Identity in Physics: Statistics and the (Non-)Individuality of Quantum Particles

Abstract

This paper discusses the issue of the identity and individuality (or lack thereof) of quantum mechanical particles. It first reconstructs, on the basis of the extant literature, a general argument in favour of the conclusion that such particles are not individual objects. Then, it critically assesses each one of the argument's premises. The upshot is that, in fact, there is no compelling reason for believing that quantum particles are not individual objects.

1. Introduction: the general argument against the individuality of quantum particles

The issue whether the most fundamental entities described by non-relativstic quantum mechanics are individual objects is of indubious interest for both philosophers of physics and metaphysicians. Indeed, not surprisingly, it has received a great deal of attention lately. It is useful to frame the corresponding discussion in the context of a general argument that summarises all the relevant theses. The argument can be rendered as follows:

1) The Identity of the Indiscernibles (PII) – as shown, for instance, by French and Redhead (1988) - fails in the domain described by non-relativistic quantum mechanics (QM);

2) The only possible sources of individuality are PII and Scholastic *primitive thisness* (PT) - a non-analysable, *sui generis* non-empirical posit[1] grounding a thing's self-identity and numerical distinctness from other things;

3) PTs are metaphysically suspicious, or at least they should be taken to be by those who look at science – hence at empirical data – with a view to supporting their metaphysical claims (so endorsing some form of *naturalism* about metaphysics). If PTs are primitive, non-empirical properties, how can we gain access to them empirically? If we cannot, on which basis do we postulate them?;

4) Moreover, PTs entail *haecceitism*, that is, they entail non-qualitative differences between worlds (i.e., systems of objects) such that these worlds only differ *de re* with respect to what they say about certain individuals, without differing with respect to their qualitative features;

5) But QM contradicts haecceitism for, unlike in classical statistics, in quantum statistics permuting two identical particles does not give rise to a new, statistically relevant state, and the probabilities are distributed accordingly. But if haecceitism were true, this would not be the case. More briefly, permutation invariance entails anti-haecceitism and, therefore, QM contradicts the claim that objects are individuals because they possess PTs (from 3) and 4));

C) Since (given 1), 2) and 5)) no source of individuality is available for quantum particles, we must conclude that QM tells us that quantum particles are not individual objects.

This paper will focus on quantum statistics, that is, on premises 4) and 5). Consequently, the discussion will mostly be devoted to the issues surrounding QM, permutation invariance, haecceitism and PTs. Its aim will be to clarify certain confusions, propose an individual-based account of quantum statistics alternative to those currently on offer and, more generally, outline and defend a plausible conception of primitive intrinsic identity and individuality.

[1] Meaning, basically, that it is a *purely metaphysical* posit that is not directly causally efficacious and, therefore, cannot be known in itself. Whether this also means that it should be left out of what we conjecture to be 'real' on the basis of our best physics is, as we will see, more controversial than is normally believed.

Before doing all this, however, let's look at the other three premises, that is, 1)–3) above.

2. Indiscernibles and primitive thisnesses

Against premise 1) above, Muller, Saunders and Seevinck (Saunders (2006a), Muller and Saunders (2008), Muller and Seevinck (2009)) have recently provided arguments to the effect that quantum particles are at least weakly discernible. That is, they can in some cases have all the same monadic and relational properties, but are *always* discerned by symmetric and irreflexive relations holding among them. In particular, spin correlations and more general commutator relations (involving, e.g., position and momentum) discern both fermions and bosons in all types of quantum mechanical systems and in Hilbert spaces of any number of dimensions. These arguments rely, it is true, on plausible but not absolutely uncontroversial assumptions concerning whether relations can be non-reducible to monadic properties of their relata and discern otherwise indiscernible objects, and whether the relations constructed in the presented proofs truly are physically genuine properties.[2]

At any rate, without undertaking a detailed examination of Muller, Saunders and Seevinck's arguments, we can just claim here that *if* we accept their basic assumptions, it looks like 1) is false and some form of PII actually holds in QM. In particular, Muller, Saunders and Seevinck appear right in assuming the countability of particles at the *formal* level and then look for their *physical* discernibility, taking this not to be circular: for, it is exactly the existence of (alleged) discerning physical relations that (allegedly) justifies taking what is counted at the formal level to correspond to genuine objects.

