**Abstract:** The argument from inductive risk (AIR) is an important challenge to the Value-Free Ideal; yet philosophers disagree over how to define it. We argue that the AIR that best aligns with Rudner's (1953) and Hempel's (1954, 1965) views is the one that describes the risk scientists take in invoking 'facts'. Further, we argue that representational decisions in science necessarily invoke both facts and non-epistemic values and should not be equated with invoking facts; therefore, the AIR should not be applied to representational decisions. Last, we define a 'representational risk', showing how this helps clarify the role of values in science.

**1. Introduction**

The argument from inductive risk (AIR) (Douglas 2000; Rudner 1953) is a significant challenge to the value-free ideal (VFI) for science; many take it to prove the VFI untenable (Elliott 2011; Steel 2015; Winsberg 2018). However, there is disagreement around how to define the concept of inductive risk and, by extension, the AIR (Elliott & Richards 2017). Biddle and Kukla (2017) and Powers (2017) exemplify divergent views on this topic. Biddle and Kukla (2017) define inductive risk as "the risk of wrongly accepting or rejecting a hypothesis on the basis of evidence" (216), elsewhere implying the evidence must be statistical evidence (215). Powers, on the other hand, favors a broad definition of inductive risk: "the risk of engaging in a scientific practice that is incongruous with the fulfillment of some favored set of criteria based upon some favored set of values" (226). Elliott and Richards (2017) question whether inductive risk must involve hypothesis acceptance or rejection and whether the AIR should refer only to consequences of error or to non-epistemic consequences more generally. In this paper, we examine Hempel's (1935a, 1935b, 2000) and Rudner's (1953) conceptions of hypothesis acceptance or rejection and argue that the AIR that best aligns with Rudner's (1953) and Hempel's (1954, 1965) views is the one that describes the risk scientists take in invoking 'facts'. In Section 3, we argue that representational decisions in science necessarily invoke both facts and non-epistemic values and should not be equated with invoking facts; therefore, the AIR should not be applied to representational decisions. In Section 4, we define a distinction between inductive risk and 'representational risk', and show how this helps clarify the role of values in science. Section 5 concludes.

**2. Defining the Argument from Inductive Risk**

In her influential article, Douglas (2000) refers to "Hempel's limited view of inductive risk", suggesting Hempel overlooked its relevance throughout the scientific process (563). In this section, we challenge this suggestion by examining Hempel's conception of hypothesis acceptance or rejection (Hempel 1935a,1935b, 2000). We further argue that Rudner (1953) invokes the same conception of hypothesis acceptance or rejection, and that Hempel's (1954, 1965) notion of inductive risk aligns with Rudner's view of why the scientist *qua* scientist makes value judgments. Finally, we defend a definition of the AIR that is consistent with Rudner and Hempel's views.

In Hempel's (1935a), he reviews Carnap's early conception of protocol statements ("the result of pure immediate experience without any theoretical addition") and distinction between empirical laws ("general implicative statements") and singular statements (e.g., "Here is now a temperature of 20 degrees centigrade") (51-52). On this view, general statements are tested by their singular consequences, i.e., by unique experimental or experiential results. However, because singular consequences are infinite, general statements can never be fully verified, only more or less supported. This prompts Hempel to conclude that all general statements have the character of a hypothesis (1935a, 52). He then recalls Carnap's own conclusion that singular statements have the same character: singular statements can only be more or less confirmed, and there is no clear minimum degree of confirmation for a singular statement to be adopted; thus, the adoption or rejection of a singular statement depends upon a decision (1935a, 58). Turning to interpret Carnap's and Neurath's more recent ideas, Hempel comments: "*Even the protocol statements are revealed to be hypotheses* in relation to other statements of the whole system; and so a protocol statement, like every other statement, is at the end *adopted or rejected by a decision*" (58, italics ours). This implies that *all* empirical statements have the character of a hypothesis. The same view is evident in Hempel's (1935b, 96) and 1937 essay "The Problem of Truth"(Hempel 2000, 52). Thus, for Hempel, to accept or reject a hypothesis is to decide to adopt any empirical statement.

