The Means-End Account of Scientific, Representational Actions

1. Introduction

In the past fifteen years, there has been an increased interest among philosophers of science in discussing the nature of representation as it is used within scientific practice (for overviews see, Boesch 2015, Suárez 2015a, and Frigg and Nguyen 2016a). Over time, a significant number of philosophers have shifted their focus away from substantive accounts of scientific representation which refer to the *features* of representational vehicles and their targets and instead offer pragmatic accounts of scientific representation which focus more heavily upon the *actions* of *users* of representational vehicles. Apart from avoiding criticisms raised against substantive accounts, pragmatic accounts of scientific representation can explain a wide range of representational uses while drawing our attention closer to the actual practice of science.

Despite these advantages of pragmatic accounts, there has been little said about the notions of action, intention, and agency being employed by these accounts. Just as one example among many, Ronald Giere (2010) argues that representation occurs when “Agents (1) intend; (2) to use model, M; (3) to represent a part of world, W; (4) for some purpose, P” (2010, p. 269). Though he uses work in the philosophy of language to help explain the communicative nature of representation, he does not analyze the notions of intention or use which he employs. Since these agential concepts are playing an important role in his account (and, indeed, in all pragmatic accounts), the lack of analysis of these concepts constitutes a significant gap in our understanding of the representational practices of science. For this reason, I will turn in this paper to some work within the philosophy of action, and in particular to an account of the nature of intentional actions, to better understand the nature of scientific, representational actions.

Given the broad commitments of pragmatic accounts of scientific representation alongside some guiding suggestions offered by the proponents of these accounts, I will argue that a suitable account of action can be found in the work of G.E.M. Anscombe (2000). She argues that intentional actions are marked off from other actions in virtue of the form of the internal means-end structure of the descriptions of the agent’s intentional action, which is itself revealed by a particular sort of ‘Why?’ question. After briefly describing Anscombe’s account of intentional action, I will argue that representational actions in science can be understood and analyzed in virtue of their internal means-end structure. What I shall call the Means-End Account of Scientific, Representational Actions offers three central features: (I) the final description in the means-end ordering of descriptions is some scientific aim; (II) that interaction with a vehicle distinct from its target stands as an earlier description which is ordered toward the final description as means to end; and (III) the means-end structure is *licensed* by scientific practice, in the sense I have previously described (Boesch 2017). After describing each of these features in greater detail through an example, I show how the Means-End Account can demarcate scientific, representational actions from representational actions in other disciplines and from other types of scientific actions. I close by identifying some payoffs of the Means-End Account: that it offers the first account of the scientific, representational actions which ground pragmatic accounts of scientific representation and that it identifies representation as a *form* of action which is of use when exploring how representation is intertwined with other scientific activities.

1. From Dyadic to Triadic Accounts of Scientific Representation: A (Brief) History

To show explicitly the value of turning to the philosophy of action for this topic, it will be of use to first offer a brief characterization of the history of accounts of scientific representation. Early accounts of scientific representation were “dyadic” (Knuuttila 2005, p. 1261), in which scientific representation was understood as a two-place relationship that holds between some vehicle (e.g. a model) and some target system (e.g. a theoretical or empirical mechanism). The representational relationship, on dyadic accounts, is explained in virtue of some more fundamental relationship that holds between the vehicle and target—most commonly offered in terms of a structure-preserving mapping relationship, e.g. isomorphism, partial isomorphism, isomorphic embedding, and homomorphism (see, e.g., Bartels 2006, French and Ladyman 1999, French 2003, and van Fraassen 1980), or a more general relationship of similarity (e.g. Giere 1988).[[1]](#footnote-1) Dyadic accounts of scientific representation have been subject to several criticisms. As just one example, a prominent set of criticisms (Suárez 2003 and Frigg 2006) follows the work of Nelson Goodman (1976) and argues that both similarity and isomorphism (and other forms of structure-preserving mapping relationships) are insufficient accounts of scientific representation, since they do not have the same logical features as representation.

Partially due to these criticisms, philosophers of science later began to offer pragmatic accounts of scientific representation.[[2]](#footnote-2) Pragmatic accounts are “(at least) triadic” (Knuuttila 2005, p. 1261) because their proponents argue that there is an irreducible place for the agent in the representational relationship. They argue that “what representations are depends on how we *use* them” (Knuuttila 2011, p. 266). I have already noted the central role for the scientist’s agency, intentions, and use in Giere’s (2010) account. Suárez’s inferential conception of scientific representation similarly makes an essential reference to “the presence of agents and the purposes of inquiry” (2004, p. 773). These accounts are far from the only ones to give prominence to the agency and use of scientists in offering an account of scientific representation (see also Hughes 1997, Teller 2001; Bailer-Jones 2003; Suárez 2004, 2010, 2015a, and 2015b; Giere 2004 and 2010; Contessa 2007 and 2011; van Fraassen 2008, and Mäki 2009).

