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Understanding conflicting views of endocrine disruptor experts: a pilot study using argumentation analysis

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ABSTRACT

To what extent do substances have the potential to cause adverse health effects through an endocrine mode of action? This question elicited intense debates between endocrine disrupting substances (EDS) experts. The pervasive nature of the underlying differences of opinion justifies a systematic analysis of the argumentation put forward by the experts involved. Two scientific publications pertaining to EDS science were analyzed using pragma-dialectical argumentation theory (PDAT). PDAT's methodology allowed us to perform a maximally impartial and systematic analysis. Using PDAT, the structure of the argumentation put forward in both publications was reconstructed, main standpoints, and arguments were identified, underlying unexpressed premises were made explicit and major differences in starting points were uncovered. The five differences in starting points identified were subdivided into two categories: interpretative ambiguity about underlying scientific evidence and normative ambiguity about differences in broader norms and values. Accordingly, two differences in starting points were explored further using existing risk and expert role typologies. We emphasize that particularly the settlement of normative ambiguity, through the involvement of broader ethical, social or political values, inherently requires multi-stakeholder approaches. Extrapolation of our findings to the broader discussion on EDS science and further exploration of the roles of EDS experts in policy processes should follow from further research.

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The toxicological and epidemiological research of hazards and risks has proven indispensable in supporting evidence-based decision-making in the environmental health domain. A wide range of regulatory agencies and scientific institutes rely on the principles of this research to derive safe limits for the exposure to all kinds of chemical and physical agents. However, this does not

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mean that experts always agree about the interpretation and evaluation of the available evidence.

There are numerous examples of environmental health risk issues where experts disagree about whether apparent exposure levels can in fact adversely impact public health or the environment. For example, it remains debated whether the available evidence shows that current exposure levels to electromagnetic fields may cause detrimental effects in humans (compare e.g. Sage, Carpenter, and Hardell 2016 and SCENIHR 2015). Expert disagreement about the carcinogenic properties of glyphosate (compare EFSA 2015 and FAO/WHO 2016, and IARC 2017) has made the herbicide's regulatory (re)approval in the EU quite controversial (Science 2016). These are just a few examples where experts differ in their interpretation of scientific evidence surrounding a risk issue.

In this article, we are interested in the differences of opinion occurring between experts in the scientific debate on endocrine disrupting substances (EDS). Beronius et al. (2010) discussed the impact of risk assessment methodologies and expert judgment on the process and outcomes of risk assessments of Bisphenol A. However, the values held by experts that could potentially influence their scientific judgments were not further evaluated. The influence of values and worldviews on the substance of experts' policy advice and the dynamics of scientific discussions in general have been studied extensively (see e.g. Douglas 2000; Elliott 2017; Pielke, 2007; Sarewitz 2004; Spruijt et al. 2014), though we are unaware of studies that specifically identify differences in values at stake in the EDS controversy. Therefore, we aim to analyze some of the values that appear to play a role in the various expert positions in the scientific debate on EDS risk and to identify whether these are based on different interpretations of the underlying scientific knowledge, or whether normative (value) judgments are involved. In the policy and (risk) governance sciences, the distinction between (un)certainty in science and knowledge on the one hand and (lack of) consensus on norms and values on the other hand is important, since these are thought to require different strategies to conflict settlement. The credo "more research is needed" applies to uncertainty in knowledge, while dissensus on norms and values requires multi-stakeholder approaches (Hisschemöller and Hoppe 1995; Renn 2008). Examples of such approaches are participatory discourses (IRGC 2005; Renn 2008) or 'extended peer-community' approaches (see e.g. Ravetz 1999).

Drawing from the existing distinction between uncertainty in knowledge and dissensus on norms and values, we use a classification provided by Renn (2008) to distinguish between two types of ambiguity, interpretative and normative ambiguity. Interpretative ambiguity refers to different interpretations of specific pieces of scientific evidence, for example about the meaning of toxicological evidence versus epidemiological evidence, or weight-of-evidence. Normative ambiguity refers to differences in values and ethical norms, for example about the acceptability or tolerability of a risk. Note that these two types of ambiguity are not mutually exclusive, and that a certain difference of opinion can contain elements of both (see e.g. Renn 2008). Interpretative ambiguity could, for example, involve normative judgments about the adversity of effects (i.e., whether an observed outcome from a toxicological study constitutes an adverse effect or not). Subsequently, one could argue that, in such cases, interpretative ambiguity would also require the attention of those affected by the risk issue. By contrast, due to the nature of the (often ethical) values involved, we argue that multi-stakeholder approaches are inherently required to settle normative ambiguity, or conversely, that it would be ineffective to settle this type of ambiguity solely in the scientific sphere.

To identify interpretative and normative ambiguity in the scientific debate on EDS risk, we use the pragma-dialectical argumentation theory (van Eemeren, Grootendorst, and Henkemans 2010; van Eemeren and Grootendorst 1984) as the framework to analyze two scientific publications from the realm of regulatory science (i.e., Lamb et al. 2014; Bergman et al. 2015). These two publications touch upon a wide variety of topics relevant for EDS science. We demonstrate the added value of the systematic analysis of argumentation to explore differences in the values

Table 1. Key concepts and their uses in pragma-dialectical argumentation theory.