In Rudner's (1953), he begins by giving paradigmatic examples of hypothesis acceptance or rejection decisions following formal statistical testing, decisions about drug safety and belt-buckle quality, whose consequences differ in seriousness. Rudner's initial discussion is effective in communicating three points. First, one can be wrong in accepting or rejecting a hypothesis, which Rudner refers to as a mistake. Second, mistakes differ in their consequences. Third, because consequences differ in seriousness, hypothesis acceptance or rejection invokesa value judgment. That is, scientists make value judgments because they must assess, in an ethical sense, the seriousness of a mistake (Rudner 1953, 2). Importantly, Rudner does not argue that scientists make value judgments only when the ethical consequences of a mistake are serious. Indeed, such an argument would fail, since to determine in the first place whether consequences are serious (i.e., to distinguish between the ethical significance of drug safety versus belt-buckle quality) requires making a value judgment. Thus, Rudner's point is that hypothesis acceptance or rejection *always* invokesa value judgment, that the "scientific method *intrinsically* requires the making of value decisions" (Rudner 1953, 6, italics in the original). While Rudner uses paradigmatic examples from statistical testing to make this point clear, we argue that he does not intend to limit its importance to this context. This is suggested by his move to connect his comments to the then-recent discussion between Carnap and Quine. Rudner's interpretation of Carnap's "external" questions, practical questions around what language structures to employ, is that they are "value questions", while his interpretation of Quine's argument is that Carnap's external questions cannot be viewed as extra-scientific (Rudner 1953, 5). Rudner concludes that a consequence of Quine's position is that scientists *qua* scientists make value judgments (Rudner 1953, 6). That Rudner sees the broad significance of Quine's argument is evident in his assertion that "objectivity for science lies at least in *becoming precise* about what value judgments are being and might have been made in a given inquiry" (Rudner 1953, 6, italics ours). If Rudner meant scientists make value judgments only at the end of a formal hypothesis test or empirical study, we argue, this call to become precise would make less sense. Instead, we interpret Rudner's understanding of hypothesis acceptance or rejection to align with Hempel's, as to apply to the acceptance of empirical statements more generally.

In introducing the term inductive risk in his (1954), Hempel uses the example of attributing the disposition 'solubility-in-water' to a lump of sugar that is not actually put in water. He remarks that to do so "is to make a generalization, and this involves an inductive risk" (14). He signals that inductive risk occurs throughout the scientific process, as he stresses that if we were to reject any procedure that involves inductive risk we would be prohibited from using dispositional concepts (14-15). That this is problematic is implied, as Hempel's remarks serve to inform his critique of operationalism. In revisiting the concept of inductive risk in his (1965), Hempel notes that any empirical law is accepted on the basis of incomplete evidence, though "[such] an acceptance carries with it the 'inductive risk' that the presumptive law does not hold in full generality" (92). While his ensuing discussion of statistical testing might suggest that his remarks on values apply only to hypothesis acceptance or rejection in that context, we do not interpret them so narrowly. Rather, we argue that Hempel, like Rudner, uses examples from statistical testing because they are salient and rhetorically effective, though his comments are more far-reaching. Hempel confirms as much in his (1981), in which he discusses the debate between Rudner (1953) and Jeffrey (1956). To a list of difficulties facing Jeffrey's argument Hempel adds:

Even if the scientist limits himself to determining probabilities for hypotheses, he must perform tests to obtain the evidence on the basis of which to calculate those probabilities. He must, therefore, it seems, *accept certain empirical statements* after all, namely the evidence sentences by which he judges the probability of contemplated hypotheses. (Hempel 1981, 395, italics ours)

Thus, though Hempel in the above uses 'hypotheses' in the limited sense in which Rudner is sometimes presumed to use it (e.g., Biddle & Kukla 2017, 215), he confirms that Rudner's argument extends to the acceptance of empirical statements generally.