1. Three Ways Forward from Pragmatic Accounts

In some ways, the shift toward pragmatic accounts of scientific representation makes it difficult to offer any further insights about scientific representation. At least some pragmatic accounts of scientific representation deflate the concept of representation entirely to use. Deflationary accounts of representation imply that “the analysis of the concept of representation, even where feasible, cannot determine its conditions of application, and therefore cannot explain its use” (Suárez 2015b, p. 47). It is unclear what further insights can be offered by an account which cannot describe when and how representations will be used within scientific practice. Even for those pragmatic accounts which maintain substantive elements in addition to a foundation in human actions embedded in a practice, there remains a concern that little more can be said about the pragmatic grounding of these accounts. As Tarja Knuuttila has put it: “if representation is grounded primarily in the specific goals and the representing activity of humans as opposed to the properties of the representative vehicle and its target, nothing very substantial can be said about it in general” (2009, p. 144). Nonetheless, there are still several ways forward which jointly help to make general progress in better understanding the practice of representation within science.

 One way forward is to begin by acknowledging the essentially pragmatic nature of scientific representation, but then turn to examine and describe the more fundamental features and relationships which are frequently utilized when scientists represent. These more fundamental relationships are what Suárez (2003, p. 229) calls the “means” of representation—while representing scientists take advantage of these features, they are alone insufficient to explain the representational relationship. These include things like similarity (e.g., Giere 2004 and Weisberg 2013), as well as other structure-preserving mapping relationships (Bartels 2006, Bueno and French 2011, Frisch 2015, and van Fraassen 2008). These studies are insightful and useful in understanding some instances and means of representational use since they can help draw our attention to some of the strategies and features that scientists use.

 Another way forward, suggested by Suárez (2015b, p. 47), is to pay more attention to the uses of representational vehicles in practice. Practical studies of classes of representational vehicles attend not to the more fundamental relationships being utilized in representational activities, but to the classes of representational vehicles which scientists construct, revise, and employ. Interesting and insightful studies have been made about various classes of vehicles, including models (e.g. Morgan and Morrison 1999, Knuuttila 2005, Weisberg 2007, Knuuttila and Loettgers 2011, 2014, and 2016) and other representational vehicles like diagrams and figures (e.g. Perini 2005a and 2005b, Sheredos et al. 2013, and Woody 2004). Similarly, sociologists of science have done many useful studies examining the development and employment of some particular representational vehicle (e.g. Lynch and Woolgar (1990), Latour (1999), and Coopmans et al. (2014)). Studies of representational vehicles are of obvious value to deepening our understanding of the uses of scientific representation since they draw our attention to the ways in which classes of vehicles or specific instances of representation are utilized within practice.

 There is a third way forward which, so far, has not yet been discussed by philosophers of science. It is to pay greater attention to the nature of agency which is central to pragmatic accounts of scientific representation and offer an account of scientific, representational actions. Many accounts indeed do offer some insight into what sorts of actions they have in mind. Van Fraassen, for example, speaks of using, making, and taking something as a representation in his famous *Hauptsatz* or central point about the nature of representation(2008, p. 23). Suárez (2004) speaks of the surrogate inferences that are made with regard to the target system being represented. And Giere (2004, 2010) speaks, as I mentioned above, about an agent’s intentions and use. Despite the insights which have arisen from these accounts of using, making, taking, inference-making, intending, and so on, nothing has been said about the nature of the actions themselves with regard to their internal structure. Put differently, what is the nature of the action being performed when a scientist uses, makes, takes (etc.) a vehicle as a representation? What are the features and elements that make up the representational use of a vehicle? Taking up such an inquiry requires offering and working through an account of the nature of actions, working to apply the account to the representational practices in science so as to analyze the nature of scientific, representational actions.

 In this paper, I will follow this third way forward, getting behind the references to using, making, taking, and so on to examine the internal structure of scientific, representational actions. My argument will speak generally about scientific, representational actions as a whole. The generality of my account will leave several elements unspecified, since as Knuuttila notes, we must proceed forward from pragmatic accounts in a way which leaves room for the “specific goals” taken up in the activity of the scientists (2009, p. 144). The account defended here will leave room for the specific goals a scientist might take up by offering a general account of some of the formal, internal features of the intentional actions of representing in science. Before I offer and defend an account of the nature of scientific, representational actions it will be of use to turn first to some work on the nature of intentional actions drawn from philosophers of action.

1. Desiderata of an Account of Scientific, Representational Actions

There are numerous accounts of the nature of agency and intentional actions within the philosophy of action. Before diving into the literature in greater detail, it is of use to first identify general features of the notion of agency as it is being utilized in pragmatic accounts of scientific representation. The most helpful insights are two related claims, one negative and one positive, about the relationship between representational use and mental states: (1) that representational actions are not explained in terms of internal, individual mental states and (2) that representational actions are to be explained in terms of the wider scientific practice.

