The Point of the Matter: Performativity in Scientific Practices

Maaike Bleeker and Jean Paul Van Bendegem

Introduction

Laura Karreman

The conference *Does it Matter? Composite Bodies and Posthuman Prototypes in Contemporary Performing Arts* (Ghent University, 2015) featured a 'keynote dialogue' between performance scholar and philosopher Maaike Bleeker (Utrecht University) and mathematician and philosopher of science Jean Paul Van Bendegem (Free University of Brussels). Speaking from their respective areas of interest and expertise, Bleeker and Van Bendegem discussed various examples of scientific processes that exposed performative mechanisms resulting from the entanglement of technological tools and human agency—a dynamic that is a characteristic feature of scientific practices.

M. Bleeker (✉)
Utrecht University, Utrecht, The Netherlands
e-mail: M.A.Bleeker@uu.nl

J. P. Van Bendegem
Vrije Universiteit Brussel, Ixelles, Belgium
e-mail: jean-paul.van.bendegem@vub.be

C. Stalpaert et al. (eds.), *Performance and Posthumanism*,
https://doi.org/10.1007/978-3-030-74745-9_12

The dialogue of Bleeker and Van Bendegem was enriched by the fact that both scholars share a special interest in the other's research area. Bleeker's curiosity about performative processes of the scientific domain is reflected in the analysis of the 'hunt for Higgs' (Bleeker and Van der Tuin 2014), which shows how the Higgs particle was 'made to perform' in a scientific practice that involves types of both human and non-human agency. Van Bendegem's interest in drawing connections between mathematics and performing arts practices has led him to engage with prominent figures in this field, such as Belgian choreographer Anne Teresa De Keersmaeker and theatre maker Kris Verdonck. Inspired by these and other interactions he is concerned with exploring new avenues of thought, by looking at possible parallels that may be drawn between practices of knowledge transmission in the arts and sciences.

The way in which Bleeker and Van Bendegem's dialogue has taken shape in this chapter is the result of a thought experiment, which was designed specifically for this volume. The aim of this experiment was to enable an in-depth exploration of the three main topics that surfaced in Bleeker and Van Bendegem's original dialogue at the conference, which related to knowledge production, knowledge transmission and the impact of specific practices in artistic and scientific domains. In the set-up of the thought experiment, the format of a dialogue was maintained, for this volume, the dialogue was shifted from the oral domain to the realm of writing. Both philosophers wrote three individual reflections, in which they demonstrated how the three aforementioned epistemological topics come alive in their respective areas of critical inquiry. In the final stage of this extended written exchange, each of them presented some closing thoughts in response to their interlocutor's reflections.

The outcome of this thought experiment materializes here in two parts. In the first part Bleeker and Van Bendegem individually relate to the three topics: knowledge production, knowledge transmission and the complex collaboration of technological and human agents in scientific and artistic practices. The second part of the text consists of their closing reflections, in which they respond to each other. The resulting dialogue is a dynamic exploration of thought and practice in philosophy, sciences and the humanities. Time and again in this dialogue, it becomes apparent how one thought inspires another to unfold. A surprising reciprocity between these two thinkers emerges in the process.

The Problem of Knowledge Production: Finding or Constructing Proof

Jean Paul Van Bendegem

Philosophy of science has undergone some major changes in the twentieth century. No one will disagree with this near-tautological statement. Instead of focusing on the results—theories, laws, predictions (seen as logical derivations), machines…—the whole scientific process came into view, which introduced a vocabulary of revolutions (Thomas Kuhn 1962), incommensurability (Paul Feyerabend 1975), logic(s) of discovery (Tom Nickles 1980), social determinants (David Bloor 1976; Barry Barnes 1977) and scientific practices (Andrew Pickering 1995). One particular set of practices concerns the gathering of evidence and/or the construction of proof. As to the former, we can no longer speak of collecting the facts, whatever they are, assuming that they are out there waiting to be found by us. And, as to the latter, proof in terms of final, objective justifications is no longer defensible in the fields of logic and mathematics, as they have undergone similar changes as the philosophy of science. Let me elaborate on this a bit further.

"We found evidence that …" seems quite an innocent start of a phrase but it carries with it a world view that accepts (at least) that (i) there are things to be found, (ii) they somehow draw our attention, (iii) we register them, and, most importantly, (iv) they do not involve us. The last point needs clarification. What I mean is that whatever is found is not influenced by us in any way—we are here, what is to be found is over there—and, by consequence, it does not matter who finds it. It is objective in (at least) this particular sense. Perhaps in a small set of cases we can act as if this is the whole story (or, should I say, the whole truth). Take any handbook of classical mechanics. Look for the chapter on collisions. The pictures do seem to depict the world as we find it (sorry for the cheap Wittgensteinian-*Tractarian* reference!): two masses collide, one does this, the other one does that (and they are determined to do so). That is precisely what textbooks are supposed to do: to let us believe that what works for the small set works for the whole. But does it?

"We have found evidence that the Higgs boson exists". Have we? Firstly, we constructed a machine of staggering complexity, the L(arge) H(adron) C(ollider), that involves nearly the whole of physics, mathematics and computer science, that involves a community of technicians, scientists and managers to maintain the instrument, to "keep it alive"—I dare use these terms because, after a check-up, the LHC is "activated" again—and that requires an environment where it can "survive", economically, socially and politically. Secondly, experiments are performed and "performance" seems to be the right term, in the sense that what happens is partially ritualized, often codified, and it takes place on a particular stage, in this case, an underground laboratory. There is nothing to be seen; only the dials and the digits inform us that something has happened and that it has been measured by the LHC. Note that the plural is correct: we do not talk about a single experiment but millions of them. Thirdly, all this "raw" material—is that still an appropriate term?—is sent through the "grid", a network of computers worldwide, making use of existing networks, to perform the most amazing calculations of a statistical nature (more about mathematics in the next section), and then to return to Geneva to produce graphics on screens. Fourthly, these drawings, for that is what they are, need to be interpreted, basically, "meaningful" spikes in the picture need to be traced. If at the "right" location, the spike "becomes" a trace of a Higgs boson and we proudly claim: "We have found it!" Have we really? We made it, we constructed it, we manufactured it, we created an environment where it could manifest itself… All these Latourian phrases seem more appropriate.