Concept	Uses in pragma-dialectical argumentation theory (PDAT)
Standpoint	Refers to what is at issue in argumentative discourse, i.e., what is argued about by the parties (van Eemeren et al. 2014). By advancing a standpoint, a party assumes a positive or negative position towards a proposition. This commitment to a proposition obliges the party that put forward the standpoint to defend their standpoint (i.e., by advancing supporting argumentation) if challenged to do so by another party (van Eemeren et al. 2014)
Argumentation	Throughout this article, the term *a*rgumentation is predominantly used to refer to a collection of arguments. A formal definition of this term, which explicitly contains a process and product dimension, is "a verbal, social and rational activity aimed at convincing a reasonable critic of the acceptability of a standpoint by putting forward a constellation of one or more propositions to justify this standpoint (van Eemeren et al. 2010, p. xii)".
Argument	Understood as simple inferences from a collection of premises to a standpoint. One argument typically consists of two premises: an explicit premise and an implicit premise (or unexpressed premise).
Unexpressed premise	Understood as (intentionally) omitted elements implicitly present in the argumentation for which a party can nevertheless be held accountable (van Eemeren et al. 2010). As such, an unexpressed premise forms the (implicit) link between a (sub)standpoint and one supporting argument. Since argumentation is only logically or pragmatically complete when unexpressed premises are made explicit, parties can be held accountable for an implied unexpressed premise (van Eemeren et al. 2014). (Identified) unexpressed premises may themselves be considered unacceptable or unreasonable.
Difference of opinion	Understood as an (anticipated) disagreement between two parties regarding a given standpoint, i.e., a standpoint can be met with doubt, or an opposing standpoint can be put forward (van Eemeren et al. 2010). Is the driving force for putting forward argumentation, i.e., without any (anticipated) difference of opinion, putting forward argumentation would be pointless (van Eemeren et al. 2014).
Starting point	Set of (typically unexpressed) knowledge, experiences, beliefs, norms and values that provides the basis for standpoints and argumentation put forward in a critical discussion (van Eemeren et al. 2010). Ideally, discussants agree on the starting points of a discussion before commencing in an exchange of argumentation. If there is no shared understanding of the relevant starting points, then misunderstandings may occur or the starting points themselves may become the subject of discussion, rather than the standpoints at issue (van Eemeren et al. 2014). In a scientific discussion, starting points could follow from the particular field of expertise, underlying paradigms and fundamental scientific principles in which a discussant's scholarly work is grounded. Starting points could also follow from an expert's personal beliefs, e.g. related to the roles of experts in policy processes and decision-making and the role of scientific expertise in contemporary society.
Reasonable(ness)	Used to assess the quality of an argumentative move. Argumentation is considered reasonable when it does not contain anything that forms an obstacle to resolving a difference of opinion (van Eemeren et al. 2010). The set of ten discussion rules for a critical discussion can be used to evaluate the reasonableness of argumentation (van Eemeren et al. 2010), though this evaluation is beyond the scope of this article.

expressed by experts. These differences may subsequently clarify why some differences of opinion among EDS experts appear to be pervasive.

Two questions related to the scope of our research may emerge: (1) Why focus on the debate of EDS science? (2) Why use argumentation theory as the analytical 'lens' to study this debate? First, the potential of substances to cause adverse health effects through an endocrine mode of action remains an intensely debated area (see e.g. Autrup et al. 2015; Zoeller et al. 2014). A widely accepted definition of an EDS has been proposed in the 2002 WHO-IPCS state-of-the-science report: 'an endocrine disruptor is an exogenous substance or mixture that alters function(s) of the endocrine system and consequently causes adverse health effects in an intact organism, or its progeny, or (sub)populations' (WHO-IPCS 2002). However, the practical application of this definition is surrounded by controversy. It is not uncommon for experts to disagree about important aspects of EDS science, such as aspects pertaining to the identification of EDS:

- What evidence is specifically required and to what extent will the required scientific evidence about adverse health effects, modes of action and the causal link between the two be available?
- What does evidence in 'intact animals' constitute precisely and how should results from *in vitro* studies or other non-animal studies be considered?
- To what extent do EDS comply with the assumption that adverse physiological effects follow a threshold mechanism?

Experts in the field of EDS science may answer differently to these questions. We think an approach is justified that systematically analyzes the argumentation put forward by the various experts and expert groups that take a position in this debate, for various reasons. First, an argumentation analysis provides insight into the complex argumentation put forward in a (scientific) discussion. This insight is needed to say anything about the structure of the argumentation put forward and the way the discussion proceeds. Making use of the analytical tools provided by the pragma-dialectical argumentation theory, an analyst can identify the exact standpoint(s) under discussion and any supporting argumentation. The analyst could also describe to what extent parties respond to one another's standpoints and argumentation. Also, implicit elements in the argumentation (standpoints or premises) can be made explicit. Second, an argumentation analysis could be used to assess the quality of a discussion (i.e., whether rules for an argumentative discussion are not violated), though this type of analysis will not be performed in this article. Third, an argumentation analysis may illuminate prerequisite knowledge, professional experiences or personal beliefs (i.e., starting points, see Table 1) that remain implicit, but should nevertheless be made explicit to understand the origin of a discussant's standpoint and the supporting argumentation. However, the only way to systematically identify such starting points is to use the aforementioned analytical tools to reconstruct the argumentation structure, and then subject this argumentation structure to thorough analysis. Identified substantive points of departure in the discussion are further distinguished in interpretative ambiguity from normative ambiguity.

Finally, an in-depth argumentation analysis of publications in the realm of regulatory science requires consideration of two prerequisites. First, the credibility of such an analysis will strongly depend on the impartiality of the analysts, so (inherently normative) judgments about the truth-value of the premises used in the argumentation put forward in both publications are outside the scope of this article. Second, such a neutral position is particularly relevant when analyzing 'regulatory science' publications. One could evaluate to what extent argumentation put forward is in accordance with 'regulatory reality'. That is, various regulatory frameworks concerned with the safety of industrial chemicals or pesticides have data-requirements to enable science-based risk management. However, a report from the RIVM (2016) has shown that for EDS, the current minimal data requirements in EU's relevant regulatory frameworks are insufficient to identify an EDS based on the currently proposed (science-based) EU criteria. To maintain a neutral position

in our argumentation analysis, we refrain from evaluations based on such contextual information and strictly focus on the specific argumentation (and related unexpressed premises) put forward in the two publications. For the present analysis, this means that the focus is limited to a discussion about the scientific merits of the WHO/UNEP 2012 report, as addressed by the argumentation put forward in the two publications selected for analysis in this article. On the basis of the aim and scope of our study, we have articulated four main research questions (1a, 1 b, 1c and 1d) and one sub question (2):

- 1a. How does the discussion between Lamb et al. (2014) and Bergman et al. (2015) proceed in argumentative terms?
- 1b. Based on this argumentation analysis, how do the starting points identified from the Lamb et al. (2014) publication and the starting points identified from the Bergman et al. (2015) publication differ from each other?
- 1c. To what extent do these differences in starting points pertain to interpretative or normative ambiguity?
- 1d. Using this classification of the identified starting points, what types of value differences appear to be at stake in the analyzed discussion?
- 2. How does argumentation theory provide additional value through its ability to explicate and clarify obstructions to the various differences of opinion in the field of EDS science?