Two important remarks must be added, however. First, Muller, Saunders and Seevinck claim that weakly discernible objects are not individuals but 'relationals', which entails that PII still doesn't ground individuality in the quantum case. However, the distinction between individuals and relationals only follows from a *definition* of individuality as absolute discernibility which it is not necessary to accept. In fact, on the appropriate 'philosophically neutral' construal of it, individuality consists of the possession of well-defined identity conditions (self-identity and numerical distinctness

[2] Muller, Saunders and Seevinck start from single-particle operators whose physical significance is quite uncontroversial, and go on to *construct* relations out of (some of) the corresponding projectors and their possible values.

from other things) and, consequently, separate existence (perhaps, for extended periods of time, i.e., in the diachronic as well as in the synchronic sense). Clearly, this means that individuality need not coincide with the strongest (or, for that matter, with any) form of discernibility. A second, related, worry is expressed by Ladyman and Bigaj (2010), who question Muller, Saunders and Seevinck's claim that weak discernibility vindicates PII on the basis that such form of discernibility doesn't correspond to the possibility of actually telling particles apart from each other through physical means. Independently of whether or not this is what led to (or, at any rate, justifies) the introduction of the concept of a relational, if Ladyman and Bigaj's complaint is correct then premise 1) is in fact true. For present purposes, suffice it to say that, *under certain assumptions*[3], PII can be said to hold in QM, and premise 1) accordingly rejected. Having said this, it becomes in any case essential at this point for the defender of the individuality of quantum particles to evaluate the other premises.

Against 2), the following must be pointed out: surely, individuality can be extrinsic and qualitative (as the Leibnizian supporters of PII have it) or intrinsic and non-qualitative (as contended by the Scholastic tradition supporting PTs), but – if only by counting the combinations – it can be seen that a third option is possible. Someone like Ladyman (2007), for instance, would object that there is a third way (one may call it 'contextualism') that makes identity extrinsic (as with PII) but non-qualitative (as with PTs) and which is supported by current science. Ladyman uses the example of graph theory – where mathematical systems exist that are constituted by several objects which are not even weakly discernible – to support the claim that the identity of objects need not be rooted in discernibility. And similar things can be said about physical theories such as General Relativity and QM.[4] Clearly, unless one *assumes* a Leibnizian definition of individuality, this means to accept non-qualitatively grounded but extrinsically determined individuality: for, in such a contextualist setting the well-defined identity-conditions granting the separate existence of things are already secured.

Besides allowing for the rejection of 2), this is also relevant with respect to 3). Because contextualism offers an analysis of facts of identity and difference which is not carried out in terms of qualities but, it would seem, it is not, because of this, in conflict with

[3] That is, if one endorses the 'neutral' definition of individuality above, and rejects Ladyman and Bigaj's request that metaphysical discernibility correspond to the availability of physical procedures to actually distinguish.

[4] The contextualist take on identity supported by Ladyman was endorsed earlier by Stachel (see, for instance, Stachel (2004)), who developed it exactly in the context of a discussion of General Relativity and the ontology of space-time, and then attempted to show that it is of more general validity.

science and is, as a matter of fact, supported by it. If this is true, then even in the context of a naturalist conception of metaphysics – aiming, as we have mentioned, to ground metaphysical claims on empirical data and well-established scientific theories – non-qualitatively-analysable identities and individualities are acceptable. In other words, the possibility and scientific credibility of contextualism allows one to depart from the Leibnizian-Quinean tradition of grounding individuality in qualitative uniqueness without *ipso facto* entering the dangerous domain of non-scientifically-informed metaphysics.[5] Crucially, though, once this is accepted, it is a short step from *contextual* to *intrinsic* ungrounded (i.e., non-qualitative) identity and individuality, that is, to a rejection of the claim against PTs as metaphysically suspicious expressed in premise 3) (better still, to the identification of an alternative to PT – more on this in a moment).

Indeed, from the metaphysical viewpoint, whatever one says about the identity- and difference-making *relations* posited by contextualists can equally be said to apply in the case of PTs (i.e., *monadic properties*), as the only difference between the former and the latter concerns *n*-adicity, which can hardly ground a general differentiation between 'good' and 'bad' metaphysical posits. More specifically, either

a) PT is a mysterious, inaccessible full-blown metaphysical property because it is non-qualitative, but then the relations posited by the contextualist also are; or

b) The contextualist claims that his/her talk of identity-relations must not be intended as ontologically 'thick' (that is, about full-blown metaphysical entities) but rather 'thin' (that is, not entailing 'ontological inflation'), but then PTs can be conceived of as equally thin.