"Ah yes, but we can prove that it is the Higgs boson". Better still: "We can prove it with mathematical certainty!" Why? Because mathematical proof is the best you can imagine. Why? Because each and every step in the reasoning process has been made explicit and can be checked by everyone, even computers can do it. Except that proofs of such high quality are not what mathematicians produce, at least when the level of complexity is sufficiently high. The "real" proofs contain gaps, make large jumps, rely on the reader's background knowledge and often leave the logical principles implicit. Gottlob Frege, Bertrand Russell and Alfred North Whitehead, the Bourbaki group, all had a go at a complete version of (the language of) the mathematical universe. They encountered the same problem that Esperanto did: any language that is too universal is spoken by no one in particular. If statistics become involved, then the matter becomes even more difficult, for now we have to interpret probability statements. Of course, it is certain that an "honest" (really?) die has a chance of 1 out of 6 to produce a 3. (Unless someone with a hammer is present.) This still leaves us with the question: But how are proofs found?

Certainly not in this world of ours, so where then? Our imagination? But is that a "place" where things are "found"?

The Problem of Knowledge Production: Making Matter Perform

Maaike Bleeker

The hunt for the Higgs particle presents a most interesting example indeed of how to prove something is a performance, or actually a constellation of performances, by humans as well as by their instruments and matter. At the press conference announcing CERN's success in proving Higgs' theory, Rolf-Dieter Heuer, the director of CERN, announced the discovery of the Higgs particle by saying: "As a layman I would now say, I think we have it, do you agree?" His announcement followed an explanation of the complex probability calculations that form the basis for this statement. It is a remarkable and complicated statement, for what is actually being confirmed, or negated, by Heuer's speech act? Framing his statement by saying "As a layman I would say" is ironic. Obviously, the director of CERN is not a layman. At the same time, his statement could be understood as a way of reaching out to an audience of non-specialists, explaining that the probability calculations are physics' way of saying: "I think we have it".

These probability calculations require capacities that exceed those of humans and can only be performed by extensive networks of computers on the basis of data captured by sensors sensing what humans cannot perceive. These sensors and computers open up what media theorist Mark Hansen calls "an expanded domain of sensibility that can enhance human experience" (2015, 4). To access this domain of sensibility, "humans must rely on technologies to perform operations to which they have absolutely no direct access whatsoever and that correlate to no already existent human faculty or capacity" (2015, 4–5). This performance of technology is the basis for Heuer's claim that "As a layman I would now say, I think we have it. Do you agree?"

Peter Higgs, sitting on the front row, sheds a tear. Fifty years and billions of money have been spent to produce the proof of the theory he penned down as a still relatively young and unknown scientist. And now the proof is there. Or is it not? For, what is Heuer actually saying? As a scientist these calculations convince him to the point that as a layman he would say: "I think we have it". But apparently this is not enough for him as a scientist, for it is followed by a question directed to his audience of fellow scientists present at the presentation: "Do you agree?" Their applause confirms his statement and the validity of the claim expressed in it. The existence of the Higgs particle is thus presented as a matter of probability that requires an additional performance, namely that of inter-subjective confirmation, to be acknowledged and accepted as truth. With their applause, the community of scientists not only expresses its participation in this moment of celebration; it also performs the confirmation of the validity of the decades-long process of producing this 'proof' of Higgs' theory.

The calculations that are thus confirmed to be proof demonstrate the probability of the success of another performance of technology, namely that of the Large Hadron Collider, to produce a particle that performs according to the parameters predicted by Higgs' theory. Proving Higgs' theory meant literally to make matter perform in the way that Higgs had predicted the particle named after him would. This was not a matter of detecting the existence of the particle 'out there' but to first produce the particle and then detect the traces of it having existed. The proof of Higgs' theory thus demonstrates the inseparability of scientific apparatus and the phenomenon observed, as theorized by Karen Barad (2007) after Niels Bohr. Bohr's philosophy of quantum physics challenges the assumption that processes of measurement are transparent and that measurements reveal the pre-existing values or properties of independently existing objects as separate from the measuring apparatus and the observing agencies.

Demonstrating the truth of Higgs' theory meant to design an experiment in which the Higgs particle—"the missing piece in the Standard Model puzzle", as the press release of the Royal Swedish Academy of Sciences announcing the Nobel Prize in Physics for 2013 puts it[1]—is challenged forth as matter (even though its ultra-short existence can only be detected after the fact by detecting the traces of its decay). This challenging forth happens by means of apparatuses constructed to make matter perform while at the same time it is within this performance that the Higgs particle is supposed to materialize. In the collider, nature is made to perform and made to perform in such a way as to produce the proof of Higgs' theory, which is also the proof of the collider's intended efficiency. In order for the experiment to be successful, the Higgs particle therefore has to perform too. It has, to use performance theorist Jon

McKenzie's (2001) felicitous expression, to "perform, or else" it does not exist. And it has to perform within the parameters according to which the detectors are designed to detect its traces.

Bohr's insights have important epistemological as well as far-reaching ontological implications. "What he is calling into question is an entire tradition in the history of metaphysics: the belief that the world is populated with individual things with their own set of determinate properties" (Barad 2007, 19). Moreover, Barad shows how Bohr's ideas also challenge traditional humanist accounts of knowledge and of knowing as something done by a self-contained rational human subject. Rather, she argues, "Knowing is a distributed practice that includes the larger material arrangement. To the extent that humans participate in scientific or other practices of knowing, they do so as part of the larger material configuration of the world and its ongoing open-ended articulation" (379).

