory understanding is not necessary for objectual understanding since one can gain objectual understanding by means of non-explanatory representations. Kvanvig (2009a, 101–2) argues that we can understand an indeterministic system even though we cannot explain why things happen as they do. Elaborating on arguments by Lipton (2009), Gijsbers (2013) distinguishes between the understanding we get from explanation and the understanding we get from unification. He argues that we can obtain understanding without explanation via unification alone, e.g. when phenomena are unified by classifying them on the basis of perceived similarities.

So far, only Khalifa (2013c) has offered a suggestion of how to reduce objectual to explanatory understanding.<sup>20</sup> A crucial part of his strategy is to insist that the objects of objectual and explanatory understanding match exactly if the former is reduced to the latter. Explanatory understanding of why/how the Argentinean economic crisis of 2001–2 occurred can then account for objectual understanding of the occurrence of this crisis, but not of Argentinean economics. Now Khalifa thinks that logical, probabilistic, and similarity relationships provide understanding only inasmuch as they contribute to explanation. As a consequence, such relationships cannot mark off objectual from explanatory understanding. This strategy enables Khalifa to argue that strong antireductionism faces a dilemma. If the structural relationships that are supposed to distinguish objectual from explanatory understanding do not contribute to explanation, they belong to a different topic. If accounting for these relationships contributes to explanation, objectual understanding just consists in having more coherent explanatory understanding, which is compatible with reductionism. Khalifa's objection against modest reductionism is that those alleged non-explanatory relationships which are supposed to suffice for some objectual understanding (e.g. in Kvanvig's example of an indeterministic dynamics) do in fact contribute to explanation.

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<sup>20</sup> Grimm (2011, 88; 2016) argues that the difference between explanatory and objectual understanding is a difference in degree only. According to him, understanding is grasping dependency relations; in cases of so-called objectual understanding, more of these relations are grasped than when it comes to understanding particular states of affairs.

### **5.3. How to deal with the fact that understanding comes in degrees?**

Understanding comes in degrees and can vary in breadth and depth. Even though most authors acknowledge this, many accounts address outright understanding, i.e. facts that obtain if “*S* understands *P*” is true. However, the present literature also offers three strategies to address degrees of understanding.

The first strategy develops an account of minimal understanding, to which outright attributions of understanding are supposed to refer. Degrees of understanding then are introduced by pointing out how minimal understanding may be broadened and deepened. An example may be Grimm (2016), who assumes a minimal understanding that is achievable for young children and higher animals. A second strategy, pursued by Khalifa (2011; 2013a) and Kelp (2015; 2016), first gives an account of maximal understanding and then explains degrees of understanding in terms of approximations to maximal understanding. This strategy can be combined with a contextualist semantics for outright attributions of understanding. Khalifa identifies the standard for maximal understanding with knowing the best explanation of a phenomenon, Kelp with having fully comprehensive and maximally well-connected knowledge of the phenomenon under consideration. A third strategy is to directly explicate what it means for a subject to understand something to a certain degree. The threshold for outright attributions of understanding may again be determined contextually. Hills (2015) seems to favor such a strategy, as do van Camp (2014) and Baumberger and Brun (2016).

## **6. Concluding remarks**

The recent turn to understanding has sparked exciting philosophical discussions. But so far, no consensus has emerged as to what understanding is. At the moment, the debate is not so much centered around proposals for a complete analysis of understanding. Rather, as our survey has made plain, the discussion is focused on a number of hotly debated questions:

- What types of understanding are there, and how are they related to each other (see Sections 3 and 5.2)?
- To what extent and in which way need understanding reflect facts about what is understood (Section 4.1)?
- What type of epistemic achievements are necessary for understanding – knowledge, justified belief, grasping etc. (Section 4.2)?
- How can we best make sense of the idea that understanding involves the grasp of connections (Sections 4.2.2–4.2.4)?
- What norms and values are constitutive for understanding (Section 4.3)?

Given the fact that the broad philosophical interest in understanding is only fairly recent, it should not come as a surprise that answers to these questions are still controversial. Further progress may require not only a deeper exchange between epistemologists and philosophers of science, but also the collaboration with philosophers from other disciplines, e.g. philosophy of mind and philosophy of language.