In other words, non-qualitative features of things are either acceptable or to be rejected entirely, they cannot be allowed in a selective way, i.e., only for some metaphysical views. And once contextualism is deemed acceptable, as it seems it should be, *facts of number and countability come to possess a direct metaphysical significance, not necessarily grounded in qualitative facts,* that can equally well be taken to coincide with the possession of PTs by objects. It is clear that the naturalist will opt for a thin conception of the relevant elements: hence, it looks as though *both* the relations considered fundamental by the contextualist and PTs can and should be regarded as only expressing the fact that

---

[5] Clearly, this is relevant even beyond the context of the discussion of the ontological status of quantum particles, as it is connected to important general questions concerning the methodology one should implement when exploring issues at the boundary between empirical science and metaphysics. Obviously, there is no space to examine these aspects in detail here.

things are self-identical and numerically distinct from everything else, with *no ontological addition* to what we regard as 'proper' things and properties.[6] In light of this, option b) above appears to restore the legitimacy of PTs, so leading to the rejection of premise 3).

One may complain that it is part of the *definition* of PT that it is *not* ontologically thin, as it is explicitly introduced as an additional metaphysical factor, over and above objects and their properties. This reaction appears at least partly justified, but doesn't require anything more than a conceptual-terminological qualification. Indeed, it appears useful to restrict the label 'primitive thisness' or 'haecceity' to primitive intrinsic identity when intended as a 'thick' metapysical property, truly additional to other properties of things – something like the individuating factors posited by Duns Scotus; but, especially in view of the above considerations, it still makes sense to conceive of a non-inflationary, thin form of primitive intrinsic identity. From now on, therefore, talk of PTs will be set aside and, in harmony with the naturalist stance, primitive intrinsic identity and individuality will be exclusively intended in the weaker sense.[7]

If the foregoing is correct, it follows that the whole range of options with respect to individuality is in fact available for quantum particles, at least as things stand so far: for, not only Leibniz/Quine individuality as rooted in discernibility but also primitive identity and individuality – both contextual and intrinsic – are open possibilities, even for naturalists. In virtue of this, obviously enough, the careful examination of quantum statistics and its metaphysical consequences (premises 4)-5)) becomes all the more important and interesting.

3. Quantum statistics, primitive identity and haecceitism

The problem with quantum statistics, as is well-known, is that it is radically different from classical statistics, which deals with what one would take as paradigmatic individual objects. Considering two systems and two available states, for example, classically one gets four possible combinations (consider two fair coins). In the quantum

[6] Recall, in this connection, that in their proofs Muller, Saunders and Seevinck need to *assume* the bare numerical difference grounding the countability of quantum particles. Although they take the countability of particles to be a merely formal feature of the theory, one may instead take it to have an ontological import, that is, to justify talk of individuality even independently of the considerations of discernibility that it is supposed to ground.

[7] Incidentally, the metaphysically deflationary reading of primitive intrinsic identity and individuality also goes back to the Scholastic tradition, although to the ramification of it shaped by Ockham's nominalism rather than by Scotus' realism. Ockham surely didn't intend haecceitates as ontological additions to objects and properties.

case, instead, these are only three (consider two (qualitatively) identical bosons in the same system). In particular, in quantum mechanics only (anti-)symmetric states are possible – this is the well-known 'Permutation Symmetry' typical of the quantum domain.

The traditional explanation for this, which some (for example, French and Krause (2006)) call the 'Received View', is that particles are not individual objects, and this is why we shouldn't expect states to be sensitive to *which* object has which property: if an object is not an individual, it doesn't have a well-defined identity, distinct from that of other objects, and thus there are no permutations to be made in the first place in cases such as, say, the above two identical bosons and their state-dependent properties.

If one doesn't like this conclusion, it is an option to simply refrain from drawing metaphysical conclusions from the physics - but this is not what we are doing here. Making identity contextual *à la* Ladyman is also a solution, for if the identity of a thing is extrinsically determined by relations, then swapping things by keeping the relations fixed doesn't give rise to new arrangements, genuinely distinct from the original ones. However, one may want to ask whether (primitive, given the failure of traditional PII) intrinsic individuality is possible for quantum particles – perhaps, because s/he would like to think that the ontological status of an entity as belonging to this or that fundamental ontological category (in particular, to that of individuals) is entirely determined by factors *internal* to it.

What immediately pulls towards a negative answer is that even though, as we have seen, it doesn't force one to posit metaphysically suspicious Scotian PTs, the postulation of primitive intrinsic identities leads to a problem with *haecceitism*. In more detail, one may think that if things are intrinsically individuated it becomes possible for two things existing in different worlds to be the same object independently of what qualitative claims are true of them in each world. Substituing worlds with statistically possible arrangements, one sees that this is exactly what permutation invariance rules out, which is the reason why Ladyman and other contextualists contend that even if PII doesn't hold identity and individuality *must* in any case be extrinsically determined.