 Let us examine these in greater detail. Suárez is explicit in denying that “representation is necessarily the property of individuals… [or that] representation is ‘in the head’” (Ladyman, Bueno, Suárez, and van Fraassen 2011, p. 432; c.f. Suárez 2010, pp. 98-99). If we are to have a truly pragmatic account of representation in science, Suárez argues that we must avoid “[a]n intentionality conception [of scientific representation which] … takes it that sources and targets are determined by some intentional state of some particular agent or agents, regardless of community, practice, and indeed any intended or unintended uses” (Ladyman, Bueno, Suárez, and van Fraassen 2011, p. 432). He argues that an account which reduces representation to the singular intentions or mental states of some individual misses the important role that the broader scientific practice and community plays in scientific representation. Indeed, on Suárez’s view, scientific representation is not ‘in the head’ but rather “‘in the world’, and more particularly in the social world – as a prominent activity or set of activities carried out by those communities of inquirers involved in the practice of scientific modelling” (Suárez 2010, p. 99).

Following Suárez’s work, I have recently argued that scientific representation is “necessarily communal” insofar as it “is not isolated from the practice in which it is embedded” (Boesch 2017, §3). Scientific representations, I argue, are ‘licensed’, i.e. established as representational by the broader scientific practice. Licensing is a complex “set of activities of scientific practice by which scientists establish the representational relationship between a vehicle and its target” (Boesch 2017, §4) and includes elements like “the context in which [the vehicle] was created, the application of theoretical and empirical constraints, the awareness of and management of idealizations, and the history of its reception and use” (Boesch 2017, §5). My point is that if you are going to understand how, why, and in virtue of what some vehicle is a representation in science, you cannot ignore its history, its development, and how it is understood and used by the broader scientific practice. Put more directly to the concerns at hand, an account of scientific representation must move beyond individual mental states and consider the broader practice in which representational actions are embedded.

1. Anscombe’s Account of Action

In selecting an account of action for the purposes at hand, it will be important that we follow the suggestions above to identify an account which pays attention to the broader circumstances and does not terminate in discussions about mental states. There are therefore reasons to shy away from the standard causal account which argues that actions are intentional in virtue of being caused by particular sorts of mental states (see, e.g. Davidson 2001). Such an account turns our attention inward to mental states, rather than outward to the circumstances and society in which an action occurs. Furthermore, the relevant mental states occur before the action actually takes place, meaning that “the subsequent ‘effects’—i.e., the actual performance or doing, is simply a matter of nature taking its course” (Frey 2013, p. 4). As Harry Frankfurt argues, the causal account thereby “direct[s] attention exclusively away from the events whose natures are at issue, and away from the times at which they occur” (1998, p. 70). Frankfurt’s criticism is particularly relevant given that we are attempting to offer an account of scientific, representational actions as they occur within the context of scientific practice, not of the mental states which precede these actions. As such, we will need a different account of action which pays closer attention to the actual action itself and which helps to show the way in which an action is embedded in a wider practice.

 G.E.M. Anscombe (2000) developed an account of intentional action which agrees with the basic point that actions are not intentional because of private, internal mental states. She is quite clear on this point, arguing that “intention is never a performance in the mind” (2000, p. 49). Instead, she argues that an investigation into intention must begin with the actions themselves: “The only events to consider are intentional actions themselves, and to call an action intentional is to say it is intentional under some description that we give (or could give) of it” (2000, p. 29). Put otherwise, the term ‘intentional’ does not have reference to a connection to internal mental states, but instead, “the term ‘intentional’ has reference to a *form* of description of events” (Anscombe 2000, p. 84). There is not room to discuss her account in much detail, but a brief overview of a few features will be of use in what follows.

 To understand what Anscombe means by the ‘form of description of events’, we must first get clear on a few key concepts. An action, she argues, can be described in several accurate ways. Consider a simple action, like when I get a refill on my cup of coffee as a reward and encouragement to finish a paper. It can be described as ‘getting a refill,’ ‘tipping a coffee pot,’ ‘activating certain neurons, neural regions, and nerves,’ ‘rewarding myself for finishing a section on my paper,’ (if there is a crack in my mug) ‘making a mess,’ and so on. We can distinguish between these descriptions through the application or non-application of “a certain sense of the question ‘Why?’” (Anscombe 2000, p. 9). The application or non-application of the ‘Why?’ question can be seen in the coffee refill example. Some of these descriptions are such that when asked why I am doing the thing described by that description, I will offer an answer—they are such that I will *not* refuse the ‘Why?’ question. So, for example, if you ask me ‘Why are you getting a refill?,’ I will accept the application of the question when I respond, e.g., that I am rewarding myself for finishing a section on my paper. However, you may also ask about descriptions to which I refuse application of the ‘Why?’ question (Anscombe 2000, pp. 11-13). For example, if you ask, ‘Why are you making a mess?” I may deny the application of the question by saying that I did not know that I was doing so. Genuine lack of awareness is one way that someone can deny the application of the ‘Why?’ question. Others include descriptions of something involuntary (e.g. activating certain neurons, since we cannot voluntarily activate specific neurons) as well as things which are ‘downstream’ from our action such that we cannot say that the agent is doing them now (e.g. getting tenure, since at the end of writing the paper I will not have tenure, even though the paper may very well ultimately contribute to my getting tenure).

