Evidence

Lecture 7 (20. Jul 2022)

Perrin on the Reality of Molecules – Part II

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Contents

This lecture covers: Smith and Seth (2020), *Brownian Motion and Molecular Reality*: chs. 1, 4–5 (skipping over 2–3 in the interests of time)

1 Admin Crap

1. REMEMBER TO RECORD THE LECTURE!
2. schedule make-ups for missed lectures:
   a. 26. Jul (Tuesday): 12:00–14:00; every hour thereafter up to starting at 17:00
   b. 28. Jul (Thursday): 10:00–12:00; 11:00–13:00; 12:00–14:00; 16:00–18:00

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c. 29. Jul (Friday): 10:00–12:00; every hour thereafter up to starting at 17:00

3. the first lecture next week will finish Smith and Seth (*i.e.*, combine the originally planned lectures 8 and 9); possible topics for the remaining 2 lectures:
   a. The Evidential Complexities of Modern Big Science (gravitational wave astrophysics and LIGO)
   b. Bayesianism
   c. Glymour's Bootstrapping
   d. Role of Causal Structure

2 Background

2.1 Theory-Mediated Measurement – Quick Review

Roughly speaking, a measurement such that the value of the quantity targeted cannot be determined without making calculations using the machinery of a given theory; the interesting case comes when one employs such a technique with a theory one is in some sense still testing or trying to confirm, as this *prima facie* seems to present an epistemically problematic circularity.

2.2 Brownian Motion – Quick Revew of Most Relevant Facts

Brownian motion is the random motion of a particle—random fluctuations in the particle's position—while suspended in a dilute medium, as a result of collisions with the medium's surrounding atoms or molecules.

1. the distribution of the directions and magnitudes of the motions of the individual molecules hitting the particle is constantly changing, and so at different times the particle is hit more on one side and in a given direction than another, yielding seemingly random changes in the particle's position and random, discontinuous changes in its velocity ("jumps")
2. to determine the "true" motion of a suspended particle is an instance of theory-mediated measurement: the motion ("instantaneous velocity") one "directly" observes through a microscope is actually the result of an "average" of individual jumps (generally on the order of millions or billions per second) over the time scales at which the human eye can discriminate changes in motion (typically on the order of 1/100th of a second)

2.3 van Fraassen on Perrin – Quick Review

van Fraassen (2009, p. 23) argues that we should view Perrin's results not as showing the "truth" (in some appropriately rich realistic sense) of the molecular hypothesis, but rather as providing an "empirical grounding" for the hypothesis in general, and molecular kinetics in particular.
van Fraassen (2012, pp. 782–783) explains the idea of "empirical grounding":

> [T]he demand on theories is that they be empirically grounded, which involves both theoretical and empirical tasks. The crafting of a relationship between theory and phenomena is an interplay of theory, modeling, and experiment during which both the

identification of parameters and the physical operations suitable for measuring them are determined. . . .

Empirical grounding is this process of simultaneously, harmoniously extending both the theory and the range of relevant evidence. There are three parts to it. . . :

Determinability: any theoretically significant parameter must be such that there are conditions under which its value can be determined on the basis of measurement.

Concordance, which has two aspects:

Theory Relativity: this determination can, may, and generally must be made on the basis of the same theoretically posited connections.

Uniqueness: the quantities must be uniquely 'coordinated'; there needs to be concordance in the values thus determined by different means.

Refutability, which is also relative to the theory itself: there must be an alternative possible outcome for the same measurements that would have refuted the hypothesis on the basis of the same theoretically posited connections.

3 Introduction to Smith and Seth

I think it's fair to say these dudes really care about evidence, and in particular *what* it is that can be used as evidence (and, concomitantly, of course, how it can come to play that role). They claim (ch. 1) that the book will primarily address two over-arching issues.