Theory of argumentation analysis

To perform an argumentation analysis systematically, we use the pragma-dialectical argumentation theory (PDAT), a theory of argumentation developed by van Eemeren and colleagues (van Eemeren, Grootendorst, and Henkemans 2010; van Eemeren and Grootendorst 1984). PDAT is a well-known approach in the area of argumentation theory and was developed as a response to an experienced lack of a systematic approach to study argumentation in a wide variety of (social) settings, e.g. argumentation in 'every-day life', argumentation in legal settings or argumentation in scientific discussions. PDAT aims to include and build upon concepts from other schools of thought studying argumentation. Since its inception in the beginning of the 1980s, the theory was further developed through discussions among scholars in argumentation theory and beyond, exemplified by the wealth of literature available (see e.g. The Handbook of Argumentation Theory of van Eemeren et al. 2014).

According to PDAT, the goal of an argumentative discussion is to solve a difference of opinion by means of reasonable argumentation. Resolving a difference of opinion means that two discussants jointly see if a standpoint is tenable against criticism. For more detailed information on PDAT we refer to the Supporting Information. Here only the concepts and key steps of analysis are summarized. Note that some of the key concepts of PDAT are named after terms that are also used in 'common language'. Also, some of these concepts may appear to be similar to one another, while the same concept may be understood differently within different schools of thought. Because the concepts used throughout this article bear specific meaning (following PDAT terminology) and have been developed in line with traditions in the discipline of argumentation theory, these concepts should be interpreted accordingly. Table 1 provides an overview of key concepts and their specific uses in PDAT. Throughout this article, we use italics when we refer to one of the concepts of PDAT to avoid ambiguity as much as possible.

Remark: Could Table 1 be placed here instead of its position much earlier in the text? This would work better for the intended flow of the information.

We specifically focus on two vital steps in the analysis of an exchange of argumentation. The first step of our analysis is identifying the stages of the ideal model of a critical discussion in the actual argumentative contributions of both parties involved (van Eemeren, Grootendorst, and

Henkemans 2010). This model consists of four stages that discussants should ideally follow when participating in a critical discussion: the confrontation stage, opening stage, argumentation stage and concluding stage (see Supporting Information Table S1 for more detailed information).

The second step is identifying the standpoints and the argumentation, making explicit of implicit elements in the argumentation, reconstructing the argumentation structure and identifying the argument schemes used. PDAT distinguishes between the external and internal organization of argumentation, referring to 'argumentation structures' and 'argument schemes', respectively (van Eemeren et al. 2014). Argumentation structures provide a complete overview of the standpoints and all underlying argumentation, and their hierarchal relationships. The three types of argumentation structures are multiple argumentation, coordinative argumentation or subordinative argumentation (see Supporting Information Table S2 for more detailed information). Argument schemes describe the specific type of relationship between a (sub)standpoint and one single underlying premise. The three types of argument schemes are argumentation based on a symptomatic relation, argumentation based on a causal relation or argumentation based on a relation of analogy (see Supporting Information Table S3 for more detailed information). Note that one could also distinguish 'reasoning schemes' (e.g., modus ponens or modus tollens, see Supporting Information). However, since reconstruction of such schemes requires that all premises contained in the argumentation are explicit, which is relatively unusual, we rarely use the term 'reasoning schemes'.

Method

Two scientific publications in the field of EDS science have been analyzed using PDAT. These publications are Lamb et al. (2014) and Bergman et al. (2015). Briefly, Lamb et al. (2014) have drafted an elaborate criticism of the WHO-UNEP (2013) report on the state of the science of EDS. Subsequently, Bergman et al. (2015) drafted a rebuttal to criticize the Lamb et al. critique. The 2012 WHO-UNEP report itself is not part of the argumentation analysis. We selected these publications for two reasons. First, both publications discuss a wide variety of aspects of EDS science. Second, the publications present different, sometimes competing argumentation with regard to these aspects of EDS science.

The argumentation analysis of the two publications was performed according to the following steps. First, the main standpoints were identified. Then, argumentation in support of these standpoints was identified and the structure of the argumentation was reconstructed. This yielded two comprehensive argumentation structures, one for each publication. In the case of notable (sub)standpoint—argument relationships, unexpressed premises were made explicit and the apparent argument scheme was identified. To illustrate how these steps work out in practice, a practical example of an argumentation analysis can be found in the Supporting Information. Subsequently, all insights gathered by this argumentation analysis have been used to attempt to make explicit the starting points that we think the two author groups appealed to throughout their publications. Finally, we have identified instances where we think these starting points appear to differ between the two author groups and we identified the type of ambiguity at stake (i.e. primarily interpretative ambiguity, primarily normative ambiguity, or elements of both).

Next, the main standpoint and main supporting argumentation put forward in the two publications will be discussed. Some arbitrarily selected results of our argumentation analysis will be described, since the argumentation structures are too comprehensive to describe in their entirety. These selected examples serve to illustrate how concepts like argumentation structure, argument scheme and unexpressed premise work out in practice, while simultaneously using examples that pertain specifically to EDS science.

Results

Main elements and specific examples of argumentation put forward in Lamb et al. (2014)

Main standpoint of Lamb et al. publication

The main standpoint, which comes forward from our analysis of this publication, is: 'The WHO-UNEP 2012 report should not be used to support evidence-based decisions' (p.37). Although the whole publication focuses on the criticism that the WHO did not provide a balanced perspective and did not provide an update of the state of the science, this does not appear to be the main standpoint. As Lamb et al. consider the 2012 WHO-UNEP report to fall short on some of the aspects that govern such systematically collected and evaluated evidence, one may infer that the report should in fact not be used for evidence-based decision-making. In the concluding paragraph this is explicitly stated (p.37):

> *Overall, the WHO-UNEP 2012 report on endocrine disruptors fails to achieve its objectives as an updated state-of-the-science review on endocrine disrupting chemicals, and therefore, should not be used to support evidence-based decisions.*

The word 'overall' announces a summary of the publication, which starts with one of the main arguments and the standpoint. The indicator 'therefore' shows the argumentation is progressive, which means the subsequent premise could be seen as the main standpoint.