 Suppose that, in the coffee example, there are three descriptions to which the ‘Why?’ question applies: (A) ‘Tipping the coffee pot;’ (B) ‘Getting a refill;’ and (C) ‘Rewarding myself for finishing a section.’ Anscombe argues that these descriptions have a unique formal connection to one another which is central to explaining the intentional nature of the action. Consider the following series of ‘Why?’ questions and answers:

 Why are you (A) tipping the coffee pot?

 (B) To get a refill.

 Why are you (B) getting a refill?

 (C) To reward myself for finishing a section.[[3]](#footnote-3)

There are two important things to notice about this example. First, Anscombe thinks that it is important that (A) is a means to the end of (B), and (B) is a means to the end of (C). That is to say that the reason or purpose in tipping the coffee pot is to get a refill, and the reason or purpose of getting a refill is to reward my hard work. Second, it is important to notice that (A) - (C) are not *separate actions,* but rather *separate descriptions* of one and the same action. In these contexts and circumstances, with the mug under the coffee pot (which is itself full of coffee), tipping the coffee pot *is* getting a refill, not a step toward getting a refill. Similarly, getting a refill *is* rewarding myself, not a step toward rewarding myself.[[4]](#footnote-4)

 We are now in a position to see what Anscombe means when she says that “the term ‘intentional’ has reference to a *form* of description of events” (Anscombe 2000, p. 84). The form is an internal means-end structure, in which the multiple accepted descriptions of one and the same action are ordered as means to ends. So, the intentional nature of an action has very little to do with internal mental states and instead has everything to do with the *structure* of the descriptions of the actions—which is itself understood within the broader context of the action since the contexts and circumstances (that the mug is under the coffee pot, that the coffee pot is full, etc.) are key in making it such that an earlier description (e.g. (A) tipping the coffee pot) is the same action as a later description (e.g. (B) getting a refill).

Furthermore, Anscombe argues that the broader context plays a central role in the agent’s practical reasoning which itself reveals “what good, what use, the action is” (Anscombe 2005, p. 114). So, to understand how and why an action is intentional, we must understand the aims of the action and how the contexts and circumstances connect certain descriptions accepted by the agent. So, for example, understanding how refilling coffee was intentional involves understanding my aims (rewarding myself), our society (that coffee is a desirable drink) and how the circumstances connect the descriptions—that the coffee pot is full, that the mug is under the coffee pot, that it is not leaking, and so on, are essential conditions to making it such that tipping the coffee pot (in this case) *is* an instance of refilling my mug.

 So, if we are going to understand the nature of scientific, representational actions as intentional actions in the Anscombean sense, we will need to pay careful attention to the *form* of the scientist’s action (the way in which descriptions are ordered as means to ends), the aims of the scientist (why she is representing—“what good, what use, the action is” (Anscombe 2005, p. 114)), as well as the circumstances in which she is acting, since these play a central role in structuring the form of the action.

1. The Means-End Account of Scientific, Representational Actions

There are two important demarcation projects in offering an account of scientific, representational actions. The first is to explain in virtue of what the actions are *scientific*, representational actions, i.e. how they are different from representational actions in other contexts. The second demarcation project is to offer an account of how the actions differ from other scientific actions, i.e. how the actions are scientific, *representational* actions. Each of these demarcation tasks will be conducted in terms of the “*form* of description of events” (Anscombe 2000, p. 84). Here, I will offer what I call the Means-End Account of Scientific, Representational Actions in which there are three features which hold of the form of the action which can jointly address the two demarcation questions and offer insights into the nature of the representational practices in science: (I) the final description in the means-end ordering of descriptions is some scientific aim (e.g. scientific explanation, prediction, theorizing, etc.); (II) that interaction with a vehicle distinct from its target (e.g. a mathematical model, diagram, figure, etc.) stands as an earlier description which is ordered toward the final description as means to end; and (III) the means-end structure is *licensed* by scientific practice, as I have previously described (Boesch 2017).

*6.1 Three Features of Scientific, Representational Actions*

 Before describing how these features which hold of the internal means-end structure of scientific, representational actions can answer the two demarcation questions and offer insights about scientific, representational actions, it will be useful to spend some time explaining each of the features and describing them in greater detail. A running example will be of use during this stage, so let us consider a scientist who is using a mathematical model as a representation of some target system, e.g. a scientist who uses the Lotka-Volterra equations to represent the population dynamics of a predator-prey system of foxes and rabbits. What is going on when the scientist uses the equations in this way? Like the example of getting a coffee refill above, there are several ways to describe her action. She could be described as ‘writing down numbers,’ ‘manipulating an equation,’ ‘analyzing dynamical features of the equation,’ ‘coming to an understanding of the dynamics of populations resulting from predator-prey interactions,’ ‘shaking the table,’ and so on. As before, some of these descriptions will be denied the application of Anscombe’s ‘Why?’ question: for example, perhaps she does not know she is shaking the table and so would deny this description of her action. Let us suppose that she accepts three of these descriptions of her action, offered in the following imagined series of ‘Why?’ questions and her replies to those questions. As before, the use of the ‘Why?’ question helps to reveal how these descriptions are all of one and the same action and ordered as means to ends.