Large-scale highly technological research projects such as the hunt for Higgs at CERN involve complex constellations of scientists and their instruments in which human researchers are literally nodes in networks that operate on a scale and in cognitive modes that exceed human understanding. These 'agencies of observation' (another Baradian term) do not perform on their own. Rather, groups of humans and technology form complex assemblages of actors (human–machine-matter-data) intra-acting with one another in various ways. Barad uses the term 'intra-actions' rather than 'inter-actions' because the latter would suggest something happening in between already existing entities and her point is that these intra-actions precede the existence of what they relate. It is through intra-actions that things come to matter. Understanding the implications of this inseparability requires a radical posthumanist performative approach that takes into account the performance of humans as well as of instruments and matter, and the complex intra-actions between them.

Re-Imagining Knowledge Transmission: From One-Way Channels to Open-Endedness

Jean Paul Van Bendegem

Transmitting knowledge: How to imagine this? Should we keep life simple and accept the sender – channel – receiver (S – C – R) model and calculate, as Claude Shannon has done, the informational entropy of the message so as to reduce the errors where error means any syntactical difference between the sign(al)s at S compared to the sign(al)s at R? I am not downplaying the importance of this model, for it allows us to get a signal on the iPhone as it is enhanced by electronic means (hence the metallic sound) to be understandable. It also allows us to enjoy that CD, although it contains a high number of errors in its digital code. But even under the most classical (= analytical) definition of knowledge as *justified, true belief*, this does not fit the model. So, how to imagine this?

A teacher teaches a pupil (a bit of) mathematics, say the Pythagorean theorem, the infamous $a^2 + b^2 = c^2$. Why? The teacher is a trained mathematician who has a set of beliefs, among them the conviction that it is vital that everyone has some mathematical knowledge and hence the next generation should know this, so the teacher has a preconceived, possibly if not likely a biased, conception of the pupil. He or she has been trained to use certain procedures, ways of doing and practices to transmit this knowledge. Usually these procedures operate both sequentially and in parallel: body language, spoken words and signs, written words and signs… These procedures should create understanding and meaning in the pupil's head. The pupil may or may not have a clue why this piece of information is important as he or she is not a mathematician and has a different set of beliefs, including the belief that the teacher knows what he or she is talking about. Nevertheless, the pupil is supposed to be willing, "wanting" to learn. The innocent phrase "Consider a right-handed triangle" betrays a world of intricate language games: how is one supposed to do "the considering", will any right-handed triangle do? (If the figure on the blackboard has to be manipulated it cannot be any size, likewise a triangle consisting of the North Pole and two points on the equator ninety degrees apart will not do because it is curved, assuming, by the way, that the Earth is a perfect sphere, which it is not.) Is the labelling a, b and c necessary, …? These considerations are not figments of my imagination as I have been able to show (in the context of an exhibition on mathematics and art, titled *0/10*[2]) what happens when one or more of these background conditions are violated. What happens if the teacher is incompetent? What happens if the teacher is a sex worker? What happens if other signs (musical signs, choreographic patterns, real objects such as people and chairs…) are used? The results are often humorous because expectations are violated and "damage" the mathematical proof. It ceases to be "convincing".

Let us resist the temptation to make the model more complex although it is an obvious strategy. We should take into account the model in the minds of S and R of the whole process, thus introducing a form of reflexivity because how they view the transmission process influences that very process. We could continue and defend that a knowledge transmission channel is never uniform, thereby allowing us to see it as just one unique channel, so rather we have a heterogeneous series of channels operating in parallel. All too soon we will be writing down expressions such as

$$S_{S'-C'-R'} - (C_1|C_2\ldots|C_n) - R_{S''-C''-R''}$$

that look like an improvement but now error-correcting codes are not of much help. Getting a message faithfully from S to R appears now as something close to a miracle. Or, if you prefer, most messages are distorted one way or another. But what should we do then? Let us start again.

Transmitting knowledge: How to imagine this? The expression "transmitting knowledge" suggests a direction (from S to R in the simple model) and is quite passive, as what is transmitted is supposed to remain unchanged. So, if instead of "transmitting" we emphasize the two-way direction, then terms such as "sharing", "creating together", "experiencing together"…come to mind and, rejecting passivity, terms such as "constructed meanings", "collective practices"…pop up, and how different is the sound of "creating collective practices together" or "sharing constructed meanings"? And now the real drama can begin. The collective meaning creation in a group of scientists will differ from that among scientists and "ordinary" citizens and will differ in turn from that among citizens and scientists-as-citizens, and among this and the next generation and … Perhaps "drama" is not the right choice of words (for "drama" suggests a beginning and an end, maybe even an unfolding, and this need not be the case). Is not "open-ended" a better choice? It resists both a genesis as a comforting and explanatory device and it also resists an end-goal to be reached no matter what, which dictates the (preferably unique) road to follow. That sounds familiar: not knowing where you came from, not knowing (not even wanting to know) where you will arrive, is that not simply called wandering from passage to passage, through the arcades, Benjamin-like (also unfinished)?

Re-imagining Knowledge Transmission: Re-enactment as a Non-representational Approach

Maaike Bleeker

In his *The Idea of History* (originally published in 1945), philosopher of history Robin Collingwood proposes re-enactment as a perspective on sharing thoughts and ideas. With re-enactment he does not refer to redoing past events, like re-enactments of historical battles or the redoing of performances from the past created by performance and dance makers. Rather, re-enactment is part of his speculative approach to possibilities of understanding the choices and decisions made by historical agents and how these have resulted in history as we "know" it. To this end, he argues, historians must envision the situation with which the historical agent was trying to deal and then imagine the reasons for choosing one course of action rather than another, and thus go through, or re-enact, the process the historical agent went through in deciding on a particular course.

