Evidence
Lecture 8 (26. Jul 2022)
Perrin on the Reality of Molecules – Part III

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Contents

This lecture covers: Smith and Seth (2020), *Brownian Motion and Molecular Reality*: chs. 4–7

1 Admin Crap

1. REMEMBER TO RECORD THE LECTURE!

2 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.

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.

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> 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.

2.1 Perrin's Vertical-Gradient Results

What exactly were the propositions that had evidential support accrue? How did it act as evidence? What did the evidence consist of?

1. what accrued evidential support from Perrin's experiment:
    a. the measurements clearly provided evidence for "observable features" (or "directly" manipulable features) of the experimental system manifesting Brownian motion, such as the density gradient of the granules; how does one determine what counts as such?
    b. at least with respect to Brownian motion itself, independent of the molecular hypothesis, Smith and Seth (2020) claim it is:
        i. p. 138, their emphasis:
            > *[A]t any given temperature the mean translational kinetic energy of the granules is the same (within experimental accuracy) in all dilute emulsions.*
        ii. p. 139, their emphasis:
            > *[I]gnoring variations in temperature, the rate of vertical rarefaction of the granules caused by gravity in any dilute emulsion is proportional to the buoyant weight of the granules.*

   c. do these have the same logical form as any of the ones I enumerate in Curiel (2022, §4)? clearly not, as the first (at least) is a universally quantified indicative proposition; do you think these are really what accrued evidential support?

   d. more importantly, however, Smith and Seth (2020) focus on how the measurements serve as evidence capable of supporting the *theoretical assumptions* required to interpret the measurements *as* measurements of "unobservable" quantities such as mean kinetic energy; I leave it as an exercise for the student to work through the relevant assumptions, analyze their logical form, and see whether they match any of the forms of proposition I enumerated in Curiel (2022, §4)

2. to begin to get a grip on what served as evidence, and how it did so, consider the following claim (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.*

   Let's take this apart.

   a. Thus, an essential component of the evidence for the "theoretical elements", *viz.*, the formulæ (implicitly) defining Avogadro's number and the mean translational kinetic energy of the granules, respectively, in terms of "observable features" (or manipulable features) of the experimental set-up and the assumptions required to derive them—what allowed it in part to act as evidence—is that those formulæ and assumptions "enter constitutively" into the measurements

   b. what does "entering constitutively into a measurement" mean?

   c. I take it that it must mean more than something like "playing a role in the performance of the measurement", since it is difficult to see how a formula could do this at all

   d. it seems, therefore, that it must include at least this much: being required in order to calculate the value of the quantity of interest based on the values of the "observed features" that the performance of the measurement "directly" yielded

3. That the results of the measurements were "well behaved" constituted a "test" of the results—*i.e.*, they provided evidence in favor of some claim about the results; what is that claim? I think they refer to it in passing at the start of the chapter (p. 130):

   > . . . how their being so[, *viz.*, the results' of a measurement being well behaved,] in itself amounts to evidence for their validity.

they never say what they mean by "validity" of results, but it seems plausible that it comes to something like this:

   a. they are capable of serving as validating evidence in favor of (at least) the most important assumptions required in order for the theory-mediated measurement *to itself be capable of serving as* evidence for the claims the measurements were made to support

   b. I say this because they speak of a measurement as providing "validating evidence" for those assumptions, and they speak of the validity of the assumptions themselves (*e.g.*, p. 142)

   c. what they mean by "validity" of an assumption (Smith and Seth 2020, p. 164, their emphases):

      > We choose the word "validity" here rather than "truth" because the force of this additional evidence is narrow. What the evidence for the assumption of one measure from its convergence with another supports is the claim that the assumption is safe to adopt for purposes of theory-mediated measurement of the quantity in question at least over a yet to be fully determined range of circumstances.

4. they spell out on pp. 139–140 perhaps the most important feature of the evidential relations grounded in the fact that the results were well behaved (in their sense), *viz.*, that the logic of the evidence in favor of the law of sedimentation equilibrium takes the form of what Curiel (2021) calls a "Newtonian-abductive proposition", *viz.* a conditional whose consequent is a biconditional; they spell out the usual contents of the elements of the proposition on pp. 167–168, which we will discuss below in §3 of these notes

5. finally, Smith and Seth (2020, p. 131) remark—rightly!—that there are at least two further steps any completely philosophical adequate analysis of the evidential structure of Perrin's work (or that of any scientific work) would require:

   a. an analysis and assessment of the relationship between the "raw" data the measurements generate and its statistical properties on the one hand, and the "final results" derived from that data and used in the evidential arguments on the other

   b. an analysis and assessment of the range of manipulable parameters the experiments explored, and whether they suffice as warrant for the inductively generalized claims made on their basis

   we do not have time, sadly, to enter into discussion of these issues

3 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 are valid IFF results are stable)

convergently complementary Smith and Seth (2020, pp. 168–169, their emphases):

> [T]he evidence transferred from stability through the bi-conditional to the validity of the measure is itself conditional on the background assumptions; for they can house sources that give rise to a misleading stability. This is why a standard part of the practice of theory-mediated measurement is to pursue evidence independent of the measure for its background assumptions.

