Discussion Note: Making Sense of Understanding*

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J.D. Trout (2002) presents a challenge to all theorists of scientific explanation who appeal to the notion of understanding. Trout denounces understanding as irrelevant, if not dangerous, from an epistemic perspective and he endorses a radically objectivist view of explanation instead. In this note I accept Trout's challenge. I criticize his argument and defend a non-objectivist, pragmatic conception of understanding that is epistemically relevant.

1. Introduction. In his paper "Scientific Explanation and the Sense of Understanding," J.D. Trout (2002) launches a vigorous attack on conceptions of explanation that (implicitly or explicitly) assume that good explanations produce a feeling of understanding. He claims that the sense of understanding is "just a kind of confidence, abetted by hindsight, of intellectual satisfaction that the question has been adequately answered" (213). According to Trout, such a feeling of understanding is a dangerous and misleading phenomenon that should not be allowed to play a role in the evaluation of explanations, for it is nothing else than an unjustified illusion. His main argument against the epistemic import of the sense of understanding is based on evidence from experimental psychology, in particular concerning two well-known cognitive biases: the hindsight bias and the overconfidence bias (see below). Trout's own view of explanation is objectivist and "virtually unique in its utter disregard for the role of the subjective sense of understanding as determinant of explanatory goodness" (229).

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In this discussion note I will criticize Trout's position and argue, in opposition to it, that understanding is important from an epistemic point of view. To be sure, I agree with Trout that a purely subjective 'feels right' sense of understanding is irrelevant to science and may indeed be misleading in some situations. But this does not exhaust the possible meanings of 'sense of understanding,' and I will defend the epistemic significance of a pragmatic sense of understanding that is neither objective nor completely subjective.

2. Trout's Argument. The sense of understanding that Trout criticizes is defined by him as the subjective experience that a good explanation "feels right" (212). After quoting statements by scientists from various periods in history to the effect that they experienced such a sense of understanding (Galen, Ptolemy, Kekulé, Darwin, Avogadro, Perrin), Trout observes that the subjective sense of understanding "may be conveyed by a psychological impression that the explanatory mechanisms are transparent and coherent, or that the explanation seems plausible, and so should be confidently accepted" (214).

However, says Trout, such a subjective feeling is neither a necessary nor a sufficient condition for a good explanation. Moreover, it is not a reliable indicator of the truth of a theory or explanation. Indeed, in many of the cases cited, the scientists who relied on the feeling of being right were dead wrong. Instead of being the direct result of our knowledge of true theories or explanations, the sense of understanding is a product of two well-known biases in cognitive psychology (223). The first of these, the hindsight bias, is the effect, demonstrated in many psychological experiments, that people systematically overestimate their predictive power in after-the-fact contexts: they remember their earlier predictions as having been more accurate than they actually were (the 'I-knew-it-all-along' effect). This bias is operative in explanatory accounts: with hindsight, one often has the mistaken feeling of understanding precisely why a particular event occurred (225–226). The second effect that results in counterfeit understanding is the overconfidence bias: people are "systematically prone to believing that they are right when they are not" (226). This effect also applies in the case of answers to explanatory why-questions: any subject—layperson or scientist—will experience biased (unjustified) feelings of understanding when giving an explanatory account to answer a why-question.

Trout accuses many—if not all—philosophical theories of explanation of making the mistake of relating explanatory virtue to a subjective sense of understanding. Even as seemingly uncompromising an objectivist as Hempel could not resist the temptation to give an account of how deductive-nomological explanations produce a feeling of understanding (namely, by showing us that the explained event was to be expected). By

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contrast, Trout prefers a thoroughly objectivist view, in which understanding has no epistemic function and explanations require only accurate theories. The sense of understanding does not do any epistemic work at all—so we had better produce accurate theories without bothering about understanding: "when it comes to explanation, there is no substitute for simply being (approximately) right" (230). Unfortunately, Trout remains silent about what precisely such an objectivist account of explanation would have to look like.