Collingwood has been criticized for mixing up the ideas of the historian re-enacting the situation from the past with those of the historical agent involved in the historical situation. And indeed some of his examples do suggest precisely that. Other examples, however, allow for a different reading, one that is surprisingly close to contemporary enactive approaches to perceptual cognition. One of these examples is that of Archimedes and his insight into the law of special gravity. Getting the idea of gravity, Collingwood explains, involves grasping the relationships observed by Archimedes between mass and volume of an object, an insight that, history tells us, occurred to Archimedes while taking a bath (Collingwood 1993, 287, 444–446). Getting the idea of gravity thus involves a kind of re-enactment of grasping this set of connections perceived by Archimedes as a result of which we 'get' his idea. This does not require taking a bath, nor is it about getting a better understanding of the historical person Archimedes and his situation. Rather, it is a matter of grasping the logic perceived by Archimedes and in this sense re-enacting his idea.

Re-enactment thus understood presents a non-representational approach to the transmission of knowledge and ideas, in which transmission is not a matter of transporting some independently existing entity from one person to the next but rather the result of a grasping, or what Whitehead (1978) describes as a prehending of, the logic also grasped by someone else. In such grasping, the idea is re-actualized. From the perspective of such a non-representational approach, the transmission of ideas is a matter of organizing the conditions for them to be triggered in someone else and thus be rearticulated. This is, one might argue, what Jean Paul Van Bendegem experiments with in his exhibition project *0/10* mentioned above, in which he explores the effects of changing the conditions of transmitting the Pythagorean theorem.

Re-enactment as a perspective on knowledge transmission shifts attention from representation to enactment: to what happens in the doing, to embodiment and materiality. How such doing is constitutive of grasping even highly abstract principles is the subject of Gilles Châtelet's *Figuring Space: philosophy, mathematics, and physics* (2000), Elisabeth de Freitas and Nathalie Sinclair's *Mathematics and the Body* (2014) as well as Brian Rotman's reflections on research into the transmission of mathematical insights by Nemirovsky and Ferrara. Rotman describes how:

> by tracking the moment-to-moment eye movements (saccade gestures) of a group of mathematics students arguing about, notating, and engaging with real and imagined diagrams, Nemirovsky and Ferrara found the students' thinking to encompass 'parallel streams of bodily activity' manifest as a 'coordinated activity among hands, eyes, and talk in the process of expanding, or bringing into the open, aspects of visual meaning' (2004), an organic notion that leads them to concur with the thesis that 'children's thinking' and hence human thinking in general, 'is more akin to an ecology of ideas, co-existing and competing with each other for use, than like monolithic changes from one stage to the next'. (Rotman 2008, 34)

Bodily engagement and movement, this research into cognition suggests, is not only part of how we understand what other people are doing and feeling but also of grasping highly abstract ideas. It is part of how we participate in processes of producing and sharing knowledge by navigating ecologies of ideas with and through our bodies.

Knowledge Production in Practice: What Mathematicians Do

Jean Paul Van Bendegem

Any mathematics handbook will have problems in the exercises section that start with "Show that …" or "Prove that …" An example: "Show that the sum of the first hundred natural numbers 1, 2, 3, …, 100 is equal to 5050". There is an easy way to solve the problem: do the actual counting (and the answer will be yes, it is equal). There is another way, just by looking at this figure:

$$\begin{array}{cccccccc} 1 & 2 & 3 & \dots & \dots & 98 & 99 & 100 \\ 100 & 99 & 98 & \dots & \dots & 3 & 2 & 1 \\ 101 & 101 & 101 & \dots & \dots & 101 & 101 & 101 \end{array}$$

On the second line the numbers are written in descending order and if the sum is made for each pair in the first and second line, the answer is always 101. So we have counted 101 a hundred times so that is 10100 but we have counted the required sum twice, so divided by two, hence 10100/2 = 5050. (This "proof" is claimed to have been found by Carl Friedrich Gauss, a young boy at the time, who thus "proved" his mathematical talent.)

If the handbook is on number theory, very likely the next exercise will be: "Generalize the previous result and prove that $1 + 2 + 3 + \dots + (n-1) + n = n.(n + 1)/2$". Would one not be tempted to simply generalize the scheme above?

$$\begin{array}{cccccccc} 1 & 2 & 3 & \dots & \dots & n-2 & n-1 & n \\ n & n-1 & n-2 & \dots & \dots & 3 & 2 & 1 \\ n+1 & n+1 & n+1 & \dots & \dots & n+1 & n+1 & n+1 \end{array}$$

So n times $n + 1$, but we double counted, therefore, $n.(n + 1)/2$.

But is that what mathematicians do? It depends on the handbook. Some of them will insist that a "clear" method of proof should be used such as *mathematical induction* and that produces a curious kind of reasoning that goes like this: if I can prove that the claim holds for $n = 1$, and if I can prove that if the result holds for n, then it also holds for $n + 1$, then I can conclude that it holds for all numbers n. The proof now looks like this:

1. For $n = 1$, we see that $1 = 1.(1 + 1)/2$ and that is correct.
2. Assume $1 + 2 + 3 + \ldots + (n–1) + n = n.(n + 1)/2$. Add $n + 1$ to both sides, to find $1 + 2 + 3 + \ldots + (n–1) + n + (n + 1) = n.(n + 1)/2 + (n + 1)$. The expression on the right is equal to $(n + 1).(n/2 + 1) = (n + 1).(n + 2)/2 = (n + 1).((n + 1) + 1)/2$ and that is the same expression as before but with $n + 1$ in the place of n.

So it holds for all n. QED.