Main argumentation structure of Lamb et al. publication

The main argumentation structure of the Lamb et al. publication, as outlined in the argumentation structure below, focuses on the claim that the report was not balanced and did not accurately reflect the state of the science:

1. The WHO-UNEP 2012 report should not be used to support evidence-based decisions
1.1. The WHO-UNEP 2012 report does not provide a balanced perspective
1.1.1 The integrity of decisions at all levels of the 2012 report is questionable
1.1.2 In some instances, the 2012 report failed to consider whether the weight of evidence supports their conclusions or alternative explanations are more likely when they described trends of increasing endocrine-related disorders and concluded these are due to environmental EDCs
1.1.3 The 2012 report does not sufficiently address elements relevant to the definition of EDCs.
1.1.4 The summary for decision-makers has more shortcomings than the report itself
1.2. The report does not accurately reflect the state of the science on endocrine disruption

1.2.1 The report does not meet the expectations of a state-of-the-science review
1.2.2 The report is not an update of the WHO-IPCS 2002 report

(2014) (2015) The standpoint is supported by two main arguments (1.1 and 1.2). We consider this argumentation as multiple, because each argument would by itself be sufficient to support the standpoint. For instance, if the report was perceived as balanced but did not reflect the state of the science accurately (according to Lamb et al.), it may still not be considered adequate to support evidence-based decision-making. Similarly, we consider that the four arguments supporting the assertion that the WHO 2012 report did not provide a balanced perspective (1.1) are examples of multiple argumentation. The arguments are independent and provide an alternative defense in case one of the arguments is not accepted by the reader, which is very common in discussions that are directed at a diverse audience. The second main argument (1.2) is also supported by multiple argumentation.

Example of complex (subordinative) argumentation

Because of the relative strength of the claim that the integrity of decisions in the report is questionable (1.1.1), this kind of argumentation would need support from further subordinative argumentation:

1.1.1 The integrity of decisions at all levels of the 2012 report is questionable

1.1.1.1a The impression has been given that the weight of evidence for causation is stronger than it is
1.1.1.1a.1a Unjustified inferences are made to suggest causation
1.1.1.1a.1b Literature was cited selectively, without discussion of contradictory studies
1.1.1.1b Conclusions were predisposed to the identification of potential EDCs
1.1.1.1b.1 No adequate systematic approach has been used to assess causation

According to our reconstructed argumentation structure, substandpoint 1.1.1 is supported by argument 1.1.1.1a, which refers to an impression of misrepresentation of the weight of evidence. As impressions typically have limited persuasive force and thus generally need further explanation, this argumentation is supported by more additional subordinative argumentation.

Example of identifying and evaluating an unexpressed premise

In some cases, the unexpressed premise may give new information that has consequences for the argumentation, as PDAT proposes that the protagonist should also be held committed to premises left implicit. If these premises are not made explicit, these commitments may be overlooked or a potential weaker link in the argumentation may remain ignored. The unexpressed premises in the article written by Lamb et al. mostly contain premises that have elsewhere also been stated explicitly. The following example deals with argumentation concerning adequate approaches to causation. Usually, making unexpressed premises explicit takes two steps. First, an attempt is made to reconstruct the logical reasoning. This involves adding a premise that makes the argument logically valid. Second, the unexpressed premise is made more informative. We consider that the substandpoint that no adequate systematic approach has been used to assess causation (1.1.1.1b.1) is supported by the argument that Bradford Hill's criteria (or similar systematic methods to assess causation) have not been used, (1.1.1.1b.1.1a). The (formal) reasoning can be reconstructed as follows, using modus ponens as the basic reasoning scheme:

1. If *p*, then *q* (If Bradford Hill's criteria (or similar systematic methods) have not been used, then no adequate systematic approach has been used to assess causation.)
2. *p* (Bradford Hill's criteria (or similar systematic methods) have not been used.)
3. *q* (No adequate systematic approach has been used to assess causation.)

To make this modus ponens structure more informative, the missing premise could be made explicit:

(1.1.1.1b.1.1a') Bradford Hill's criteria (or similar systematic methods) are an adequate systematic approach to assess causation

In this case, the unexpressed premise shows that there is an assumption, or starting point, that Bradford Hill's criteria are in fact considered adequate to assess causation systematically. Thus, making unexpressed premises explicit may provide information about starting points and subsequently bring to light a difference in starting points. Other stakeholders, such as the authors of the WHO-UNEP 2012 report, may not hold the same opinion regarding this starting point.

Main elements and specific examples of argumentation put forward in Bergman et al. (2015)

Main standpoint of Bergman et al. publication

The main standpoint of the response to the critique of "State of the Science of Endocrine Disrupting Chemicals 2012" coming forward from our analysis of this publication is: 'The criticism by Lamb et al. on the 2013 WHO-UNEP report is unjustified'. The standpoint could be detected quite easily. First, we interpret the response as a defense against the critique that the report should not be used to support evidence-based decisions, so the authors of the rebuttal will presumably refute this criticism. Second, already in the abstract, the Bergman et al. publication appears to presents various reasons why, in their opinion, the critique was flawed. That is, according to our interpretation of the Bergman et al. publication, Lamb et al. have quoted the 2012 WHO/UNEP report in an incomplete and misleading fashion, misused conceptual frameworks for assessing causality and defined extremely narrow standards for synthesizing and reviewing evidence, among others. Third, according to Bergman et al., the authors of the critique have not directed their messages at the scientific community but at decision makers instead. This implies that the critique lacks a focus on scientific issues, which has also been stated explicitly (p. 1016).