In our interpretation of Hempel (1935a, 1935b, 2000), the acceptance of empirical statements does not denote acceptance that those statements are true. Indeed, this would conflict with Hempel's conviction that empirical statements can only ever be confirmed to a degree, and that "it is preferable not to speak of empirical truth or falsity" (Hempel 2000, 44). Instead, we take Hempel's acceptance of empirical statements to denote the invocation of what are ostensibly facts, regardless of the cognitive attitude of the person doing the invoking (Elliott & Willmes 2013). Of course, this interpretation hinges on an ability to distinguish between facts and values. We argue that allowing this distinction adds clarity to current discussions of inductive risk, as on the traditional picture only facts can be 'wrong' or subject to 'error', etc.

This brings us to consider what conception of inductive risk is most consistent with Hempel and Rudner's views, and whether this conception has any advantages and/or disadvantages. On our reading, this conception denotes the possibility of invoking a fact that is not true.[[1]](#footnote-1) The AIR that follows is to this effect:

1) Scientists invoke 'facts', though they may not be true

2) Invoking 'facts' that are not true can have consequences

3) Consequences differ in seriousness

4) To assess the seriousness of consequences is to make a value judgment

5) Scientists make value judgments

From one angle, this is a narrow conception of the AIR, as it defines a specific hazard (invoking facts) and links it to a specific hazardous event (invoking facts that are not true) that can have further undesired, yet unspecified consequences. The advantage of this conception is that it targets the very decisions that proponents of the VFI claim should be value-free, i.e., decisions about what is a fact. Furthermore, it encourages distinguishing between invoking facts (i.e., invoking values 'indirectly') and invoking facts and values (i.e., invoking values directly and indirectly), as we will discuss in Section 3.

From another angle, this is a broad conception of the AIR, as it applies to the invocation of facts without conditions, e.g., that the invocation be based on statistical evidence rather than another type of evidence (e.g., Biddle & Kukla 2017, 215) or that its implications be predictable (e.g., Andreasen & Doty 2017, 132) or for practical action (e.g., Steel 2015, 82). As we have established, Rudner's claim is that acceptance decisions *always* depend on a value judgment, as one is intrinsically involved in assessing the implications of the decision. If such a decision has no predictable, practical implications, the non-epistemic evaluation of this state of affairs may increase the chance of acceptance, but the state of affairs itself will not eliminate the inductive risk. There is an advantage to preserving this insight, as if it is clear that inductive risk is always present in invoking facts, it is clear that the role of values in science is constant.

If there is a disadvantage to this conception of the AIR it is that it does not highlight the possibility that scientists' direct invocation of non-epistemic values will, in and of itself, have undesired consequences. Yet, we argue, the AIR cannot do this and stay focused on its target. We will return to this in Section 4.

**3. Representational Decisions and the Argument from Inductive Risk**

In this section, we argue in favour of distinguishing 'representational decisions' in science. Representational decisions, as we define them, occur during an active process of building a scientific representation, directly inform that representation, and determine in what way the representation will assist reasoning.[[2]](#footnote-2) We will argue that such decisions necessarily invoke facts and non-epistemic values, and should not be equated with invoking facts alone. Therefore, the AIR should not be applied to representational decisions. To be clear, our argument presupposes a difference between the following types of statements:

1) It is raining in California

2) It is raining in California and that is good for the people

We argue that to apply the AIR to a compound sentence such as 2 results in conflating facts and values in their most easily distinguishable forms, asserting that a statement such as 'that is good for the people' can be epistemically incorrect and ignoring that it directly invokes non-epistemic values.