3. The Pragmatic Sense of Understanding. Although Trout admits that there are many senses of 'understanding' (222), he distinguishes only two: on the one hand, an objectivist conception according to which we have understanding of a phenomenon if we know all relevant laws, principles, and background conditions; on the other hand, a subjectivist conception according to which this knowledge must be accompanied by a particular subjective state or feeling. (According to Trout our knowledge must have "the phenomenology of understanding" (222).) However, both conceptions are inadequate as accounts of scientific understanding. The objectivist conception, endorsed by Trout, provides a necessary but not a sufficient condition for understanding and accordingly is too weak, or so I will argue below.[1] The extremely subjectivist conception of understanding, rightly rejected by Trout, is too narrow—in fact, it is a straw man position. Trout's criticism of this conception does not establish that understanding in any sense other than the objectivist one is useless or dangerous from an epistemic point of view.

In Trout's objectivist view of understanding, one understands a phenomenon (e.g., why jets fly, Trout's example) if one possesses all relevant knowledge (Bernoulli's principle and background conditions). But clearly this requirement is too weak. In addition, one should at least be able to use this knowledge to deduce a prediction (explanation) of the occurrence of the phenomenon. Thus, a student may have memorized Bernoulli's principle and have all background conditions available but may still be unable to use this knowledge to account for the fact that jets can fly—in that case we would not say he understands. And the proverbial bushman, seeing a flying jet for the first time in his life, may have the same knowledge available without having the faintest understanding of the observed phenomenon—we might want to say that he has less understanding than the student.

1. Trout's objectivist conception resembles Hempel's covering law model of explanation. Hempel started a debate about explanation, to which I cannot do full justice in this short note. My aim is only to argue that there is more to scientific understanding than Trout assumes; see De Regt and Dieks 2004 for an elaborate analysis of the relation between understanding and explanation.

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Wittgenstein's discussion of understanding a mathematical series nicely illustrates this point. Wittgenstein (1953, Sections 151–155) considers a situation in which somebody (A) writes down a series of numbers: 1, 5, 11, 19, 29, while someone else (B) watches and tries to figure out how the sequence should be continued. Wittgenstein: "If he succeeds he exclaims: 'Now I can go on!' —So this capacity, this understanding, is something that makes its appearance in a moment" (1953, Section 151). But what is it that appears so suddenly? In this case there are several possibilities: perhaps B has found the formula $a_n = n^2 + n - 1$, or he has not tried to find a formula but has asked himself what the series of differences between succeeding numbers is (4,6,8,10 and so on), or B simply says 'I know *that* series' and continues it.

> But are the processes which I have described here *understanding*? 'B understands the principle of the series' surely doesn't mean simply: the formula '$a_n = \ldots$' occurs to B. For it is perfectly imaginable that the formula occurs to him and that he should nevertheless not understand. 'He understands' must have more in it than: the formula occurs to him. And equally, more than any of those more or less characteristic *accompaniments* or manifestations of understanding. (Wittgenstein 1953, Section 152)

Understanding involves more than mere knowledge of the relevant formula (or in the scientific case: theories, laws, and background conditions), but this 'more' should not be sought in any of the subjective experiences that may accompany the appearance of understanding. Wittgenstein (1953, Section 154): "If there has to be anything 'behind the utterance of the formula' it is *particular circumstances,* which justify me in saying that I can go on—when the formula occurs to me." Understanding is not only knowing the formula, but in addition *being able to use* the formula in the case at hand.

In Trout's discussion of understanding why jets fly, this ability to use the available knowledge in an appropriate manner is missing. In his objectivist view, it is only the logical relations between the pieces of information at hand that count. But if this information is to provide understanding, a subject is involved as well (indeed, Trout introduces himself as the subject: "I understand why jets fly" (222)) and this implies that not only knowledge of principles and background conditions but also particular skills of the subject are involved in the process of achieving understanding. This introduces an element that is *pragmatic,* because it concerns "the use and usefulness of the theory" (van Fraassen 1980, 88) and "requires reference to the persons involved in the process of explaining" (Hempel 1965, 425). The pragmatic element allows for the possibility that two people may disagree about whether a phenomenon is understood, while they both

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possess the same theoretical and background knowledge. The disagreement results from contextual differences: the "circumstances" (Wittgenstein) may differ for different persons. Accordingly, this pragmatic aspect implies that understanding is not completely objective, i.e. not independent of the subject.