Main argumentation structure of Bergman et al. Publication

Our reconstruction of the main *argumentation structure* of the Bergman et al. publication is shown below:

1. The criticism by Lamb et al. on the 2013 report is unjustified.

1.1 It created the false impression of a scientific controversy
1.1.1 Lamb et al. falsely claimed that the integrity of decisions at all levels of the WHO report should be called into question
1.1.1.1 Lamb et al. had alternative motives for writing this critique: to confuse the scientific data
1.1.1.1.1 They misdirected the reader into thinking that the 2012 report was biased
1.1.1.1.2 They employed the same tactics as the tobacco industry to undermine attempts of introducing standardized packaging for cigarettes
1.1.1.1.3 They were sponsored by the chemical industry
1.2 It does not engage with the scientific substance of the report
1.2.1 The claim that the report is neither a state of the science nor an update of the previous report is false
1.2.2 The claim that the lack of a formal assessment of causation and weight-of-evidence approaches leads to subjectivity and the suggestion of causation is false
1.2.3 Lamb et al.'s claim that other environmental causes of disease trends than chemicals were not acknowledged is false
1.2.4 Lamb et al.'s criticism on our [Bergman et al.'s] characterization of the endocrine system is unfounded
1.2.5 The criticism against the summary for decision-makers is unfounded

The main arguments for the standpoint that the criticism is unjustified are that it creates the false impression of a scientific controversy and that the critique does not engage with the scientific substance of the report. This already indicates that the critique was perceived as misleading by Bergman et al., in the sense that the critique supposedly ignores the science of endocrine disruptors and tries to create a scientific controversy that did not exist. The latter is motivated by attributing alternative motives onto Lamb et al. as an explanation of why this alleged 'artificial controversy' was constructed. We consider all arguments as independent, since they provide

Table 2. Overview of the identified differences in starting points.

Nr.	Topic	Lamb et al.	Bergman et al.	Type of ambiguity
1	Degree of controversy within scientific EDS debate	The 2012 WHO-UNEP report did not acknowledge controversy over the interpretation of data in several instances (creating a false sense of agreement)	This is not a scientific controversy; Lamb et al create the fake impression of scientific controversy	Primarily interpretative ambiguity
2	Weight-of-evidence approaches	Objective methods to evaluate the weight of the evidence do exist; a 'best professional judgment' approach is not warranted for a state-of-the-science report and prone to bias	Objective methods to evaluate the weight of the evidence do not exist; scientific judgments are inherently required, warranting the 'best professional judgment' approach	Elements of both interpretative ambiguity and normative ambiguity
3	Establishing causality and use of Bradford Hill's criteria/viewpoints	Bradford Hill's criteria are an adequate starting point to unequivocally establish causation	Bradford Hill's viewpoints cannot be applied unequivocally; e.g. the social, economic or political context may influence the required strength of evidence required to take policy action	Primarily normative ambiguity
4	Framing of endocrine system	The endocrine system is resilient, as it is specifically designed to cope with environmental chemical exposures, through natural homeostatic processes (that is, within the boundaries of homeostasis)	The endocrine system is vulnerable to environmental exposures. The endocrine system of developing fetuses is susceptible to transient fluctuations of circulating hormone, potentially leading to irreversible malformations.	Elements of both interpretative and normative ambiguity
5	Function of a state-of-the-science report	Robust, objective and systematic scientific procedures are central to a state-of-the-science report that is to be used to support evidence-based decision-making	The underlying scientific standards of a state-of-the-science report should be explicitly responsive to considerations of public health protection	Primarily normative ambiguity

alternative reasons for concluding that the authors had alternative motives. Each of them would be sufficient to prove that the standpoint is true (assuming that the premises are true). The claim that the critique did not engage with the scientific substance of the report is supported by various examples of how the critique misconstrued the report and did not accurately reflect the scientific discussions under scrutiny.

Example of identifying and evaluating an argument scheme

The following example shows how an unexpressed premise helps to determine what argument scheme has been applied.

1.1.1.1 Lamb et al. had alternative motives for writing this critique: to confuse the scientific data

1.1.1.1.1 They misdirected the reader into thinking it was biased
1.1.1.1.2 They employed the same tactics as the tobacco industry to undermine attempts of introducing standardized packaging for cigarettes

1.1.1.1.3 They were sponsored by the chemical industry

The misdirection and tactics that were used to present the WHO-UNEP 2012 report as unreliable, as well as the connections to the chemicals industry, are seen as evidence for the statement that Lamb et al. had alternative motives for writing this critique. Without the unexpressed premise, though, it is not totally clear why the second argument would be relevant. If the analogy was a comparison based on similar tactics, it is unclear what the relevance would be of mentioning the tobacco industry and in what way this would help prove the statement to be acceptable. The fact that the tobacco industry was mentioned is the point that actually creates the weight of the argument. By making the unexpressed premise explicit, it becomes clear that the argument scheme used here is argumentation based on a relation of analogy, since an analogy has been made between the tactics used by the chemical industry and those used by the tobacco industry:

(1.1.1.1.2′) And the tactics used by the tobacco industry are comparable to the tactics used by the chemical industry

As Lamb et al. acknowledge that in drafting their publication, they received funding support from several chemical industry sponsors, their argumentation is seen as representative of this branch of industry by Bergman et al. (as has been made explicit with argument 1.1.1.1.3). The proposed similarity of tactics employed by the tobacco industry and alleged tactics employed by the chemical industry is what appears to have led to the attribution of alternative motives onto Lamb et al. The argument scheme based on a relation of analogy is as follows:

Y is true of X (having alternative motives is true of Lamb et al.)

because Y is true of Z (having alternative motives is true of the tobacco industry)

and: Z is comparable to X (the tactics used by the tobacco industry are comparable to the tactics used by Lamb et al./the chemical industry)

To ensure that the analogy is a sound one, the most important critical question to ask is:

- Are there any significant differences between Z and X?

Naturally, one is always able to find differences between Z and X, because if they were exactly the same, making an analogy would be pointless and an example of circular reasoning. The point is that they should be the same concerning all characteristics that are relevant to the argument (as discussed above).

Differences in starting points

In this section, we concentrate on the part of the analysis that we consider crucial in understanding why it will be very difficult to reach a satisfactory concluding stage in the discussion between the two author groups. The differences in starting points that appear to impede the path to resolution are addressed in more depth. Table 2 gives an overview of differences in starting points we identified, based on a close evaluation of the argumentation structures of Lamb et al. (2014) and Bergman et al. (2015), including notable argument schemes and unexpressed premises.

The first difference in starting points we identified revolves around the question whether this discussion falls into the category of a scientific controversy. Bergman et al. have stated explicitly that Lamb et al. create the false impression of a scientific controversy to confuse the scientific data. By saying this, Bergman et al. do not appear to agree with the statement of Lamb et al. that it is a scientific controversy. Alternatively, Lamb et al. have implied that the report by the WHO creates a false sense of agreement in some instances, which indicates that they hold the

opinion that on important matters there is no agreement, which in turn appears to imply that they do believe there is a scientific controversy.