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## References

- Alston, William. 2006. *Beyond "Justification". Dimensions of Epistemic Justification*. Ithaca: Cornell University Press.
- Ammon, Sabine. 2009. *Wissen verstehen. Perspektiven einer prozessualen Theorie der Erkenntnis*. Weilerswist: Velbrück Wissenschaft.
- Ammon, Sabine. 2016. "Explaining Understanding, Understanding Knowledge". In Grimm, Baumberger and Ammon 2016.
- Barber, Alex, ed. 2003. *Epistemology of Language*. New York: Oxford University Press.
- Baumberger, Christoph. 2011. "Types of Understanding: Their Nature and Their Relation to Knowledge". *Conceptus* 40: 67–88.
- Baumberger, Christoph, and Georg Brun. 2016. "Dimensions of Objectual Understanding". In Grimm, Baumberger and Ammon 2016.
- Bergmann, Michael. 2006. *Justification without Awareness*. Oxford: Oxford University Press.
- BonJour, Laurance. 1980. "Externalist Theories of Empirical Knowledge". *Midwest Studies in Philosophy* 5: 53–73.
- BonJour, Laurence. 1985. *The Structure of Empirical Knowledge*. Cambridge, Mass.; London, England: Harvard University Press.
- Carter, Adam J., and Emma C. Gordon. 2014. "Objectual Understanding and the Value Problem". *American Philosophical Quarterly* 51: 1–14.
- Carter, Adam J., and Emma C. Gordon. Forthcoming. "Objectual Understanding, Factivity and Belief". In *Epistemic Reasons, Epistemic Norms, and Epistemic Goals*, edited by Martin Grajner and Pedro Schmechtig. De Gruyter: Berlin.
- Cooper, Neil. 1994. "Understanding". *Proceedings of the Aristotelian Society, Suppl.* 68: 1–26.
- De Regt, Henk W. 2004. "Discussion Note: Making Sense of Understanding". *Philosophy of Science* 71: 98–109.
- De Regt, Henk W. 2009. "Understanding and Scientific Explanation". In De Regt, Leonelli and Eigner 2009: 21–42.
- De Regt, Henk W. 2015. "Scientific Understanding: Truth or Dare?". *Synthese* 192: 3781–97.
- De Regt, Henk W., and Dennis Dieks. 2005. "A Contextual Approach to Scientific Understanding". *Synthese* 144: 137–70.
- De Regt, Henk W., and Victor Gijsbers. 2016. "How False Theories can Yield Genuine Understanding". In Grimm, Baumberger and Ammon 2016.
- De Regt, Henk W., Sabine Leonelli, and Kai Eigner, eds. 2009. *Scientific Understanding: Philosophical Perspectives*. Pittsburgh: University of Pittsburgh Press.
- Dilthey, W. 1990 [1910]. *Der Aufbau der geschichtlichen Welt in den Geisteswissenschaften* (3rd ed.). Frankfurt a.M.: Suhrkamp.
- Droysen, Johann Gustav. 1868. *Grundriss der Historik*. Leipzig: Veit.
- Elgin, Catherine Z. 1996. *Considered Judgment*. Princeton: Princeton University Press.