Insofar as it is useful, we will distinguish between two types of representational decisions. Decisions about 'what to represent' pertain to what to include in and exclude from a representation. Decisions about 'how to represent' pertain to entities already chosen for inclusion in the representation. According to this distinction, where Douglas (2000) refers to the 'gathering' of data she is referring to decisions about what to represent; where she refers to the 'characterization' of data she is referring to decisions about how to represent. Examples of 'what to represent' decisions are deciding to include rats rather than another animal in a dioxin study, to include data following dioxin exposure for "two years, close to a natural life-span" (Douglas 2000, 569) rather than another period of time, and to include 89 control rats and 150 experimental rats rather than another number. An example of a 'how to represent' decision is to characterize rat tissue slides categorically ('no tumor', 'benign tumor', 'malignant tumor') rather than on a continuous scale (e.g., perceived pathology of changes, 0-10).

In our view, the observation that scientific studies are influenced by their goals and priorities (Elliott & McKaughan 2009; Elliott & McKaughan 2014; Parker & Winsberg 2018) can be concretized in terms of representational decisions, beginning with decisions about what to represent. For example, in the study discussed by Douglas (2000), the aim was to evaluate outcomes in rats following dioxin exposure, but, more specifically, to extrapolate results to humans and inform regulatory decisions (567). Therefore, the decision to include rats would not only invoke facts about rat and human physiology, but also the study aim (i.e., to generalize results from rats to humans, *not* to understand the effect of dioxin on fish). The decision to include data from two years of dioxin exposure would not only invoke facts about the chemical but also study priorities (i.e., to standardize dioxin exposure periods, *not* to study the effect of dioxin on the natural lifespan). The decision of how many rats to include would take a sample size calculation, which would invoke facts about effect sizes but also require specifying the effect *of interest* and the desired power to detect a difference. Decisions about what to represent are, therefore, directly informed by research goals and priorities; in other words, they invoke the same non-epistemic values that uncontroversially drive the research question. As Elliott and McKaughan (2009) have observed, this influence of non-epistemic values on representational decisions has not generally been denied, but rather labeled "epistemically uninteresting" (598).

A possible objection is that some decisions about what to represent are only indirectly related to the research topic and are themselves informed only by epistemic values. For example, one might describe a representation whose aim is to help reason about the effect of coffee on cancer risk. It is well-known that a confounder of this relationship is smoking, so, it might be argued, the choice to include (i.e., control for) smoking is driven purely by epistemic values, e.g., precision. However, we argue, the choice to include smoking still requires invoking the research question and the non-epistemic values that drive it: to include smoking, scientists must know that the aim of the representation is *not* to help reason about the effect of coffee on cancer risk among non-smokers. Still, one might object, there are cases where including or excluding a specific entity from a representation is patently epistemically illegitimate, e.g., excluding gravity from a model of the Earth's climate, because it results in a misrepresentation of the system. In these cases, one might argue, the choice of what to represent is driven purely by epistemic values. However, we contend this is not obvious, as misrepresentations can be regarded as epistemically useful and therefore legitimate. For example, Juhn (2018) describes the stages of a Carnot cycle as "all physically absurd and scarcely predictive of any behavior we might ever witness", yet remarks that the purpose of undertaking this "bit of unrealistic reasoning" is because it yields empirical information relevant to thermodynamics (274). Presumably, if scientists could gain useful information from a representation of Earth's climate in the absence of gravity, then excluding gravity would be legitimate. Thus, the only way to determine whether the inclusion or exclusion of an entity in a scientific representation is epistemically legitimate is to appeal to the research question.

Furthermore, all decisions about what to represent require judging that there are no ethical reasons to *exclude* the entity. For example, a dioxin study that includes rats requires judging that there are no ethical reasons to exclude rats, as there may be to exclude other animals. A model of the association between coffee and cancer that controls for smoking requires judging that there are no ethical reasons to exclude smoking, as there may be to exclude other variables.[[3]](#footnote-3) A possible objection is that in some scientific contexts (e.g., representations of thermodynamic systems) there is no imaginable ethical reason to exclude any entity under consideration and therefore it is unnecessary to make a non-epistemic value judgment of this sort. Yet this argument fails because to judge that there is no imaginable ethical reason is to survey the imaginable reasons and decide that none has ethical significance.