‘Why are you writing down numbers?’

 ‘I am writing the equation in different ways.’

‘Why are you writing the equation in different ways?’

 ‘I want to analyze its dynamical features.’

‘Why are you analyzing the equation’s dynamical features?’

 ‘I want to understand the population dynamics which result from the foxes’ predation upon rabbits.’

Each representational action will have its own set of descriptions which may vary due to user, aim, or vehicle. But, assuming that each case of representational action is an intentional action, it will be subject to the same sort of analysis as above. The Means-End Account of Scientific, Representational Actions identifies the general features that will hold of the action’s internal structure.

Using the example, consider the first part of the Means-End Account: (I) the final description in the means-end ordering of descriptions is some scientific aim (e.g. scientific explanation, prediction, theorizing, etc.).[[5]](#footnote-5) In this example, the final description (understanding the fox-rabbit population) clearly counts as a scientific aim. Other scientific aims include, but are not limited to, things like scientific explanation, experimentation, theorization, prediction, alongside nonepistemic aims, including things like mitigation or practical implementation (Elliott and McKaughan 2014). I do not mean to offer a full and complete list of the potential scientific aims that can be present in scientific, representational actions. While the aims are in most cases easily identifiable, the only requirement is that the aim be recognized or accepted by the broader scientific community as a scientific aim.[[6]](#footnote-6) Thus, for example, suppose that the scientist in the example above was writing the equation in different ways because she realized that the pencil scratches matched the beat of her favorite song. Such an aim is patently non-scientific. The same is true if she is writing the equation in different ways as part of a piece of art she is making. The final description must be one which her fellow scientists would count as scientific.

It is also worthwhile noting that the aims of the scientific, representational action also supply a standard of normative evaluation for the action. Insofar as a scientist achieves her aims, her representational action can be considered successful. An action might be successful with regard to some aims and unsuccessful with regard to others. Given the wide range of aims allowed by the Means-End Account, there is room to understand a similarly wide range of normative measures of evaluation, including accuracy, predictive success, explanatory power, among others. The Means-End Account remains uncommitted to which normative standards and measures might apply in any given representational action, except that they must be understood in the context of the scientist’s aims. So, certain representational actions might take accuracy or correspondence as a normative measure of success, likely (though not exclusively) when the goals include knowing, understanding, or predicting. Such is the case, for example, with the representational actions involving scale-models, e.g. the Mississippi River Basin Model. Accuracy (in at least some respects) in the construction and use of the model allows for more useful predictions and a better understanding of the dynamics of floods in the Mississippi River Basin. There are other cases where accuracy or correspondence will neither be a success or a failure of a representational action. Such is the case for models of systems which do not exist—for example in attempting to understand the evolution of sex by studying non-existent biological species with three sexes (Weisberg 2007, p. 223). Here, there is no value to correspondence (since there could be no correspondence), though there is a value to explanatory power.

The second feature of scientific, representational actions is (II) that interaction with a vehicle distinct from its target (e.g. a mathematical model, diagram, figure, etc.) stands as an earlier description which is ordered toward the final description as means to end. In the Lotka-Volterra model, there were two earlier descriptions of interaction with the vehicle: writing the equation in different ways and analyzing the dynamical features of the equation. The relevant sense of ‘interaction’ in the second feature is meant to be left open, and includes things like analyzing an equation, writing an equation down, tracing fingers along a chart, examining and considering different parts of a diagram, altering variables in a simulation, and so on. As was the case with the relevant sense of scientific aims, it is important only that the form of interaction be recognizably useful in a scientific context by the broader scientific community. Minimally, the scientific community’s recognition will involve a reasonable expectation that the form of interaction will accomplish some scientific aim. Thus, for example, the scientist’s throwing of a crumpled piece of paper with the Lotka-Volterra equations printed on it is *not* a valid form of *scientific* interaction with the model since it would not help to accomplish any scientific aims.

It is important to note that the vehicle with which the scientist interacts must be distinct from its target. The purpose of this requirement is to incorporate the idea that representation is a non-reflexive relationship, meaning that any given vehicle does not represent itself (at least not for representation as it occurs within scientific practice). What counts as distinct for the purposes of the Means-End Account includes not only separate objects (e.g. a scale model to a river valley, a mathematical equation to a theoretical system), but also different perspectives on the same object. For example, interactions with a few model organisms (e.g. these three mice) can be used to draw conclusions about the broader species or sub-species to which they belong (e.g. *Mus musculus* or C57BL/6). Similarly, interaction with this sample of lead (if it is a representative sample) can be used to understand general features about lead as a whole. The distinction in both examples is sufficient to meet the requirement as explained by the Means-End Account.