- Elgin, Catherine Z. 2004. "True Enough". *Philosophical Issues* 14: 113–31.
- Elgin, Catherine Z. 2007. "Understanding and the Facts". *Philosophical Studies* 132: 33–42.
- Elgin, Catherine Z. 2009. "Exemplification, Idealization, and Scientific Understanding". In *Fictions in Science: Philosophical Essays on Modeling and Idealization*, edited by Mauricio Suárez, 77–90. New York: Routledge.
- Elgin, Catherine Z. 2016. "Exemplification and Understanding". In Grimm, Baumberger and Ammon 2016.
- Friedman, Michael. 1974. "Explanation and Scientific Understanding". *The Journal of Philosophy* 71: 5–19.
- Gardiner, Georgi. 2012. "Understanding, Integration, and Epistemic Value". *Acta Analytica* 27: 163–181.
- Gettier Edmund. 1963. "Is Justified True Belief Knowledge?" *Analysis* 23: 121–123.
- Gijsbers, Victor. 2013. "Understanding, Explanation, and Unification". *Studies in the History of Philosophy of Science* 44: 516–22.
- Gijsbers, Victor. 2015. "Can Probabilistic Coherence be a Measure of Understanding?". *Theoria* 30: 53–71.
- Goldman, Alvin. 1999. *Knowledge in a Social World*. New York: Oxford University Press.
- Gordon, Emma C. 2012. „Is There Propositional Understanding?“ *Logos & Episteme* 3: 181–192.
- Gordon, Emma C. 2016. "Social Epistemology and the Acquisition of Understanding". In Grimm, Baumberger and Ammon 2016.
- Greco, John. 2000. *Putting Skeptics in their Place. The Nature of Skeptical Arguments and Their Role in Philosophical Inquiry*. Cambridge: Cambridge University Press.
- Greco, John. 2010. *Achieving Knowledge. A Virtue Theoretic Account of Epistemic Normativity*. Cambridge: Cambridge University Press.
- Greco, John. 2014. "Episteme: Knowledge and Understanding". In *Virtues and Their Vices*, edited by Kevin Timpe and Craig A, 285–302. Boyd. Oxford: Oxford University Press.
- Greene, Brian. 2008. "Put a Little Science in Your Life". *New York Times*, Open Ed, June 1, [http://www.nytimes.com/2008/06/01/opinion/01greene.html?pagewanted=all&\\_r=0](http://www.nytimes.com/2008/06/01/opinion/01greene.html?pagewanted=all&_r=0).
- Grimm, Stephen R. 2006. „Is Understanding a Species of Knowledge?“ *British Journal of Science* 57: 515–35.
- Grimm, Stephen R. 2009. "Reliability and the Sense of Understanding". In De Regt, Leonelli and Eigner 2009: 83–99.
- Grimm, Stephen R. 2010. "The Goal of Explanation". *Studies in the History and Philosophy of Science* 41: 337–344.
- Grimm, Stephen R. 2011. "Understanding". In *Routledge Companion to Epistemology*, edited by Sven Bernecker and Duncan Pritchard, 84–94. New York: Routledge.
- Grimm, Stephen R. 2012. "The Value of Understanding". *Philosophy Compass* 7: 103–17.
- Grimm, Stephen R. 2014. "Understanding as Knowledge of Causes". In *Virtue Epistemology Naturalized: Bridges Between Virtue Epistemology and Philosophy of Science*, edited by Abrol Fairweather, 329–45. Dordrecht: Springer.
- Grimm, Stephen R. 2016. "Understanding and Transparency". In Grimm, Baumberger and Ammon 2016.

- Grimm, Stephen R., Christoph Baumberger, and Sabine Ammon, eds. 2016. *Explaining Understanding: New Perspectives from Epistemology and Philosophy of Science*. New York: Routledge.
- Haddock, Adrian, Alan Millar, and Duncan Pritchard, eds. 2009. *Epistemic Value*. Oxford: Oxford University Press.
- Hempel, Carl Gustav. 1942. "The Function of General Laws in History". *Journal of Philosophy* 39: 35–48.
- Hempel, Carl Gustav. 1965. *Aspects of Scientific Explanation and Other Essays in the Philosophy of Science*. New York: Free Press.
- Hempel, Carl Gustav, and Paul Oppenheim. 1948. "Studies in the Logic of Explanation". *Philosophy of Science* 15: 135–75.
- Hills, Alison. 2009. "Moral Testimony and Moral Epistemology". *Ethics* 120: 94–127.
- Hills, Alison. 2015. "Understanding Why". *Noûs*. DOI 10.1111/nous.12092.
- Janvid, Mikael. 2012. "Knowledge versus Understanding: The Cost of Avoiding Gettier". *Acta Analytica* 27: 183–197.
- Janvid, Mikael. 2014. "Understanding Understanding: An Epistemological Investigation". *Philosophia* 42: 971–85.
- Kelp, Christoph. 2014. "Knowledge, Understanding and Virtue". In *Virtue Epistemology Naturalized: Bridges Between Virtue Epistemology and Philosophy of Science*, edited by Abrol Fairweather, 347–60. Dordrecht: Springer.
- Kelp, Christoph. 2015. "Understanding Phenomena". *Synthese*. Doi 10.1007/s11229-014-0616-x.
- Kelp, Christoph. 2016. "Towards a Knowledge-Based Account of Understanding". In Grimm, Baumberger and Ammon 2016.
- Khalifa, Kareem. 2011. "Understanding, Knowledge, and Scientific Antirealism". *Grazer Philosophische Studien* 83: 93–112.
- Khalifa, Kareem. 2012. "Inaugurating Understanding or Repackaging Explanation?" *Philosophy of Science* 79: 15–37.
- Khalifa, Kareem. 2013a. "The Role of Explanation in Understanding". *British Journal for the Philosophy of Science* 64: 161–87.
- Khalifa, Kareem. 2013b. "Understanding, Grasping and Luck". *Episteme*, 10: 1–17.
- Khalifa, Kareem. 2013c. "Is Understanding Explanatory or Objectual?" *Synthese* 190: 1153–71.
- Khalifa, Kareem 2015. "EMU defended: Reply to Newman (2014)". *European Journal for Philosophy of Science*. Doi 10.1007/s13194-015-0112-2.
- Khalifa, Kareem. 2016. "Must Understanding be Coherent?" In Grimm, Baumberger and Ammon 2016.
- Khalifa, Kareem, and Michael Gadomski. 2013. "Understanding as Explanatory Knowledge: The Case of Bjorken Scaling". *Studies in the History and Philosophy of Science* 44: 384–92.
- Kögler, Hans Herbert, and Karsten R. Stueber, eds. 2000. *Empathy and Agency. The Problem of Understanding in the Human Science*. Boulder, CO: Westview.
- Kosso, Peter. 2007. "Scientific Understanding". *Foundations of Science* 12: 173–88.