The second difference in starting points we identified revolves around the preference for a specific weight-of-evidence approach. Lamb et al. have implied that an objective and structured weight-of-evidence approach for EDS exists, whilst Bergman et al. have stated explicitly that such an approach does not (yet) exist for EDS. Lamb et al. mention a series of requirements that make up for such an objective weight-of-evidence approach throughout their publication. However, Bergman et al. argue that objective weight-of-evidence approaches do not exist. For example, hypothesis formation is considered to be an inherently interpretative process that cannot be dealt with in an 'objective' manner. In this light, the approach deemed most appropriate is the "best professional judgment".

The third difference in starting points we identified concerns the existence of a systematic approach to assess whether an association is causal and what this approach should entail. Apart from the belief that such an approach exists, Lamb et al. describe various conditions that have to be fulfilled before the criteria for causality will be met, predominantly inspired by Bradford Hill's criteria. Nevertheless, Bergman et al. give the impression that Lamb et al. have unrealistic demands, as such an approach is not deemed feasible when proof of causality in the field of EDS science is supposedly very difficult, if not impossible. They assert that no approach will completely protect against bias and that absolute criteria to assess causality are impossible. Therefore, a different approach is deemed unavoidable.

The fourth difference in starting points we identified pertains to a disagreement about assumptions held concerning the physiological function of the endocrine system and its potential to cope with transient exposures to environmental chemicals. Lamb et al. appear to portray the endocrine system as a homeostatic system adaptable to circumstances. Alternatively, Bergman et al. appear to portray the endocrine system as vulnerable to irreversible disruption, mainly due to its programming functions in developing (unborn) children. These differing illustrations of the endocrine system appear to lead to equally differing judgments about how disturbing an alteration of the endocrine system may be at a given life stage of the exposed individual.

The fifth difference in starting points is more fundamental and shows overlap with some of the differences in starting points described above. In essence, it appears that Lamb et al. and Bergman et al. have differing perspectives regarding the function of a state-of-the-science report, particularly in the context of how evidence-based decision-making should be supported. On the one hand, Lamb et al. appear to emphasize the necessity of a state-of-the-science report to live up to their proposed scientific standards and approaches. The authors note that, only in this way, one can then be confident in the decision-making that arises from such a state-of-the-science report. On the other hand, Bergman et al. appear to emphasize that the underlying scientific standards of a state-of-the-science report should be explicitly responsive to considerations of public health protection. From the perspective of Bergman et al., the level of evidence or strength of association that is necessary to take policy action cannot be determined by some 'fixed' standard, but rather depends on the decision-making context. For example, under certain circumstances, a weak strength of association may be very significant from a public health perspective.

Discussion

In this study, we have analyzed two scientific publications in the debate on EDS science from an argumentation point of view, using the pragma-dialectical argumentation theory. From this argumentation analysis, five differences in starting points have been identified. These differences in starting points will be characterized based on the nature of the disagreement. Where relevant,

Table 3. Four Myths of Nature and their key characteristics (based on Dake, 1992 and Steg and Sievers, 2000).

Myth of nature	Key characteristics
Nature is capricious	Nature is considered to be an unmanageable system. Supporters of this cultural bias are hypothesized to believe that incidents and accidents happen by chance and cannot be predicted.
Nature is tolerant, but within limits	Nature is considered a robust system, but which has its boundaries. Supporters of this cultural bias are hypothesized to believe that the appropriate authority (i.e. experts and decision makers) can derive and establish the limits of nature.
Nature is benign	Nature is considered a robust and resilient system. Supporters of this cultural bias are hypothesized to believe that natural systems have the inherent capability to cope with virtually any (man-made) impacts.
Nature is ephemeral or fragile	Nature is considered a fragile system. Supporters of this cultural bias are hypothesized to believe that only minor disturbances of a natural system could lead to catastrophic, irreversible consequences.

similarities to existing risk and expert role typologies from scientific literature will be identified. Finally, some strengths and limitations of this argumentation analysis will be discussed.

Starting points and types of ambiguity

We draw from Renn (2008) to discern interpretative ambiguity and normative ambiguity and subsequently distinguish between the type of value differences at stake. We consider the first difference in starting points (degree of scientific controversy) in Table 2 as primarily interpretative ambiguity, while the third (establishing causality) and fifth (function of a state-of-the-science report) difference in starting points are considered to be primarily normative ambiguity. The second (weight-of-evidence approaches) and fourth (framing of the endocrine system) difference in starting point share elements of both interpretative and normative ambiguity.

Analogies of starting points with existing risk and expert roles typologies

The fourth difference in starting points pertains to differing perspectives of the function of the endocrine system in the physiology of humans and wildlife. This fourth difference in starting point may, at the human physiological level, not be conflicting, such that both perspectives can co-exist. We are interested, however, in why the two author groups appeared to elect one position over the other in the argumentation presented in their publications. We argue that this specific difference in starting points could be explained by differences in culturally determined perspectives of risk. To illustrate this, we use the concept of 'Myths of Nature' (Dake 1992; Steg and Sievers 2000), derived from the 'Cultural Theory of Risk' (Douglas 1992; Rayner 1992; Tansey and O'Riordan 1999). Dake (1992, p. 24) defines a Myth of Nature as 'one set of beliefs about what the world is like, what its risks are like, and who is to blame for untoward events'. A Myth of Nature is considered a specific type of cultural bias, which is a set of values and beliefs shared within a group (Dake 1992). Indeed, a Myth of Nature is a cultural bias that specifically pertains to environmental risks. According to Cultural Theorists, individuals draw from their cultural biases to conceive their personal perceptions and interpretations of a risk (see e.g. Rayner 1992). Insight in one's Myth of Nature may then explain why an individual may emphasize some aspects of a risk, such as the risk's potential hazardous impacts to human health, whereas other aspects may remain underexposed, such as the benefits associated with the risk and the potential lack of viable or marketable alternatives. Cultural Theorists generally discern four prototypical Myths of Nature: 'nature is capricious', 'nature is tolerant, but within limits', 'nature is benign' and 'nature is ephemeral or fragile' (Dake 1992) (see Table 3; Figure 1).