The third and final feature of scientific, representational actions is (III) the means-end structure is *licensed* by scientific practice, in the sense I have previously described (Boesch 2017). As I described above, a representation is licensed through a complex “set of activities of scientific practice by which scientists establish the representational relationship between a vehicle and its target” (Boesch 2017, §4), including “the context in which [the vehicle] was created, the application of theoretical and empirical constraints, the awareness of and management of idealizations, and the history of its reception and use” (Boesch 2017, §5). Here, I am extending the notion of licensing to include the scientific, representational *actions* which undergird scientific representation. For actions, what matters is that the means-end structure itself be licensed; i.e. that the means is an accepted form of accomplishing the end. So, in the example above, analyzing the dynamical features of the Lotka-Volterra model is a licensed means of better understanding the relationship between predators and prey, including the specific fox-rabbit population at hand. However, suppose that the scientist was analyzing the dynamical features of the model but was aiming to understand the radioactive decay of some isotope of carbon. In such a case, while both her aim and means are scientific, the relationship between the means and the end is not licensed by the scientific community since the Lotka-Volterra model is not used to represent radioactive decay.[[7]](#footnote-7)

Bruno Latour (1999) has effectively described many of the elements of what I call licensing in the construction and development of a diagram. Latour describes in meticulous detail the many minute steps by which scientists move and abstract away from the target system of forest-savannah interaction in the construction of a diagram which represents that system. The task involves, for example, dividing the land into sections, sampling soil, describing colors, taking plant samples, and drawing many iterations of the diagram before it is completed. The use of the diagram as a means to gaining understanding or creating explanation about the forest-savannah system is, on my account, *licensed* by these many activities on the part of scientists which, as Latour so carefully describes, are themselves subject to the aims, norms, and theory of scientific practice. The same is true for the relationship between other representational vehicles as means and certain aims and goals: the mouse, as a model organism, is licensed to allow for certain tentative conclusions to be made about the efficacy and safety of human consumption of some pharmaceuticals; the Mississippi River model was licensed to make predictions about floods and the mitigation provided by the implementation of proposed flood-control systems in the river basin; Schelling’s model is licensed as a means of providing a potential explanation of the types of societal habits which can lead to segregation; and so on and so forth.

*6.2 The Demarcation of Scientific, Representational Actions*

 As identified above, there are two main ways in which scientific, representational actions need to be demarcated from other sorts of actions: (1) in virtue of what are they *scientific,* representational actions? and (2) in virtue of what are they scientific, *representational* actions? The Means-End Account addresses each of these demarcation questions.

 Let us consider first what makes these actions *scientific*. The answer here is to be found in all three parts of the Means-End account. Both the action’s aim offered in its final description and its means offered in an earlier description must be accepted as scientific by the broader scientific community. Furthermore, the connection between the means and the end is itself licensed by scientific practice. While representational actions in other disciplines (e.g. art) might utilize *similar* means and similar ends, they nonetheless are distinguished in virtue of being part of a different practice, constituted by a different set of aims, means, and set of licensing practices (Boesch 2017). On the Means-End Account, an action is scientific when it is informed and constrained by the practice of science, much in the same way that an action is a viable chess move when it is informed and constrained by the rules and practice of the game of chess. Some move, e.g. ‘Castling’, is a *chess* move in virtue of its relationship to the external rules of the game of chess and an understanding of its strategies and the practices that have arisen alongside the game. For the same reason, a representational action is scientific in virtue of its relationship to the external practice of science.

 Of course, there are a wide range of scientific actions beyond only representation. The Means-End Account must help also to demarcate scientific, *representational* actions from other sorts of scientific actions. The central point of demarcation is that actions described by the Means-End Account have *denotational form.* Denotational form is drawn from the notion of denotation, the standing-in of a representational vehicle for its target. Nelson Goodman, whose work on representation is often cited in discussions of scientific representation, argues that “denotation is the core of representation” (1976, p. 5). Several philosophers of science have similarly argued that denotation is an important part of an account of scientific representation (Hughes 1997, Elgin 2010, and Frigg and Nguyen 2016b). The Means-End Account does not make reference to a relationship of denotation that holds between the vehicle and the target, but rather makes reference to the denotational form that holds of the scientist’s action. Denotational form holds when an agent uses some vehicle as a stand-in for a target. Formally, this is present when there is one action with at least two descriptions (ordered as means to ends) in which the earlier description involves interaction with a vehicle and a later description involves the (potential) achievement of some end about the target. The Means-End Account describes actions which have denotational form, since features (I) and (II) require two different descriptions, one of an end to (potentially) achieve some aim about the target and the other of a means of interacting with the vehicle (which is distinct from the target found in the end).