- Kuorikoski, Jaakko. 2012. "Simulation and the Sense of Understanding". In *Models, Simulations, and Representation*, edited by Paul Humphreys and Cyrille Imbert, 168–87. New York: Routledge.
- Kvanvig, Jonathan. 2003. *The Value of Knowledge and the Pursuit of Understanding*. New York: Cambridge University Press.
- Kvanvig, Jonathan. 2009a. "The Value of Understanding". In Haddock, Millar and Pritchard 2009: 95–111.
- Kvanvig, Jonathan. 2009b. "Response to Critics". In Haddock, Millar and Pritchard 2009: 339–51.
- Laudan, Larry. 1981. "A Confutation of Convergent Realism". *Philosophy of Science* 48: 19–49.
- Le Bihan, Soazig. 2016. "Enlightening Falsehoods: a Modal View of Scientific Understanding". In Grimm, Baumberger and Ammon 2016.
- Lipton, Peter. 2004. *Inference to the Best Explanation* (2nd ed.). New York: Routledge.
- Lipton, Peter. 2009. "Understanding without Explanation". In De Regt, Leonelli and Eigner 2009: 43–63.
- Locke, John. 1975 [1689]. *An Essay Concerning Human Understanding*, edited by Peter H. Nidditch. Oxford: Oxford University Press.
- Longworth, Guy. 2008. "Linguistic Understanding and Knowledge". *Noûs* 42, 50–79.
- Martin, Michael. 2000. *Verstehen. The Uses of Understanding in the Social Science*. New Brunswick, NJ: Transaction.
- Mizrahi, Moti. 2012. "Idealizations and Scientific Understanding". *Philosophical Studies* 160: 237–52.
- Morris, Kevin. 2012. "A Defense of Lucky Understanding". *British Journal for the Philosophy of Science* 63: 357–71.
- Newman, Mark. 2012. "An Inferential Model of Scientific Understanding". *International Studies in the Philosophy of Science* 26: 1–26.
- Newman, Mark. 2013. "Refining the Inferential Model of Scientific Understanding". *International Studies in the Philosophy of Science* 27: 173–97.
- Newman, Mark. 2014. "EMU and Inference: What the Explanatory Model of Scientific Understanding Ignores". *European Journal for Philosophy of Science* 4: 55–74.
- Pettit, Dean. 2002. "Why Knowledge is Unnecessary for Understanding Language". *Mind* 111, 519–549.
- Plato. 1988. *Theaetetus, Sophist*, translated by Harald North Fowler. Cambridge, MA: Harvard University Press.
- Pritchard, Duncan. 2008. "Knowing the Answer, Understanding and Epistemic Value". *Grazer Philosophische Studien* 77: 325–39.
- Pritchard, Duncan. 2010. "Knowledge and Understanding". In *The Nature and Value of Knowledge: Three Investigations*, co-authored with Alan Millar and Adrian Haddock, 1–88. Oxford: Oxford University Press.
- Pritchard, Duncan. 2014. "Knowledge and Understanding". In *Virtue Epistemology Naturalized: Bridges Between Virtue Epistemology and Philosophy of Science*, edited by Abrol Fairweather, 315–27. Dordrecht: Springer.