This brings us to consider decisions about how to represent entities chosen for inclusion in scientific representations. This is a vast and heterogeneous group of decisions that includes those under 'data characterization' (e.g., how to aggregate data), as well as many others, such as how to quantify parameters in simulation models. While Douglas (2000) argues that it is possible to make "a wrong (i.e., epistemically incorrect) choice" (565) at the stage of data characterization, her conception of 'incorrect' appears to depend on the observation that such choices can fail to capture consequences of interest or capture too many consequences that are unimportant. We argue that it is not possible to define an 'incorrect' way to represent something without appealing to the phenomenon of interest and the aspect of reasoning that the representation aims to assist. Therefore, all 'how to represent' decisions invoke the same non-epistemic values that drive the research question.

To see this, it is useful to consider Winsberg's (2018) example of quantifying parameters in a model of skydiver behavior (48). Winsberg compares the two parameters 'acceleration of gravity' and 'terminal velocity', noting that the former comes with a single approximate value (9.8 m/s2),whereas the latter depends on numerous factors and cannot be quantified so straightforwardly. Winsberg argues that it is not preferable to speak of the 'correct' value for a parameter like terminal velocity, but rather the 'best' value for it, in the sense of "relativized adequacy for purpose" (2018, 48). This is itself a vivid example of a 'how to represent' decision that cannot be informed by facts alone, but necessarily invokes the non-epistemic values that undergird the model. Yet, we argue, and nowhere does Winsberg deny, even quantifying the acceleration of gravity invokes the same non-epistemic values. After all, to choose the value 9.8 m/s2 takes knowing that the purpose of the model is *not* to assist reasoning about the consequences of a change to acceleration of gravity. If this were the model's purpose, then it would be legitimate to give the parameter a different value. A possible objection is that it is epistemically illegitimate to build a model to help reason about changes to immutable features of the Earth. But since there is no definitive proof of which of Earth's features are immutable, we would reply that this not 'epistemically' illegitimate- just a potential waste of time and money.

A type of 'how to represent' decision that we have not addressed concerns what language to use to label entities in scientific representations (e.g., 'rats with malignant tumors', 'rats with cancer', 'rats with Devil Tissue'). It seems intuitive that such labels have straightforward ethical significance, as discussed by Elliott (2009) and Powers (2017). They are no exception to our observation that 'how to represent' decisions invoke non-epistemic values.

**4. Representational Risk**

Recently, several authors have described representational decisions in science as sites of inductive risk (see Elliott & Richards, 2017). We have argued that to apply the AIR to these decisions is to equate them with invoking facts, to extend the AIR to decisions that directly invoke non-epistemic values to undermine its marksmanship. However, AIR theorists have established that representational decisions can have numerous undesired consequences, both epistemic and non-epistemic, which warrants further discussion. To continue this discussion with greater clarity, we propose to distinguish representational decisions from other scientific decisions, including the 'ultimate' decisions that scientists make using a completed representation to assist their reasoning. We argue that this distinction proves useful, as the risk involved in representational decisions is a complex one. To illustrate our position, we will use the bow-tie model of risk (Figure 1), which encourages understanding risk in terms of a hazard, a hazardous event, and its consequences (Rausand 2011, 6).