3.1 First Issue

1. Smith and Seth (2020, pp. 7–8, their emphases):

   > What did Ostwald, Nernst, and Poincaré think was still needed at the beginning of the twentieth century in order for the molecular hypothesis, in Ostwald's words, to be "raised to the position of a scientifically well-founded theory," or, in Nernst's, to "lose its hypothetical character"? In other words, what shortcoming did they see in the evidence at the time when Perrin and Einstein began their efforts on Brownian motion? A way to get at this question is to ask just what Ostwald, Nernst, and Poincaré and their like took the new standing of the molecular hypothesis to amount to when it lost its hypothetical character and became a scientifically well-founded theory. . . .
   >
   > ***What did the new standing of atomic-molecular theory at the end of the first decade of the twentieth century amount to?*** How did putting "a definite end to the long struggle regarding the real existence of molecules" affect science?

   Are the final two questions really the same? Are they supposed to be?

2. Smith and Seth (2020, p. 9, their emphases):

> [T]he values for Avogadro's number that Perrin inferred from different sorts of measurements he made of Brownian motion showed notably less variance than the values that had been estimated from kinetic theory itself, and they agreed well with values inferred from phenomena independent of kinetic theory during the first dozen years of the twentieth century.
>
> This last point suggests that Brownian motion was providing experimental access to the atomic-molecular realm insofar as having a reliable value for Avogadro's number meant that more reliable values for several other parameters of atomic-molecular theory could then be obtained. That suggestion is wrong, however. What Perrin determined through his theory-mediated measurements was in every case a mean kinetic energy—translational or rotational—of his granules. He could then calculate how many granules having such a mean kinetic energy are needed to match the total energy, RT, in a mole of gas at the corresponding temperature. *This number, however, is not in and of itself Avogadro's number. It can be taken as a measure of Avogadro's number only under the further assumption that molecules exist and have the same mean translational kinetic energy at the temperature in question as the Brownian motion granules have.*
>
> In other words, a gap remained between the measurements made for Brownian motion and the value then claimed for the molecular parameter. A similar gap remained between the observable motions of the granules versus unobservable molecular motion, as well as between the consistency of the observed motions with kinetic theory versus the consistency of kinetic theory with what actually occurs microphysically. What was it about the specifics of the measured results for Brownian motion that licensed inferences bridging these gaps?

3. one immediate question: will they provide (at least) a necessary or a sufficient condition for "experimental access"? (necessary is needed to answer the question in the negative, sufficient for the positive)

4. another: how do the questions raised in the second long quote relate to the first over-arching issue adumbrated in the first long quote?

3.2 Second Issue

1. Smith and Seth (2020, pp. 12–13, their emphases):

> [T]he theoretical relationships involving the mean kinetic energy of the granules can *all* be derived entirely independently of *molecular*-kinetic theory and hence independently of any question of the reality of molecules. The measurements were still mediated by those relationships, but they were theory-mediated measurements of aspects of Brownian motion taken unto itself, measurements that yielded results that at the time had to be (and in fact were) regarded as extraordinary in their own right. Viewing Perrin's efforts this way still leaves us with the question of how the gap between the visible granules and invisible molecules is to be bridged, but

> it clarifies just what that gap amounts to, and it opens up possibilities for bridging it beyond those considered by van Fraassen.
>
> This brings us to the second principal issue of this monograph: ***What did the research by Perrin and others establish about Brownian motion independently of the molecular hypothesis and kinetic theory?***

2. Smith and Seth (2020, p. 15, their emphases):

   > We fully agree [with Chalmers (2011)] that Perrin's results showed that the Brownian motion of granules exhibits the two central features attributed to molecules by nineteenth-century kinetic theory [*viz.*, the random character of molecular motion and the equipartition of energy among the degrees of freedom of the molecules]. But precisely because those results in no way presupposed that theory, we do not see how it is possible to assess the *stringency* with which they tested its "central and most basic assumptions." This explains why we think the issue of the stringency of any such test should not be a principal issue, but instead should be postponed until at least the second of our principal issues, if not the first as well, has been fully addressed.

4 What Perrin Showed about Brownian motion

In the interests of time, we skip over chapters 2–3, the historical background of research on Brownian motion before Perrin.