Both Hempel and van Fraassen hold that pragmatic aspects are epistemically irrelevant[2]—and although Trout does not use the term 'pragmatic,' he would no doubt agree. Hempel ascribes epistemic weight to scientific explanations and demands that they do not contain pragmatic aspects, while van Fraassen regards explanation itself as pragmatic and denies it epistemic value. Indeed, van Fraassen (1980, 4) explicitly contrasts an epistemic and a pragmatic dimension of science.[3] However, this view wrongly presupposes that the epistemic status of a theory depends only on a direct evidential relation between it and the phenomena it purports to describe or explain. It assumes that one can directly deduce empirical consequences from a theory or, conversely, determine the evidential support that a theory gains from empirical data. On this presupposition, the pragmatic virtues of a theory are epistemically irrelevant: they do not carry any additional justificatory weight. But this presupposition is not a priori true and turns out to be de facto false in scientific practice: the usual situation is that one cannot generate successful empirical predictions from abstract theories by a simple deductive procedure. (If one tries to do so, the theory will typically be falsified: e.g., Newton's law of inertia.) Instead, describing, predicting and explaining empirical reality by means of theories is a complex process involving additional work.

Cartwright (1983) has provided ample illustration of this. In support of her claim that the actual content of our scientific knowledge does not lie in fundamental laws and theories but in phenomenological laws, she has analyzed many examples of how explanations are constructed in actual scientific practice. She observes that theories are never true descriptions of real phenomena; they are true only of models, which fail to correspond exactly to reality (Cartwright 1983, 58–59). Relating a model to a real system is not a matter of deduction but of approximation. Formal principles telling us how to get from a theory via a model to a description of a real system, do not exist: "There are just rules of thumb, good sense, and, ultimately, the requirement that the equation we end up with must do the

2. Epistemic relevance can be defined as follows: X is (positively) epistemically relevant if it is truth-conducive, that is, if it promotes the attainment of true knowledge. N.B.: 'true knowledge' should not be interpreted narrowly, as 'true theories' (otherwise van Fraassen would dissent), but broadly, as 'true knowledge of any kind.'

3. So does McMullin (1983, 18), although he admits that "the borderline between the epistemic and the pragmatic may be hard to draw."

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job'' (133). What is more, a theory may produce different incompatible models for different purposes (158). In this non-deductive process, pragmatic decisions are unavoidable. Consequently, the epistemic value of a theory cannot be determined in isolation from its use; pragmatic aspects are epistemically relevant.[4]

In this pragmatic dimension two elements play a crucial role: whether scientists are able to use a theory for explaining a phenomenon depends both on their skills and on the virtues of the theory. More precisely, it depends on whether *the right combination* of scientists' skills and theoretical virtues is realized. Particular virtues of theories, e.g., visualizability or simplicity, may be valued by scientists because they facilitate the use of the theory in constructing models and predicting or explaining phenomena; in this sense they are pragmatic virtues. But not all scientists value the same qualities: their preferences are related to their skills, acquired by training and experience, and to other contextual factors such as their background knowledge, metaphysical commitments, and the properties of already entrenched theories.

I define the *intelligibility* of a theory as the positive value that scientists attribute to the cluster of theoretical virtues that help them in their use of the theory. Accordingly, intelligibility is not an intrinsic property of a theory, but it is a value that is projected onto the theory by scientists (cf. McAllister 1996, 31–33, who defends projectivism for the analogous case of ascribing beauty to scientific theories). Intelligibility is a context-dependent value related to properties of the theory but also to scientists' skills (in the next section I will give a more specific characterization of intelligibility). The arguments presented so far suggest that scientists need intelligible theories in order to achieve scientific understanding of phenomena. In other words, understanding scientific theories is a prerequisite for understanding phenomena scientifically.