Do note that in (1) we did not sum anything; there is only the number 1 (how do you add one number unless you are a Taoist, while clapping your hands?) and nothing else. Is it meaningful then to talk about the sum of so and so many numbers? Would you not at least expect there to be two numbers? And do note that in (2) we have done something entirely different from what Gauss did and what a simple but long-winded calculation would show. And do note in general that the above is considered to be elementary mathematics. Is not the complexity at this stage already overwhelming? Questions come easily: (a) Why is mathematical induction a reliable proof method? (b) What exactly does the symbol "n" mean that we use (d) it so freely? (c) Is this really meant to be convincing? Conversely, the answers do not come easily at all. Ad (a): philosophers of mathematics are still discussing the matter because any justification of the method creates vicious circles. Ad (b): it would be better to use the plural because we indeed use "n" in different ways in the proof but at the same time it is crucial to distinguish n from $n + 1$. Ad (c): it surely is convincing to mathematicians, among other reasons because they are familiar with the method and have seen the wonderful stuff one can do with it. In summary: What a curious rhetorical process is manifesting itself here! May I repeat that we are still on the level of elementary mathematics?

What happens when we move to full-scale academic research mathematics is staggering. In a single phrase (and referring back to the first question): a mathematical proof is no less complex than a Higgs boson. The innocent-sounding message "Andrew Wiles proves Fermat's Last Theorem"—in *Tractarian* fashion we have a fact, establishing the connection "to prove" between objects, named "Wiles" and "Fermat's Last Theorem"—when deconstructed transforms into a complex multi-faceted set of pictures of mathematical communities, implicitly deciding what problems are interesting, sharing methods, sharing strategies to "find" proofs, arguing about the correctness of a result, re-examining accepted proofs because of doubts… No wonder, really, that the applicability of mathematics to the "real" world out there has become a mystery (and for the moment remains so) and then I have not said the first word about the most curious mathematical invention of all times: infinity.

Knowledge Production in Practice: Collaborations Between Technological and Human Agents

Maaike Bleeker

In large-scale research projects, like, for example, the Large Hadron Collider at CERN, human researchers and machines function as nodes in large interactive networks that operate on a scale and in cognitive modes that exceed individuals and exceed human modes of thinking and understanding. It was human intelligence that built the machines. However, being the product of complex collaborations of large groups of experts, the capacities of the machines nor the measurements produced by them can be understood as being controlled by individual human agency. Furthermore, a large amount of interpretations needs to have already been made by the machines before human agency is able to engage with the data and in processes that exceed human capacities. This raises questions concerning the relationship between human agency and technology and of technology as itself endowed with agency. Here it seems that explorations from the field of theatre and dance could contribute to further understanding the relationship between human and technological agents in the production of new, posthuman modes of knowing.

Over past decades, a considerable number of theatre and dance makers have experimented with outsourcing agency and making technology an active agent in creative processes. John McCormick's project *Emergence* (presented at the conference *Does it Matter? Composite Bodies and Posthuman Prototypes in Contemporary Performing Arts*) features collaborations between a human dancer and an artificially intelligent performing agent. The agent is not explicitly programmed with set behaviours, as in more traditional software programming. Instead, its capabilities originate in the unsupervised learning process and have the inter-dependent relationship with the dancer embedded in that learning.

Several decades ago already, Merce Cunningham began to use the computer programme *Life Forms* to create choreographies. More recently, the British choreographer Wayne McGregor's *Choreographic Language Agent* and the *Enhancing Choreographic Objects*, as well as the Croatia-based dance and performance collective BADco.'s *Whatever Dance Toolbox,* similarly aims to provide technological tools that can act as active agents in creative processes and become co-creators (see Bleeker [2017]). New York-based artist Annie Dorsen investigates the potential of algorithm as a creative agent. In *Hello Hi There* (2010), she staged a dialogue between two autonomous chat bots, using the famous television debate between Michel Foucault and Noam Chomsky as inspiration and material. In *A Piece of Work* (2013), algorithms create an on the spot re-interpretation and rewriting of *Hamlet* and instruct a performer to execute the performance.

Art projects such as McGregor's, Dorsen's, BADco.'s and McCormick's (and there are many more) continue a longer history of theatre and dance artists devising ways of working that aim to diminish their control over the creative outcome and to distribute agency, for example by means of chance procedures (throwing the dice, using I Ching) or by means of various improvisation techniques. Different from these historical predecessors, however, is how they explore the possibilities and implications of technology becoming an active agent in creating. This is also what distinguishes their work from many other explorations of the use of new technologies on stage, in which technology appears as merely a means used by a human agent to give shape to her or his creation.

In projects like these, technology is not merely something used by a creative agent, but is itself an agent in the creation process. Technological agents create differently than the artists do. This difference is precisely the reason for artists to invest in these ways of working and in the development of technological agents. An important reason for these artists to develop these technological agents and to collaborate with them is how this opens up possibilities for moving beyond the subjective perspective of the artist and even, one might argue, beyond human modes of imagining and creating. In this respect we might understand these projects as contributions to the development of new, posthuman perspectives, where posthuman does not mean the absence or doing away with the human, but refers to a decentring of human agency, and to acknowledging the implications of such decentring. In dance and performance, the aim is to generate artistic creation. In science projects, the aim is to generate knowledge. This is an important difference. This difference might be productive, however, precisely in how the artistic projects invite different ways of understanding the agency of technology and of the potential of collaboration between human and technological agents. Their work demonstrates an understanding of agency as, to speak with Karen Barad, not something that someone or something has, but as a distributed phenomenon that is enacted, and that can be enacted by humans as well as by technology.

Some Further Thoughts, Rather Random, yet Organized

Jean Paul Van Bendegem

After reading Maaike Bleeker's responses (MB for short from now on) to the three questions put before us, I was deeply and happily struck by the similarities and affinities between our responses. In fact, I experienced them as an invitation to reconsider and revisit 'old' themes in my thinking about logic, philosophy of science and of mathematics in particular. Let me briefly present some comments on each of these themes and then end with a conclusion that refuses to conclude.