 There are two important caveats to the notion of denotational form. The first is that denotation is a non-reflexive relationship. Thus, denotational form must incorporate the non-reflexivity, meaning there must be a distinction between the vehicle in the first description and the target in the second. However, as is the case with the Means-End Account, even a difference in perspective is sufficient to account for the necessary level of distinction (e.g. it is sufficiently distinct if interaction with these three mice allows for conclusions to be drawn about *Mus musculus* as a whole). The second important caveat about denotational form is that it relies upon a deflated notion of denotation, what Suárez describes as “denotative function” (Suárez 2015b, 44). A vehicle has denotative function provided it is the sort of thing which would denote its target, supposing that its target exists. The modification to the notion of denotation is useful for an account of scientific representation since it helps to explain how it is that vehicles with fictional targets are still representations. For the purposes of the Means-End Account, it helps to explain how it is that an action can have denotational form, even if the aims involve (potential) achievements about a fictional target system.

 The denotational form of a scientific action demarcates it from other forms of scientific action. Non-representational experimentation does involve scientific interaction with something and a scientific aim, but it does not have denotational form because it lacks distinction between the object of the interaction and the object of the aim. So, for example, an experiment designed to identify an unknown chemical lacks denotational form because the interaction occurs directly with the unknown chemical. Conclusions about the object of interaction (the unknown chemical) are not generalized to be about a broader species, but are instead about the unknown chemical itself.

 Of course, there are plenty of cases of experimentation (and other forms of scientific action) which do have denotational form. But this is because representation is deeply intertwined with many different forms of activities in science. As just one example, representation is a common element to many types of experimental design. Thus, experimental actions which have denotational form have it because the experimental method involves representation. So, for example, a public health experiment which uses a sample of some population to draw conclusions about the value of some health protocol utilizes representation as an essential feature of its design. The experimental design is such that the sample population is a representation of the larger population. Indeed, much of the work in experimental design in such cases is involved with obtaining a representative sample and collecting data which allows the scientists to show others that the sample is a meaningful representation of the larger population—both constituting the licensing in such a case. The denotational form of the action in this case points to the representational nature of the action, even if it is also a form of experimentation. Indeed, as I will discuss below, the Means-End Account is useful in helping to identify the ways in which representational actions can be brought into and united with other forms of actions in science, even while providing the tools by which we can identify what makes a representational action in science distinct from a non-representational action.

*6.3 Payoffs of the Means-End Account*

 Before examining some of the payoffs of the Means-End Account, it is important to pause and summarize what the account does and does not do. The Means-End Account does *not* offer an account of the nature of scientific representation. As such, it is not able to explain new cases of representation which other accounts could not explain. It begins with the assumption that some pragmatic account or group of accounts has already provided a good analysis of the nature and use of representation in scientific practice. Following on this assumption, it offers an analysis of a component which has been heretofore unexamined: the nature of the actions that undergird and ground representation for these accounts. The Means-End Account does not, therefore, explain how some model represents its target, though it does explain what it means to say that it is used representationally by some agent working in the context of scientific practice. The Means-End Account offers an account of the actions “carried out by those communities of inquirers involved in the practice of scientific modelling” (Suárez 2010, p. 99).

 The first payoff of the Means-End Account follows upon the very fact that it describes not the nature of scientific representation, but rather the nature of scientific, representational actions. Because it takes a different target for its analysis, the Means-End Account provides novel insights for our understanding of the important practice of representation in science. Whereas pragmatic accounts of scientific representation have terminated their discussion of actions by describing using, taking, making, inference-making, and so on, the Means-End Account gets to a deeper level by offering an analysis of the agential concepts from an action-theoretic perspective. It describes the conditions which hold of the internal structure of representational actions in science. Such an account is useful for a few reasons. One is that it offers a stronger theoretical ground for pragmatic accounts of scientific representation, by filling in some of the undescribed details about the nature of the agency which grounds these accounts—for example, by explicating the relationship between normative standards and the context of use. It can also be of use in analyzing instances of representational use associated with particular vehicles and particular aims. For example, when analyzing the representational use of some diagram, the Means-End Account can be of use in analyzing the representational action, specifically with regard to how the action in this case differs from the scientific and representational actions in other cases. Most importantly, though, is that the Means-End Account offers a significant step forward in an attempt to gain a more complete grasp of the practice of representation within science. A more complete account of the practice of representation in science will explain not only the nature of scientific representation, but also the strategies and features scientists use (e.g. similarity and other structure-preserving mapping relationships), the classes of representational vehicles used and particular case studies, and, now, with the Means-End Account, the nature of scientific, representational actions.

 As I mentioned above, the Means-End Account can be of use in understanding how other forms of scientific activities (like experimentation) utilize representation, since it points to the way in which representation is deeply intertwined with other scientific activities. According to Anscombe, there are two ways we might think of a single action with multiple descriptions. One of these recognizes that each description is a full characterization of the action and can be used to describe the action as a whole. The alternative way of understanding an action with multiple descriptions is to recognize that there is a particular eminence to the final term in the series of descriptions. As Anscombe says, “the last term we give in such a series…so to speak swallows up all the preceding intentions” (2000, p. 46). So, if we are going to offer one and only one description of an action, the most proper description is the final description of the internal means-end structure. According to feature (I) of the Means-End Account, all scientific, representational actions take as their final description some scientific aim (e.g. explaining, understanding, knowing, predicting, etc.). As such, successful instances of scientific representation are not merely cases of representation, full stop. Indeed, there is no such thing as successful scientific representation which is not also properly describable as some other scientific activity, as an instance of understanding, knowing, explaining, predicting, exploring, discovering, and so on.