Hence, there exists an epistemically relevant, pragmatic sense of understanding which, while it is not purely objective, should also not be equated with the subjective, highly individual 'feels right' experience that Trout criticizes.[5] The latter sense of understanding is a straw man: nobody

4. Even if one does not accept Cartwright's radical conclusion that there is *no* truth *at all* in abstract theories and that scientific knowledge is embodied *only* in phenomenological laws, her analysis convincingly shows that scientific truth is not exclusively contained in theories, and that pragmatic virtues of theories can therefore be truth-conducive.

5. One of Trout's challenging objections to the subjective sense of understanding is that ''the understanding conveyed by a good explanation may be a community achievement [instead of] an achievement of an individual'' (230). But the conception of understanding defended here is not prone to this criticism because the acquisition of required skills, attuned to preferred theoretical virtues, is typically associated with scientific communities rather than individuals (cf. Kuhn's analysis of the role of skills in scientific practice, see Rouse 2003).

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would want to maintain that such a feeling is either necessary or sufficient for anything that deserves to be called scientific understanding. Obviously, successful scientists are acquainted with the *Aha-Erlebnis* or *Eureka* experience, and these feelings may be a source of motivation and therefore important to their work, but surely they are neither an aim of science nor a condition for scientific understanding. Against the feel-good interpretation of understanding, Trout argues that understanding "is usually the consequence of a learning process" (222) and that learning is often implicit. Consequently, the achievement of understanding does not have to go together with an explicit feeling (awareness). While this objection holds for the feel-good interpretation, it does not apply to the pragmatic conception of understanding, since the skills required for understanding are usually implicit as well (indeed, skills are archetypes of tacit knowledge).

In my construal of scientific understanding, the two cognitive biases that Trout discusses turn out to be irrelevant. Scientific understanding is not related to subjective feelings but to the skills of scientists and the pragmatic virtues of theories. Both the hindsight bias and the overconfidence bias are at work in situations in which people have to assess their own cognitive powers and beliefs. The pragmatic sense of understanding, however, does not involve such an assessment or any other kind of subjective feeling. These biases clearly provide a useful warning against relying on a purely subjective 'feels right' sense of understanding but, as I have argued in this section, this does not exhaust the possible non-objectivist senses of understanding.

4. Intelligibility and Theoretical Virtues. In Trout's account of explanatory understanding, a good explanation requires nothing more and nothing less than an accurate theory: accuracy is the only criterion for explanatory power (cf. the jet example cited above). According to Trout (223), "there is no explanatory substitute for an accurate model, or a good theory." Other theoretical virtues are irrelevant, for example those that may contribute to the intelligibility of the theory or explanation: "an explanation that is accurate—no matter how nontransparent its components—is better than an inaccurate one that merely makes us feel that we understand" (230). Contrary to Trout, I believe there are good reasons to doubt that accuracy is, or should be, the only guide in explanatory affairs: there is a role for intelligibility as well.

Of course nobody would want to deny that accuracy is a very important requirement for scientific theories and explanations, but it appears to be one among a variety of qualities valued by scientists. Philosophers of science have listed and discussed additional virtues that generally play a role in the evaluation of scientific theories; for example, consistency, scope, simplicity,

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unifying power, and fruitfulness (see Kuhn 1977, 321; McMullin 1983, 15–16; Longino 1990, 77).[6] It should be emphasized that these lists do not merely reflect the musings of philosophers in ivory towers but are supported by historical study. Many case studies have revealed that, in evaluations of theories, scientists employ other criteria than accuracy alone, and that there is sometimes a trade-off between accuracy and other virtues, which is not necessarily irrational.[7] In addition to the general virtues cited above, scientists in various fields and historical periods have promoted other, more specific theoretical qualities; for example, visualizability, causality, continuity, and locality (see De Regt 2001 for examples from modern physics). One important function of such virtues is that they may enhance the intelligibility of the theory for the scientists in question.