Theme 1 from logic: there has been (and to a certain extent there still is) a current in logical research where the game of questions and answers is being modelled. Jaakko Hintikka has been the strongest promotor of this so-called (dialogical) game semantics where two players are involved (see for an overview Hodges [2013]). The dialogue enters into the game because both players have to question the other. A special type of game is that where one of the players is 'Mother Nature' herself (and that game is therefore supposed to model scientific enquiry). Actually, I am not inventing this label here and now, it has a long tradition. It goes together with a powerful (gender-biased) picture of nature as reluctant to provide answers, who therefore has to be 'seduced', but with no guarantee at all that the forthcoming answers are correct (or 'true'). For what do we expect from '*Das Weibliche*', to make the gender-bias more explicit ? Should one be amazed that Sherlock Holmes often appears in these texts, the great misogynist who only accepted one woman as worthwhile, hence labelled 'The Woman'? Seen from this perspective, logic itself becomes a culturally thoroughly embedded game of its own or, in Baradian terms, it confirms the inseparability. Even the most formal and abstract of logical rules cannot 'escape' its embedding. For sure, cognitive anthropologists know this, logicians themselves as far as I know do not.

Theme 2 from philosophy of science: obviously 're-enactment' is a powerful concept that, at first sight, seems to be lacking in the philosophy of science and hence one could be tempted to think that here we find an important difference between scientific and artistic practices. This need not be the case because in the philosophy of science there are (at least) two important concepts that are definitely quite distinct from re-enactment, but that have many elements in common, namely 'reconstruction' and 'intervening'. I do know that reconstruction has acquired a bad reputation if it is considered as 'rational' reconstruction, as has been suggested by Imre Lakatos (see Lakatos [1971]); what one aims for is for a history 'retold' such that we come to understand the 'messy', 'real' and 'actual' history. That being said, it does invite us to consider the attempt of reconstruction as a form of justification or of understanding. Ironically this does require, first of all, a deep immersion into the 'messiness' itself. In addition, if one now includes the concept of 'intervening', as has been suggested by Ian Hacking in his seminal book *Representing and Intervening* (1983), then the 'outsider' position is blocked and one has to understand how 'Mother Nature' was dealt with. (The combination of 'Mother Nature' and interventions invites us to consider the importance of aggression and violence—what is the ecological impact of a nuclear explosion in vivo?) The Archimedes example in MB's answers shows, I think, what is at stake: the re-enactment in order to grasp Archimedes' logic requires an understanding of why, so to speak, this one particular bath he took was different to all those that he took before (and we have to leave open what taking a bath meant to him afterwards). Making the connection between mass and volume already presupposes that there are such *distinct* notions as mass and volume. Or for that matter, did we separate them first only to be confronted with the question whether they are connected or not? This brings me almost automatically to the third theme because the same questions and challenges pose themselves if we look at mathematics, including Archimedes' contributions themselves.

Theme 3 from philosophy of mathematics: as I had indicated in my responses to the three questions, mathematics is not to be excluded from the above considerations. Here too re-enactment, intervention and grasping are present and are needed to understand what happens when Archimedes proves in *On the Sphere and the Cylinder* that the volume of a sphere is $(4/3).\pi.r^3$, where r is its radius and, of course, π is that mysterious number that started out as 'merely' the proportion of the circumference of a circle and its diameter to become over the centuries one of the most enigmatic numbers we know (or to have been constructed?). This 'starting out' is of extreme importance because it shows mathematics as embedded in everyday life and hence as being part of practices of human embodied beings. It was therefore a most pleasant surprise to see MB mention the work of Brian Rotman as he has been an important source of inspiration in my thinking about the finite, the infinite and the human bodily existence. (See the review [1996] that I wrote of Rotman's book on infinity.) And, of course, I must include technology here as well for, if we now 'know' π up to 22,459,157,718,361 decimals (state of the art, November 2016, computation by Peter Trueb), this is due to not only an increase in computing power but also due to 'clever' theorems that speed up the calculations. So in mathematics too we can have a discussion about where the 'centre' is to be located and furthermore how these practices relate to artistic practices. As Merce Cunningham is mentioned by MB, a composer from the same period came to mind immediately: Iannis Xenakis. In a sense, in compositions such as *Pithoprakta* (1955–1956) he 'outsourced' part of the creative process to a computer through the use of statistical methods. Macro-properties such as density (is there an Archimedian echo here?) of the sounds produced and average intensity are in his hands, the micro-properties are in the 'hands' of the computer.

In form of a conclusion there is a final and more general comment that concerns the opening sentence of the final paragraph of MB's answer to the third question: "In dance and performance, the aim is to generate artistic creation. In science projects, the aim is to generate knowledge. This is an important difference". One must agree but at the same time differences can be generated through an underlying common structure and I do believe there is one. It is, using perhaps words too grand, all about possibilities, potentialities and their explorations. And here is the absolutely nice thing about possibility: it is a perfectly (at least) two-faced concept. On the one hand, adding possibilities complicates and complexifies matters by extending the space of potentialities, on the other hand, we can only understand what *is* through what *could have been*. How else could one understand this statement: "If I were to throw this ball at you, it would hit you"? Especially if I am not holding a ball at all and I am standing in front of a mirror.