Thus the need for different—*complementary*—measures of the same quantity, which must, of course, agree (*converge*). This raises the question: what is the criterion for "different" here? How can we be sure that two different measurements are not relevantly independent of each other?

amenable to increasing precision Smith and Seth (2020, p. 170, their emphases):

> *A theory-mediated measure is amenable to increasing precision if corrections introduced to compensate for externalities and known respects of approximation or improvements in direct measurement of accessible quantities yield more precise values of the target quantity.*

2. perhaps the most important, narrowly focused philosophical use of the idea of well behaved results in the book comes in ch. 6, §5, where (p. 284) they quote Poincaré (p. 284) on "the triumph of atomism" based on the "convincing … multiple correspondences between results [measuring Avogadro's number] obtained by entirely different processes," and address the question (p. 284):

   > [W]hat evidence could appropriately have been drawn from this?

   they do not explicitly say, but based on the subsequent discussion it seems reasonable to conclude that they think that the *validity* of the results is the primary answer

   a. stability is a necessary condition for validity (p. 285): "When the measure is not all that stable, the premises underlying it are subject to question."

   b. to address Poincaré's particular point, which seems to touch mainly on what they called in ch. 4 "complementary convergence", they say (p. 285, their emphases):

      > [W[hen two different stable theory-mediated measures of the same quantity yield, to within experimental precision, the same values, we follow Perrin in calling them convergent.… What made these distinct was a difference in the premises constitutive to each of them.

we now *seem* to get a criterion of difference—but it leaves us with the question of how we are to determine that the seemingly different premises relevantly different in a *physical* sense, the difference being substantive enough to support the evidential weight it is asked to bear

c. on the move from an interpretation of the results as evidence for claims about Brownian motion to evidence for the reality of molecules, they say (pp. 287–289, their emphases):

> [T]he premise linking the primary quantity measured to N_0 was in no way *constitutive* of the measure of the primary quantity in the sense of being indispensable to it; this premise was constitutive only to the further inference from the primary quantity to N_0. As a consequence, this premise was open to question regardless of how stable, convergent, or otherwise well-founded the measures of the primary quantities happened to be.
> .... Each of these further assumptions can legitimately be regarded as the "weak-link" in the respective determinations of Avogadro's number—this, for two reasons. First, there was no evidence tied specifically to any one of the determinations to support the further assumption in question. Second, as a corollary to this, each assumption, taken in isolation, was presupposing, and hence on its face begging the question of, the reality of molecules.
> But now the answer to our question about the evidence from the aggregate of the agreeing measurements of N_0 is obvious: the aggregate provided support, indeed virtually the only empirically grounded support, for these further premises linking each primary measured quantity to N_0. All those premises had one element in common, the number of "molecules" in a mole. What was thrown into question whenever the value of N_0 obtained in any one approach having a robust measure of its primary quantity failed to be in agreement with the others

what exact logical and physical form does this "evidence" take?

4 Their Primary Issues, Revisited

They discuss their primary differences with van Fraassen—as they framed their project in ch. 1 (Smith and Seth 2020, ch. 6.6, p. 294, their emphases):

> Departing still farther from van Fraassen, notice how these further premises—the "weak links," as we have called them—offered remarkably little information about "molecules." Because of this, they were "weak" in a second sense—*they presupposed as little about the realm of molecules as they could and still yield a value for* N_0. But that, on our view, was the great virtue of the four determinations of N_0 we have discussed in detail. They left so many questions about the microphysical realm without answers, instead opening the way for subsequent experimental research to answer them, even one by one. Van Fraassen regards the empirical grounding of molecular-kinetic theory achieved during the years we have been considering as making possible experimental testing of that theory as a whole. We regard it as having made possible a systematic experimentally

based further development of that theory, which it so badly needed given the unresolved difficulties that had encumbered it for decades and the new ones Poincaré referred to that were then emerging.

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 end of next week (5. August), then I will return it to you with my comments the following week.

References

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Smith, George E., and Raghav Seth. 2020. *Brownian Motion and Molecular Reality: A Study in Theory-Mediated Measurement.* Oxford Studies in Philosophy of Science. Oxford: Oxford University Press. doi:10.1093/oso/9780190098025.001.0001.