Scientists prefer a more intelligible theory over a less intelligible one, sometimes even at the cost of some accuracy, not because it gives them a 'feels right' sense of understanding but rather because they have to be able to use the theory. For example, around 1926 Schrödinger's wave mechanics was far more popular in the general physics community than matrix mechanics, because it was visualizable and mathematically less intricate. As Beller (1999, 36) tells us, it "was successfully applied to a great variety of problems unamenable to matrix treatment." For mainstream physicists of the 1920s, wave mechanics was more intelligible than matrix mechanics. Its theoretical virtues, especially visualizability and mathematical simplicity, contributed to a pragmatic sense of understanding, as defined in Section 3, and accordingly these virtues are not epistemically irrelevant. Consequently, Trout's thesis that "the only feature of an explanation that can render explanation epistemic is its systematic tendency to produce increasingly accurate theories" (230), should be rejected.

Intelligibility, as argued above, is a value that scientists project onto a theory. Which theories are deemed intelligible depends on contextual factors, such as scientists' skills, and can accordingly vary through time or across disciplines. Is it nevertheless possible to formulate a general test or criterion for the intelligibility of theories? The following analogy provides a suggestion. Consider a hypothetical oracle whose pronouncements always prove correct. Although empirical accuracy is guaranteed, one would not speak of scientific knowledge in this case, because there is no insight into

6. These values are called 'epistemic' by McMullin (1983, 18), because "they are presumed to promote the truth-like character of science," and 'constitutive' by Longino (1990, 4), because they are "generated from an understanding of the goal of science."

7. The production of accurate theories is more often stimulated than hindered by reliance on other (allegedly non-epistemic) theoretical virtues. For example, McAllister (1996) argues, on the basis of historical evidence, that scientists usually rely on established aesthetic canons (containing accepted aesthetic criteria for theory choice) and that this conservatism is conducive to empirical progress.

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how these perfect predictions were brought about. An oracle is a 'black box' that produces seemingly arbitrary predictions. In order to obtain insight we need to open the black box. In the case of science the predictions are generated by a theory, and, on pain of infinite regress, this theory should not be merely a new black box. In contrast to an oracle, a scientific theory should be intelligible: we want to be able to grasp how the predictions come about and what the consequences of the theory are in particular situations.

This demand can be reformulated as a criterion (or test) for intelligibility: a scientific theory is intelligible for scientists (in a particular context) if they can qualitatively recognize characteristic consequences of the theory, i.e., without performing exact calculations.[8] The pragmatic and contextual nature of intelligibility is captured by this criterion: it can accommodate the variety of ways in which understanding is achieved in scientific practice. Qualitative insight into the consequences of a theory can be gained in many ways and therefore the criterion does not favor one particular skill or theoretical virtue. Its fulfillment requires an appropriate *combination* of skills and virtues. The preferred theoretical virtues, to which skills have to be attuned, function as 'tools' for achieving understanding. (N.B., this is only a sketch of a proposed theory of scientific understanding; in De Regt and Dieks 2004, a detailed account is presented and illustrated with concrete examples.)

5. Truth and Understanding. Trout is an uncompromising realist. It therefore comes as no surprise that he assumes a strong connection between accuracy and truth (see, for example, 212, 217, 227). In accordance with his realist stance, Trout favors a "realist account of explanation" (229, 231). He holds that explanations must be based on (approximately) true theories and that, conversely, explanatory power is indicative of the truth of a theory. However, the problem is that he does not tell us in what sense explanatory power differs from accuracy. Trout asserts that

> the only feature of an explanation that can render explanation epistemic is its systematic tendency to produce increasingly accurate theories. In effect, only explanations capable of sustaining theoretical progress are good explanations. Such explanations are usually approximately true, rather than merely better than the available alternatives, as the latter may simply be the best of a rotten lot. (230)

As Lipton (1991, 61–64) has convincingly argued, such a claim is trivial and even begs the question, if we do not give an independent meaning to

8. This criterion is inspired by a remark made by Heisenberg with regard to understanding in physics; see De Regt and Dieks 2004.

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explanatory goodness apart from descriptive accuracy or likeliness. According to Lipton, we should not infer to the likeliest explanation, but to the 'loveliest' one, where the latter is the one that "provides the deepest understanding" (63). The preferable theory is not the one most likely to be true, but the one that is most satisfactory in terms of explanation. Here one may invoke some of the additional virtues discussed above. Trout, however, does not acknowledge this; for him only truth counts: "unity and consistency with background knowledge is a poor substitute for accuracy and truth, as the litany of false but unifying and consistent theories in the history of science should warn" (217).