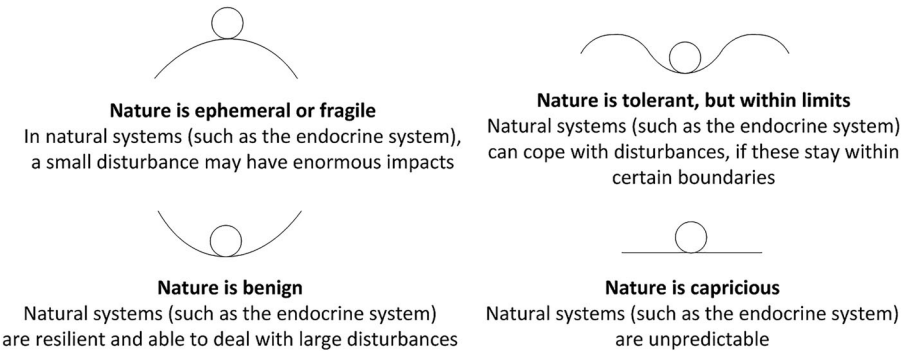

Figure 1. The four Myths of Nature, represented by a ball (behavior associated with risk) and a landscape (the type of natural system).

On the basis of the starting points identified from our argumentation analysis, we propose that Lamb et al.'s illustration of the endocrine system in human physiology resembles the 'nature is tolerant, but within limits' Myth of Nature. Lamb et al. note that a key function of the endocrine system is to deal with continuous fluctuations in hormone levels, though the limits of these homeostatic processes need to be respected. This perspective is much similar to the perspective of nature as a tolerant system that has its boundaries. Alternatively, we propose that Bergman et al.'s illustration of the endocrine system resembles the 'nature ephemeral or fragile' Myth of Nature. Bergman et al. emphasize the susceptibility of vulnerable groups to irreversible disruption of the endocrine system leading to potentially latent effects, even in situations of (very) low exposures to EDS. As such, the Myth of Nature typology draws attention to differences in beliefs about the endocrine system and subsequent differences in framing of this system. Whether this typology has added value in understanding the positions of experts in the broader discussion on EDS science should follow from additional research.

The fifth difference in starting points pertains to different emphases with regard to the function of a state-of-the-science report. A recurring theme in the Lamb et al. publication appears to be the scientific standards to which a state-of-the-science report on EDS science should live up to. For example, a summary is provided at the end of the Lamb et al. publication that pinpoints why the authors think the 2012 WHO-UNEP report cannot be characterized as a state-of-the-science review:

> *"[due to] the lack of a defined scope for the review, the absence of a process for identification, integration and interpretation of data, the lack of a structure for evaluating individual studies for relevance and reliability, and an objective method for evaluating the weight of the evidence" (*Lamb et al. 2014*, p. 36).*

In this summary, the various reasons put forward by Lamb et al. are all grounded in characteristics of what they appear to consider robust science. The merits of a state-of-the-science report therefore appear to be determined by its ability to live up to the scientific standards comprehensively described in the Lamb et al. publication. Notably, this does not mean that Lamb et al. may have little concern for human health and the environment, but rather that objective and structured approaches to analyze the available evidence are repeatedly emphasized. In the Bergman et al. publication, extensive substantiation of the scientific procedures used to develop the 2012 report are provided (though different standards and approaches are applied than those advocated Lamb et al., see e.g. the second and third differences in starting points). However, in addition to a discussion of what they consider appropriate scientific approaches, Bergman et al. refer multiple times to the importance for a state-of-the-science review (and the toxicological and epidemiological sciences in a broader sense) to have utility for public health initiatives. This point is addressed explicitly in their publication, while simultaneously alleging Lamb et al. to overlook this perspective:

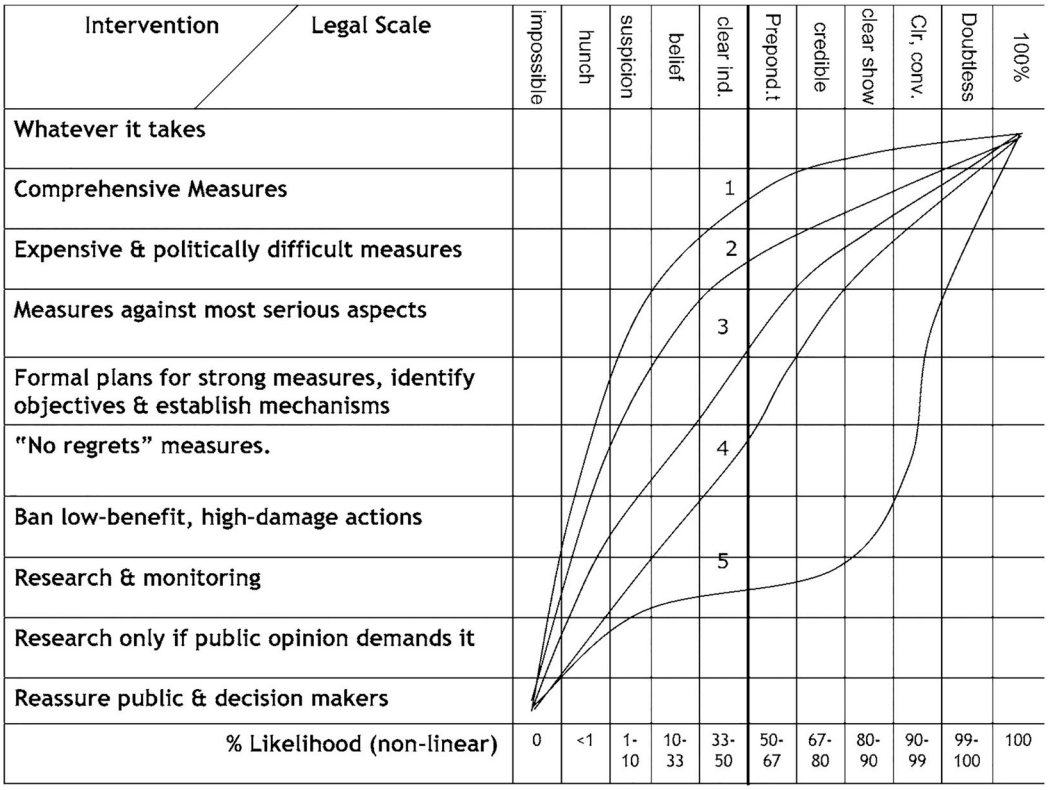

Figure 2. The typology developed by Weiss (2003). The level of international intervention to address the danger of severe and irreversible harm to the environment is plotted against the level of scientific certainty and the five expert roles. The probability scale is nonlinear and asymmetrical. Curves correspond to the following expert roles: 1. Environmental absolutist, 2. Cautious environmentalist, 3. Environmental centrist, 4. Technological optimist, 5. Scientific absolutist. Permission to use the figure has been obtained from the copyright holder (Springer Nature).