More Thoughts Again, Rather Abstract and One After Another

Maaike Bleeker

At the very beginning of this text, Jean Paul Van Bendegem (JPVB for short) observes that philosophy of science has undergone major changes in the twentieth century. These changes have foregrounded the performativity of scientific practices of knowledge production and transmission and how knowledge production and transmission are grounded in social material practices. They are, as Donna Haraway (1988) puts it, 'situated'. How the world, and the universe, come to be known is a correlate of the (organic and inorganic) bodies involved in practices of perceiving and understanding, and the social, cultural, technical and other specificities of these bodies, practices and circumstances. JPVB's own explorations with knowledge transmission (in his various 'stagings' of transmitting the Pythagorean theorem in the exhibition *0/10*) draw attention to this correlation and also to the complexity of understanding the nature of this correlation. His experiments with knowledge transmission demonstrate that not all bodily practices and not all social material circumstances will do, and also that which is transmitted (the theorem) cannot be reduced to any of the material circumstances. Or to return to Archimedes once more: his Eureka moment was directly correlated with him taking a bath, yet the insight that occurred to him is not reducible to these corporeal circumstances. Rather, his Eureka moment is the result of his capacity to observe relationships and connections, and in doing so, to abstract the theorem out of the event of him taking a bath and the constellation of elements involved in that event.

Perhaps we could think of this correlation between bodies and knowledge in terms of what Michel Foucault describes as incorporeal materialism. Foucault introduces this notion in "Discourse on Language", a lecture that has been published as an appendix to *The Archaeology of Knowledge*. In this lecture, Foucault argues that we should conceive of discourse not in terms of consciousness and continuity, nor of sign and structure, but as ensembles of discursive events. Understanding how discourse operates as event requires acknowledging that events are material yet incorporeal, Foucault observes, because.

> an event is neither substance, nor accident, nor quality nor process; events are not corporeal. And yet, an event is certainly not immaterial; it takes effect, becomes effect, always on the level of materiality. Events have their place; they consist in relation to, coexistence with, dispersion of, the cross-checking accumulation and the selection of material elements; it occurs as an effect of, and in, material dispersion. (230–231).

Grasping the nature of an event, therefore, requires that we "advance in the direction, at first sight paradoxical, of an incorporeal materialism" (231). Knowledge production and transmission likewise have their place and consist in relation to the cross-checking accumulation and the selection of material elements. They occur as effect of, and in, material dispersion. Yet, they are not themselves substance, accident, quality or process. They are events in which humans and other elements participate and as events they are material yet incorporeal.

In the introduction to *Parables for the Virtual* (2002) philosopher Brian Massumi refers to Foucault's incorporeal materialism as part of reflections on how to think movement. Movements take effect on the level of the very materiality of the body moving, yet as events movements cannot be located in or reduced to the body. "When a body is in motion, it does not coincide with itself. It coincides with its own variation. The range of variations it can be implicated in is not present in any given moment, much less in any position it passes through" (4). To think the body in movement therefore "means accepting the paradox that there is an incorporeal dimension *of the body*. Of it, but not it. Real, material, but incorporeal" (5). Thinking movement requires grasping movement as dynamic unity that, like an event, is only present in passing.

This incorporeal dimension is abstract, yet not in a detached and cold way, as abstraction has come to be understood in Marxist analyses of capitalism. The abstract nature of movements and other events is not imposed on matter, but given in the relational dimension of their occurring as dynamic unity, and in the capacity of bodies to grasp and live these relations and thus participate in their unfolding. Massumi refers to Deleuze's real-but-abstract, where "abstract means: never present in position, only ever in passing. This is an abstractness pertaining to the transitional immediacy of a real relation—that of a body to its own indeterminacy (its openness to an elsewhere and otherwise than it is, in any here and now)" (5). In *Semblance and Event* Massumi further elaborates on this abstractness and terms it 'lived abstraction' (2011, 15–17).

Could lived abstraction provide a perspective on a common structure that, JPVB observes, might be underlying the arts and sciences? When watching a dance performance, philosopher Susanne Langer observes "one does not see people running around; one sees the dance driving this way, drawn that way, gathering here, spreading there—fleeing, resting, rising, and so forth; and all the motion seems to spring from powers beyond the performers" (1953, 175). Similarly, when listening to a musical composition, one does not hear individual sounds made by instruments but melodies, developments, an internal logic of relations of similarity and difference, even when the choreographer or composer explicitly avoids providing a preconceived composition. The choreography or the musical composition transmitted by the performance is given in the relational dimension of occurrences as dynamic unity, and in the capacity of bodies to grasp and live these relations and thus to participate in their unfolding. Could we conceive of Nemirovsky and Ferrara's students in mathematics (referred to above) as similarly involved in grasping and living the relationships proposed by mathematical theorems? Could we conceive of the object of knowledge as that which choreographer William Forsythe calls a 'choreographic object', a choreographic idea or set of ideas that materializes in (usually) moving bodies but cannot be reduced to these materializations? From the perspective of lived abstraction, "what we call objects, considered in the ontogenetic fullness of process, are lived relations between subjective forms of occasions abstractly nesting themselves in each other as passed-on potentials" (*Semblance and Event*, 15). Grasping the object means enacting the relationships that produce the object as lived abstraction.

These relationships between abstraction, movement and the ways in which bodies grasp what they encounter as lived relations—as observed by Massumi after Deleuze and Whitehead—are also recognized by enactive approaches to perception and cognition. Sensory inputs are multiple, manifold, ambiguous, staggered over time, they do not cover the same range of velocities, and they are often fuzzy and incomplete. This is what Alain Berthoz describes as the fundamental problem of perception, which is unity (2000, 90). Enactive approaches to perception point to the repertoire of sensorimotor schemas (Berthoz) or sensorimotor skills (Noë) as key to how bodies are capable of doing so as a result of practical knowledge of the ways movement gives rise to changes in sensory stimulation (Noë 2004, 8). The kind of implicit knowledge, for example, that movement of the eyes to the left produces movement across the visual field.