- Riggs, Wayne D. 2003a. "Understanding 'Virtue' and the Virtue of Understanding". In *Intellectual Virtue*, edited by Michael DePaul and Linda Zagzebski, 203–26. Oxford: Clarendon Press.
- Riggs, Wayne D. 2003b. "Balancing Our Epistemic Goals". *Noûs* 37: 342–52.
- Roberts, Robert C., and W. Jay Wood. 2007. *Intellectual Virtues. An Essay in Regulative Epistemology*. Oxford: Clarendon Press.
- Rohwer, Yasha. 2014. "Lucky Understanding without Knowledge". *Synthese* 191: 945–59.
- Salmon, Wesley. 1984. *Scientific Explanation and the Causal Structure of the World*. Princeton, NJ: Princeton University Press.
- Sartwell, Crispin. 1991. "Knowledge is Merely True Belief". *American Philosophical Quarterly* 28: 157–65.
- Schurz, Gerhard, and Karel Lampert. 1994. „Outline of a Theory of Scientific Understanding“. *Synthese* 101: 65–120.
- Sliwa, Paulina. 2015. "Understanding and Knowing". *Proceedings of the Aristotelian Society* 55: 57–74.
- Sosa, Ernest. 2009. *Reflective Knowledge: Apt Belief and Reflective Knowledge, Vol. 2*. Oxford: Oxford University Press.
- Strevens, Michael. 2008. *Depth: An Account of Scientific Explanation*. Cambridge, Mass; London, England: Harvard University Press.
- Strevens, Michael. 2013. "No Understanding without Explanation". *Studies in the History and Philosophy of Science* 44: 510–5.
- Strevens, Michael. 2016. "How Idealizations Provide Understanding". In Grimm, Baumberger and Ammon 2016.
- Stueber, Karsten R. 2012. "Understanding Versus Explanation? How to Think about the Distinction between the Human and the Natural Sciences". *Inquiry* 55: 17–32.
- Trout, J. D. 2002. "Scientific Explanation and the Sense of Understanding". *Philosophy of Science* 69: 212–233.
- Trout, J. D. 2005. "Paying the Price for a Theory of Explanation: De Regt's Discussion of Trout". *Philosophy of Science* 72: 198–208.
- van Camp, Wesley. 2014. "Explaining Understanding (or Understanding Explanation)". *European Journal for Philosophy of Science* 4: 95–114.
- von Wright, Georg. 1971. *Explanation and Understanding*. Ithaca: Cornell University Press.
- Whiting, Daniel A. 2012. "Epistemic Value and Achievement". *Ratio (New Series)* 25: 216–30.
- Wilkenfeld, Daniel A. 2013. "Understanding as Representation Manipulability". *Synthese* 190: 997–1016.
- Wilkenfeld, Daniel A. 2015. "MUDy Understanding". *Synthese*. Doi 10.1007/s11229-015-0992-x.
- Wilkenfeld, Daniel A. 2016. "Understanding without Believing". In Grimm, Baumberger and Ammon 2016.
- Wilkenfeld, Daniel A., Dillon Plunkett, and Tania Lombrozo. 2016. "Folk Attributions of Understanding: Is there a Role for Epistemic Luck". Manuscript under review.

- Woodward, James. 2003. *Making Things Happen: A Theory of Causal Explanation*. New York: Oxford University Press.
- Ylikoski, Petri. 2009. "The Illusion of Depths of Understanding in Science". In De Regt, Leonelli and Eigner 2009: 100–19.
- Ylikoski, Petri. 2014. "Agent-Based Simulation and Sociological Understanding". *Perspectives on Science* 22: 318–35.
- Zagzebski, Linda. 1996. *Virtues of the Mind. An Inquiry into the Nature of Virtue and the Ethical Foundations of Knowledge*. Cambridge: Cambridge University Press.
- Zagzebski, Linda. 2001. "Recovering Understanding". In *Knowledge, Truth and Duty*, edited by Matthias Steup, 235–51. New York: Oxford University Press.