Trout distinguishes between "counterfeit understanding" and "genuine understanding" (212, abstract), where the latter is produced by a true or accurate explanation while the former is due to a false one. He cites some historical examples in order to show "that sense of understanding is not produced by a reliable relation between belief and truth" (223). Many scientists, Trout suggests, were plainly wrong and yet they experienced a 'sense of understanding' when they acquired their false beliefs. I have three objections to his argumentation. First, the relevant question is not whether these scientists were wrong but whether they were irrational. Of course, we know that Ptolemy was wrong, but was he irrational when on the basis of the evidence he had at his disposal he inferred that the earth lies at the center of the universe? Was the sense of understanding he felt when considering this thesis (or the lack of understanding he felt for alternatives) misleading or irrational? This should not be concluded from that fact that his theory is known to be false today. It seems that Trout's complaint against Ptolemy's statement expressing 'feels right' understanding is directed mainly at its flavor of infallibility and not at the sense of understanding itself.

Second, false theories can also provide explanations. Even the objectivist Hempel (1965, 338) and the realist Lipton (1991, 59–61) readily admit that false theories may have explanatory power as well; they may produce what Hempel has dubbed 'potential explanations.' Notable examples are the explanations furnished by phlogiston theory or by Newtonian mechanics. Today we can still explain phenomena with these false theories and rightfully experience a sense of understanding. If Trout wants to abandon the sense of understanding because it does not warrant truth claims, he should throw out explanatory power as well. What is more, on the basis of the pessimistic induction from the history of science, we have to acknowledge that our current theories are most likely false, and, if we adopt Trout's position, concede that we do not have any explanations at all. If this misinterprets his argument, it is because his lack of clarity regarding what his theory of truth is (if not correspondence) leaves him open to misinterpretation. As noted above, he conflates truth and accuracy, so perhaps he means that Newton's theory is still (approximately) true in the

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sense of accurate and that it will always remain so. But in that case we return to the argument of the previous section: of course any theory should be true in the sense that it describes the phenomena in its domain to a desired degree of accuracy but accuracy is not the only theoretical virtue, and it can be traded off against other virtues, for example those that may enhance a theory's intelligibility.

Third, it is even possible to coherently reject scientific realism and yet believe that science provides explanatory understanding. Indeed, such a view is held not only by philosophers but also by scientists (albeit a minority). An example is Erwin Schrödinger, who adopted a Machian anti-realist position with respect to the epistemic status of scientific theories. Schrödinger did not accept Mach's views on scientific explanation, however. On the contrary, he firmly believed that science can provide understanding in addition to mere description and he argued that this aim can only be achieved with theories that are visualizable (*anschaulich*). Thus, Schrödinger held that we may accept a theory because of its *Anschaulichkeit* without necessarily believing it to be a true representation of reality (see De Regt 1997). Schrödinger's view is similar to that of van Fraassen (1980, 19–23), who argues that we can admit that a theory is the best explanation for the observed phenomena, without having to believe that it is a description of reality.

6. Conclusion. In this note I have argued, in opposition to Trout (2002), that there is a non-objectivist sense of understanding that has epistemic import. In this pragmatic conception, understanding goes beyond merely having an accurate theory: it requires that this theory is intelligible to the scientists who use it. Scientists need intelligible theories because they have to be able to use theories in order to construct models and explanations. Intelligibility is a context-dependent value that scientists may ascribe to a theory, on the basis of theoretical virtues (e.g., visualizability, simplicity or causality) which harmonize with the skills of the scientists in question. With an intelligible theory, scientists can achieve scientific understanding of phenomena. This is a pragmatic sense of understanding, which differs from the subjective 'feel good' sense of understanding and is not vulnerable to the hindsight and overconfidence biases. Trout rightly emphasizes that an adequate account of explanatory understanding should ''honor the work-a-day details of scientific practice'' (220). However, as I have attempted to argue here, it is precisely the study of the practice of science that shows the epistemic relevance of a pragmatic sense of understanding and casts doubt on the adequacy of the objectivist realist account of explanation that Trout himself favors.

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