Or the kind of implicit knowledge that, when in the dark, or with our eyes closed, we touch different sides of a box, we feel not only a succession of surfaces, but grasp their spatial relationships as different sides of the same box. The impression of the different sides of the box on our fingers alone cannot explain how we are capable of perceiving a box as a three-dimensional object in space that we can pick up, turn around and open. Actually, it is the other way around: because of our experience with the effects of moving around boxes and other objects as well as moving objects around, we are capable of grasping the connection between simultaneous and successive impressions and thus abstracting objects out of multitudes of impressions. "[T]o perceive (…) is to perceive structure in sensorimotor contingencies", Noë observes (2004, 105). Perceiving is not merely to have sensory impressions but rather to *make sense of* sensory impressions and this is a matter of how our sensorimotor skills afford grasping relationships between impressions, and thus afford us to abstract the box out of the multitude of impressions. What we perceive—the box—is an abstraction that consists of a set of lived relations. Furthermore, Noë argues, our sensorimotor skills are not only that which allows us to perceive a box rather than a blur of sensory impressions; they are also the root of our ability to grasp more complex abstractions such as a musical composition, a choreography or the Pythagorean theorem.

Notes

1. https://www.kva.se/en/pressroom/Press-releases-2013/The-Nobel-Prize-in-Physics-2013/, last accessed on 8 March 2014.
2. In 2011 I was invited by the department of cultural activities of the Free University Brussels to set up a small-scale exhibition on the relations between mathematics and art. Rather than going down the well-trodden road of Escher-like exhibits, I opted for a different approach: is there art in mathematics itself? The result was a set of nine videos, average time around eight minutes, each one illustrating what happens when a vital condition for transmission of mathematical knowledge is violated. My personal favourite is a translation of a proof of Pythagoras' theorem in a musical performance (by setting up code).

References

Barad, Karen. 2007. *Meeting the Universe Halfway. Quantum Physics and the Entanglement of Matter and Meaning*. Durham and London: Duke University Press.

Barnes, Barry. 1977. *Interests and the Growth of Knowledge*. London: RKP.

Berthoz, Alain. 2000. *The Brain's Sense of Movement*. Cambridge, MA: Harvard University Press.

Bleeker, Maaike, and Iris van der Tuin. 2014. "Science in the Performance Stratum: Hunting for Higgs and Nature as Performance." *International Journal of Performance Arts and Digital Media* 10, no. 2: 232–245. In special issue "Hybridity: The Intersections between Performing Arts and Science," edited by Eirini Nedelkopoulou and Mary Oliver.

Bleeker, Maaike, ed. 2017. *Transmission in Motion. The Technologizing of Dance*. New York and London: Routledge.

Bloor, David. 1976. *Knowledge and Social Imagery*. London: RKP.

Châtelet, Gilles. 2000. *Figuring Space: Philosophy, Mathematics, and Physics*. Dordrecht: Kluwer.

Collingwood, Robin G. 1993. *The Idea of History*. Oxford: Oxford University Press.

De Freitas, Elisabeth, and Nathalie Sinclair. 2014. *Mathematics and the Body. Material Entanglements in the Classroom*. Cambridge: Cambridge University Press.

Feyerabend, Paul. 1975. *Against Method*. London: New Left Books.

Forsythe, William. n.d. "Choreographic Objects." *Williamforsythe.com*. Accessed March 27, 2017. https://www.williamforsythe.de/essay.html.

Foucault, Michel. 1972. *The Archaeology of Knowledge & Discourse on Language*. New York: Pantheon Books.

Hacking, Ian. 1983. *Representing and Intervening*. Cambridge: Cambridge University Press.

Hansen, Mark B.N. 2015. *Feed Forward. On the Future of Twenty-First Century Media*. Chicago and London: University of Chicago Press.

Haraway, Donna. 1988. "Situated Knowledges: The Science Question in Feminism and the Privilege of Partial Perspective." *Feminist Studies* 14, no. 3: 575–599.

Hodges, Wilfrid. 2013. "Logic and Games". In *The Stanford Encyclopedia of Philosophy*, edited by Edward N. Zalta. https://plato.stanford.edu/archives/spr2013/entries/logic-games/.

Kuhn, Thomas. 1962. *The Structure of Scientific Revolutions*. Chicago: University of Chicago Press.

Lakatos, Imre. 1971. "History of Science and Its Rational Reconstructions." In *PSA 1970: Boston Studies in the Philosophy of Science* 8, edited by Roger C. Buck and Robert S. Cohen, 91–135. Dordrecht: Reidel.

Langer, Susanne K. 1953. *Feeling and Form. A Theory of Art*. New York: Charles Scribner's Sons.

Massumi, Brian. 2002. *Parables for the Virtual. Movement, Affect, Sensation*. Durham and London: Duke University Press.

Massumi, Brian. 2011. *Semblance and Event. Activist Philosophy and the Occurrent Arts*. Cambridge, MA: The MIT Press.

McKenzie, Jon. 2001. *Perform or Else. From Discipline to Performance*. New York: Routledge.

Nickles, Thomas, ed. 1980. *Scientific Discovery, Logic, and Rationality*. Dordrecht: Reidel.

Noë, Alva. 2004. *Action in Perception*. Cambridge Massachusetts: The MIT Press.

Pickering, Andrew. 1995. *The Mangle of Practice. Time, Agency, & Science*. Chicago: Chicago University Press.

Rotman, Brian. 2008. *Becoming Beside Ourselves: The Alphabet, Ghosts, and Distributed Human Being*. Durham and London: Duke University Press.

Van Bendegem, Jean Paul. 1996. "Review article: The strange case of the missing body of mathematics. Review of Brian Rotman's 'Ad Infinitum: The Ghost in Turing's Machine. Taking God out of Mathematics and Putting the Body Back In.'" *Semiotica* 112, no. 3/4: 403–413.

Whitehead, Alfred North. 1978. *Process and Reality*, edited by David Ray Griffin and Donald W. Sherburne. New York: The Free Press.