1. Smith and Seth (2020, ch. 4, p. 129, their emphases):

   > By the *logical design* of these experiments, we mean the assumptions made and the step-by-step derivation from them of the theoretical relationship mediating between the indirectly measured quantities and the features observed. As we indicated in Chapter 1, the logical design of Perrin's experiments can be construed in two very different ways. On the one hand, the assumptions in question can expressly be about molecules, and the mediating relationships amount to an extension of molecular-kinetic theory to Brownian motion. On the other hand, the assumptions can be limited strictly to claims about the granules themselves, adopted as provisional *scaffolding*, to use Ostwald's term, to enable conclusions to be drawn *about Brownian motion* itself.
   >
   > .... Our alternative construal ... has two notable advantages for purposes of assessing just what Perrin's evidence showed. First, his experiments yielded conclusions about Brownian motion itself that were beyond dispute, at least far more so than the conclusions about molecules. In other words, *the strongest evidence coming out of the experiments concerned Brownian motion itself, separately from any claims at all about molecules.* Second, construing the logical design in this narrower way can bring out precisely what gap remained between the conclusions

pertaining to the visible realm of the granules and the further conclusions about the non-visible realm of molecules.

As we indicated in Chapter 1 when explaining our subtitle, we shall be taking the occasion of presenting Perrin's efforts on Brownian motion to bring out some logical intricacies of theory-mediated measurement. In particular, we shall be showing how his "well-behaved" results provide evidence in and of themselves for the validity of his measurements and hence for the theoretical presuppositions on which they are indispensably predicated. . . . His experimental approach (and independently of him, Einstein's proposed approach as well) recognized from the outset that, even though Brownian motion can be watched through a microscope, the quantity of primary interest, the mean square velocities of the particles, cannot be determined visually. The only way to get at this quantity was through indirect, theory-mediated measurement in which a visually accessible quantity serves as a proxy for the quantity of interest.

4.1 Perrin's Vertical-Gradient Results

Smith and Seth (2020, p. 137, their emphases):

> In Chapter 2 we concluded that molecular theory, while offering explanations for a wide range of phenomena, was generally not entering constitutively into the research on those and related phenomena; and when it did, as in the attempts to infer molecular dimensions from viscosity, diffusion, and the deviations from Boyle's law, the results were not "well-behaved." By contrast, the equations for N and W_T, and the assumptions required to derive them, which are not molecular, entered constitutively into Perrin's measurements, and those measurements yielded reasonably well-behaved results. *Precisely because those theoretical elements entered constitutively into his measurements, the demand that the results be well-behaved comprised a test of them.*

4.2 Well-Behaved Results

1. Smith and Seth (2020, ch.4, §9): A set of experimental results are *well-behaved* iff they are *stable*, *convergently complementary* and *amenable to increasing precision*.

   stable Smith and Seth (2020, pp. 167–168, their emphases):

   > *a theory-mediated measure must yield the same results, to within experimental precision, when the values of the manipulable parameters in its defining relation are varied*

   The logical form is that of a Newtonian abduction (Curiel 2021):

   IF background assumptions **THEN** (relations linking target to proxy quantities IFF results are stable)

5 Invitation to a Short Essay

I invite you to write me a short discussion (no more than 2 pages, *i.e.*, no more than 1000 words) on any issue discussed in this lecture or any of this week's readings, required or suggested. You can raise further questions, propose answers or interpretations, or whatever seems of most interest to you. If you get it to me by the start of next lecture (26. July), then I will return it to you with my comments the following week.

References

Chalmers, Alan. 2011. “Drawing Philosophical Lessons from Perrin's Experiments on Brownian Motion: A Response to van Fraassen.” *The British Journal for the Philosophy of Science* 62 (4, December): 711–732. doi:10.1093/bjps/axq039.

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van Fraassen, Bas C. 2009. “The Perils of Perrin, in the Hands of Philosophers.” *Philosophical Studies* 143:5–24. doi:10.1007/s11098-008-9319-9.

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