 The reason for the intricate connection between representation and other scientific activities is connected to the way in which the Means-End Account understands representational actions of science in terms of their *form*. On the Means-End Account, representational actions occur when an action best characterized by its final description (e.g. explanation, prediction, etc.) meets certain formal requirements regarding the ordering of descriptions and the relationship between them. As such, representation takes on an ‘adverbial’ function within scientific practice: scientists understand *representationally*, explain *representationally*, discover *representationally*, experiment *representationally,* and so on. On the Means-End Account, then, representation turns out to be one of the ways in which the many types of scientific activities occur.

 There are a couple of useful consequences to this final insight about scientific, representational actions, each of which could be more fruitfully explored in future work. For one, it suggests that there may be interesting forms of strategies associated with representational forms of certain types of activities. For example, explaining representationally might employ certain techniques that discovering representationally does not employ (and vice versa). It is possible, therefore, that studies of representation could be classified not in terms of classes of vehicles (e.g. models, simulations, diagrams, etc.), but rather in terms of classes of activities (e.g. explaining, understanding, predicting, etc.). Saying anything in detail about these differences will require a closer analysis of the practices associated with these forms of activity, perhaps including an analysis of case studies. The Means-End Account offers the tools to be able to perform such an analysis which will offer insights about a wide range of scientific practices.

1. Conclusion

 In this paper, I have taken seriously the suggestion offered by a wide number of philosophers of science in recent years that representation in science must be understood in terms of a scientist’s agency, actions, and activities. I argued that in order to have a more complete picture of the practice of representation in science, it is important to offer an account of scientific, representational actions. Following some guidelines already present in the literature on scientific representation, I argued that Anscombe’s account of intentional action has the right sorts of features to be able to fit with the other pragmatic accounts of scientific representation which have already been offered. Following her insight that intentional refers to the *form* of description of events we give to an action, I argued that scientific, representational actions have three features which help to demarcate them from other sorts of actions. The Means-End Account of Scientific, Representational Actions contributes to a more thorough picture of the practice of scientific representation, by offering a novel account of the scientific, representational actions. It also points to the potential for future work on the way in which representation is intertwined with other forms of actions in science.

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1. While van Fraassen and Giere have often been interpreted as holding dyadic accounts of scientific representation in the form of isomorphism and similarity in their early work, Suárez (2004, p.768) has pointed out that they each give importance to the role of a user even in their early work. Van Fraassen agreed with Suárez’s assessment, arguing that he always left room for pragmatics, and only makes it more explicit later on (see Ladyman, Bueno, Suárez, and van Fraassen 2011, pp. 443-444). [↑](#footnote-ref-1)
2. Other alternatives to a substantive account include denying that there is any such thing as representation in science, suggesting that instead there is a mere family of resemblance of a set of practices (see Lynch and Woolgar 1990). Giere (1994) and Knuuttila (2014) criticize this ‘no-representation’ approach. Another alternative is to offer an account of representation which applies to all disciplines in which it is found. Craig Callender and Jonathan Cohen (2006) make such an argument in terms of internal mental states. For a criticism of this account, see my response to their work (Boesch 2017). [↑](#footnote-ref-2)
3. You could of course ask why I am doing (C). But at a certain point, the answer to this question is too far ‘downstream,’ as the example of ‘getting tenure’ shows (Anscombe 2000, 38-40). [↑](#footnote-ref-3)
4. This depends a bit on what I assume the reward to be. I am assuming it is the refill of the mug (and not drinking the coffee) because I often count a refill a reward and do not then drink from it. If you find this contentious, you can consider Anscombe’s more detailed water pump example (2000, 37) which is not subject to the same ambiguities. [↑](#footnote-ref-4)
5. Note carefully that the multiple describability of actions, on Anscombe’s account means that there are many ways to describe any given action, but this does not further imply that either (1) every action has multiple aims in its descriptions nor that (2) the descriptions are purely arbitrary. [↑](#footnote-ref-5)
6. I make this point to avoid offering normative restrictions on scientific practice, especially as it changes and evolves going forward. I take it that the scientific community at any given stage will be the best judge (even if fallible) of what counts as a scientific aim. [↑](#footnote-ref-6)
7. In some cases, representational vehicles will be used in novel ways (e.g. in the transfer of a model between disciplines). In such a case, the licensing of the representational action is given through the scientist’s application of theoretical and empirical constraints to her action (for more on this point, see Boesch 2017). [↑](#footnote-ref-7)