Inductive risk is usefully conceptualized as comprising one hazard (invoking facts) and one hazardous event (invoking facts that are not true), which can have further undesired consequences (Figure 2). Because ultimate scientific decisions ('is dioxin carcinogenic?') can be framed as pertaining to a single empirical statement, it is straightforward to apply the concept of inductive risk to them. Yet unlike ultimate decisions, representational decisions directly invoke both facts and non-epistemic values, which means they introduce not one but two possible hazardous events. One of these is invoking facts that are not true; that is, inductive risk contributes to representational risk. However, the other is invoking non-epistemic values that conflict with others, e.g., the values of the representation's wider population of users or people affected by its use. For example, if scientists value knowing about severe changes to rat liver tissue following dioxin exposure, but the public values knowing about moderate changes to any rat tissue, scientists may build a representation that provokes a value-conflict. This hazardous event may have any number of undesired consequences, e.g., gaps in desired knowledge persist longer than necessary, the public trust in science decays, and so on. If one were committed to using only the lens of inductive risk to analyze representational decisions, one might assert that scientists invoke the fact 'the public wants knowledge about severe liver changes' and may err in doing so. Yet, we argue, this portrays the scientific process as one of back-to-back assessments of what is a fact, ignoring that facts can be 'thick'. On the other hand, analyzing representational decisions in terms of a more complex 'representational risk' (Figure 3) communicates that science involves direct non-epistemic value judgments, including decisions about what to represent and how to represent it.

de Melo-Martín and Intemann (2016) have argued that proving the VFI untenable requires meeting the *Necessity*, *Wishful Thinking*, and *Democracy* criteria (502-503). We argue that the construct of representational risk helps develop an account of values in science that satisfies all three. First, establishing that non-epistemic values are required to make representational decisions establishes that these values "cannot be eliminated without a cost to scientific knowledge production" (502). Furthermore, it demonstrates that value judgments in science are not just "unavoidable" (502), but necessary to produce scientific representations that help people reason about their targets in the ways they desire. Non-epistemic values in science are therefore *beneficial*, undermining value-freedom as a purported ideal. Second, establishing that non-epistemic values help prevent representational decisions from having unwanted consequences clarifies why these values do not inevitably drive scientists to wishful thinking. Again, these values help produce representations that will help people reason in the way they desire. If the desired way is to have people reason to a pre-determined conclusion, then non-epistemic values will support representational decisions that do that. However, if the desired way is to have people resist wishful thinking, then non-epistemic values will support representational decisions that do that instead. Third, establishing this direct role for non-epistemic values helps illustrate how scientists can incorporate stakeholder input in a democratic way. What the construct of representational risk helps highlight is that scientific representations must generally leave out some information—representing one thing comes at the expense of another—and that phenomena can be legitimately represented in more than one way, but not more than one way at a time. We argue that focusing on the risks involved in representational decisions can help concretize discussions about scientific goals and priorities, and articulate what trade-offs can be informed through a democratic process.

**5. Conclusion**

Biddle and Kukla (2017) have conceptualized a broad class of epistemic risks, including 'phronetic' risks, of which inductive risk is only one. We have aimed to add two subtleties. One, if our interpretation of Hempel and Rudner is correct and our arguments are persuasive, then inductive risk should be understood as contributing to other epistemic risks, not cleanly demarcated from them; we should expect to be able to disentangle inductive and epistemic risks only to the same extent we are able to disentangle facts and values. Two, most of the phronetic risks that Biddle and Kukla (2017) define, including data formation, model choice, conceptual definition and operationalization (222), have to do with representation, as do Biddle's (2018) 'framing risks' and 'power risks'. We argue that recognizing these all as representational decisions encourages analyzing their similarities as well as their differences, and invites input from philosophers of representation.







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1. In our view, any conception of 'risk' should be consistent with the non-technical understanding of this term, which Hansson (2014) remarks is the possibility of an unwanted event. [↑](#footnote-ref-1)
2. We recall that an essential feature of scientific representations is that they assist surrogative reasoning, permitting users to make inferences about a target (Swoyer 1991). [↑](#footnote-ref-2)
3. For example, we might imagine a model of human intelligence and advance good reasons to exclude race and sex. [↑](#footnote-ref-3)