> *"Lamb et al. are remiss in acknowledging that the goal of the toxicological and epidemiological sciences is not to provide assessments as an end in themselves, but to explore and evaluate conditions that offer disease prevention and public health initiatives" (*Bergman et al. 2015*, p. 1011).*

Among others, Bergman et al. describe that even a weak strength of association could very well provide grounds for protective measures, or at least does not exempt one to consider such measures, since public health may be served significantly. In addition, they describe that hypotheses formulated in the state-of-the-science review must have some utility in serving public health considerations.

Notably, this particular difference in starting points shows similarities to a theoretical typology developed by Weiss (2003). This typology's point of departure is the observation that the various formulations of the Precautionary Principle generally do not accurately define the required level of scientific certainty to justify a particular precautionary measure, such as 'measures against most serious aspects' (Weiss 2003). Note that, while some may question the use of the term 'level of (scientific) uncertainty', we prefer to use this term in this context as it is consistently used by Weiss and this term is a key aspect of the reasoning underlying the Weiss (2003) typology.

The typology of Weiss (2003) can be used to characterize the roles of experts in terms of their stance towards the Precautionary Principle. Five ideal-typical expert roles can be discerned (see Figure 2). The scientific absolutist, typically being an advocate of 'science-based regulation', will

require a high level of scientific certainty before supporting 'measures against the most serious aspects' of a new technology that may pose potential dangers to the environment. The environmental absolutist, typically being an advocate of relatively early precautionary action, will require much less scientific certainty to advocate the same type of measure, supported by the norm that the environment inherently requires protection from potential (man-made) dangers. The cautious environmentalist, environmental centrist and technological optimist hold intermediate positions.

Whether the expert role typologies of Weiss (2003) do in fact accurately capture the identified difference in starting points needs further research, since both of the analyzed publications make little explicit references to preferred policy measures regarding particular EDS. The typology does draw attention to differences in the roles that experts could adopt to provide science-based advice to policy makers. Spruijt et al. have empirically identified, among others based on the theoretical insights from Weiss (2003), differences in expert advisory roles in the field of electromagnetic fields risk research (Spruijt et al. 2015) and particulate matter risk research (Spruijt et al. 2016). Whether these differences in expert roles would also be visible in the field of EDS science would similarly be a topic for future research.

Strengths and limitations

This is the first argumentation analysis using PDAT to study (a part of) the scientific discussion on EDS, as far as we are aware. This study combined knowledge from the field of EDS science with insights from argumentation theory, values in science and existing theoretical risk and expert role typologies, making this an interdisciplinary effort. Our main analytical framework, the pragma-dialectical argumentation theory (PDAT), allowed us to systematically analyze the argumentation put forward in Lamb et al. (2014) and Bergman et al. (2015) in its entirety. In turn, this approach allowed us to focus on assumptions that can play a major role in an exchange of argumentation, but nevertheless remain implicit and, thus, somewhat intangible. The elaborate methodology of PDAT should ensure that such argumentation analyses remain true to the essence of the text(s) under scrutiny. We argue that combining the systematic analytical framework offered by PDAT with (a) insights from literature studying values in science (see e.g. Douglas 2000; Elliott 2017) and (b) existing typologies of risk and expert roles have provided us with specific 'lenses' to study pertinent value differences. This allowed us to distinguish between interpretative and normative ambiguity, and to ultimately identify various types of value differences occurring in a specific part of regulatory science on EDS. Moreover, we identified several differences over normative values that, at first glance, appeared to be camouflaged as conflicts of scientific fact.

Only two publications from one period in time have been analyzed, while the literature on endocrine disruptor science is far more extensive. The analyzed publications are embedded within an expansive, on-going scientific discussion that may cover a wider range of topics than discussed in the particular publications analyzed in this study. As this research remains an exploration of the viability of argumentation analysis to identify some apparent value differences in the scientific discussion on EDS risks, we argue that analyzing two publications was justified. Similarly, since PDAT, our analytical method of choice, requires the analyst to necessarily limit the analysis to the specific substance of the arguments at hand, the scope of our analysis is limited accordingly. However, we think that our specific research aims warrant the limited scope of our analysis.

Finally, we did not evaluate potential fallacious reasoning or provide any answer to critical questions raised by our argumentation analysis. We aimed to analyze the scientific EDS discussion from some distance to perform an analysis that is as unbiased and impartial as reasonably possible. Evaluations of fallacious reasoning would necessarily require us to make normative

judgments, which would compromise our neutral position and may potentially influence our credibility as (argumentation) analysts.

Conclusions

In this article, we set out to show how an argumentation analysis can be used to identify the main standpoints, main supporting arguments and other argumentation. We have also shown that such an approach can be used to highlight differences in starting points and subdivide contrasting starting points based on the type of ambiguity, and subsequently the type of value differences at issue. We analyzed two scientific publications in the field of EDS science to demonstrate this approach. Our results show a collection of five differences in starting points, two of which have been further investigated using existing risk and expert role typologies. We argue that it would be ineffective for at least four of these five differences in starting points to attempt to settle these solely in the scientific sphere, due to the nature of the (often ethical) value differences involved. Rather, multi-stakeholder approaches are then required. Such approaches would in practice be well served by further argumentation analysis of the pertinent value-laden positions involved. Future research could show to what extent the differences in starting points identified in this article can be extrapolated to the broader discussion on EDS science, or even to scientific discussions on other environmental health risk controversies. Finally, additional research could use the risk and expert role typologies applied in this article to further explore the roles of EDS experts when supporting evidence-based decision-making.

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