However, although primitive intrinsic identities as 'bare identities' are *necessary* for haecceitism (unless one regards trans-world identity as primitive, which is an option but not a very natural one, especially if realism about possible worlds is not taken too seriously), primitive intrinsic identities are not *sufficient* for actual haecceitistic differences.

On the one hand, i) *primitive intrinsic identities need not entail haecceitism*. As a matter of fact, intra-world identities and trans-world identities (modality) are relatively independent, and there is room for different combinations of views about each of them, some of which admitting of bare identities but *not* of haecceitism. A typical example is the possibility of adopting counterpart theory with respect to modality, so denying that the *same* individuals can be arranged in a different but qualitatively identical way by rejecting the idea that the same individual can exist in more than a world (this option has been explored in the philosophy of physics in the past - specifically, in the debate about space-time point substantivalism and the hole argument by Butterfield (1989) and Brighouse (1994)).

On the other hand, ii) *even if haecceitism holds, primitive intrinsic identities need not determine actual (i.e., physically relevant) haecceitistic differences*. Haecceitism is the thesis that there *may be* haecceitistic differences between worlds, not that there *are* and, with respect to the physics of the actual world, this can be translated into the claim that there may be reasons, *other than the lack of primitive intrinsic identity*, for which such differences are not manifested. Indeed, the enemy of primitive intrinsic identity and individuality typically *assumes the classical world as a paradigm*, and consequently deems the peculiarities of quantum statistics sufficient for showing that quantum particles do not possess primitive intrinsic individuality. However, this is a mistake (that, one may add bluntly, is distinctive of the entire Received View on the ontological status of quantum particles). The supporter of primitive intrinsic identity and individuality can, and indeed should, *explain why* the haecceitistic differences made possible by the fact that individuals have primitive intrinsic identities are not manifested in a certain subdomain of the actual world *by pointing to non-classical features, other than non-individuality, of that domain*.

In particular, this can be done in the context of QM. In fact, a number of options have been already discussed in the literature with a view to accounting for permutation invariance without involving the identity-conditions and ontological nature of quantum particles. It is true, on the other hand, that as things stand one may remain unsatisfied. The use of counterpart theory appears unavailable in QM, for unlike in the case of space-time points and models, there seems to be no way of establishing the counterpart relation as needed (Teller (2001)).[8] And other options have been put forward which are not exempt from problems: revising the equiprobability of states - Belousek (2000), restricting

[8] Teller's claims to this effect are not completely uncontroversial, but it is at least fair to claim that scepticism about counterpart theory may lead one to consider this option unappealing anyway.

the accessible states - French and Redhead (1988), attributing indistinguishability to all particles – classical and quantum – and blaming the difference between classical and quantum statistics on the difference in probability measures - Saunders (2006b). Without getting into a detailed discussion of these options, suffice it to say that either they put into question elements (such as probability measures, state-accessibility and classical distinguishability) that one may prefer leaving untouched, or they simply transform the problem into an assumption (e.g., about which states are physically realisable). An unexplored alternative, however, exists that provides a satisfactory explanation while also minimising the amount of revision required with respect to our entrenched beliefs about things. Or so it will be claimed in the rest of this paper.

The claim in what follows will be, in more detail, that a key, though dispensable, assumption is normally made concerning the continuity between classical mechanics and QM with respect to their 'property-structure', that is, the way in which properties are possessed by particles; that modifying this assumption is plausible, minimally revisionary, and explanatorily efficacious; and, crucially, that doing this preserves (or allows one to postulate) particle individuality, *in whatever form*, without even requiring one to venture into the question whether the relevant domain is haecceitistic or not, and in what sense.

3.1 An Account of quantum statistics focusing on properties rather than property-bearers

The assumption referred to at the end of the previous section is (A) that *all state-dependent (i.e., statistically relevant) properties are possessed by individual particles as their monadic properties*. (A) clearly holds in the classical domain, where it provides a ready explanation for why we expect, say, four combinations in cases like two fair coins. However, that this assumption holds is obviously not a metaphysical necessity, and a simple look at entangled states shows that in fact it doesn't hold in QM in at least some cases. Considering, for example, the singlet spin state, it is universally agreed that particles in that state do not possess any well-defined monadic state-independent property, and yet there is something meaningful that can be said about the total system, and therefore taken to be a genuine property: e.g., that there is a definite correlation between the spin values of the separate particles.[9] More generally, in the classical domain Humean supervenience, the doctrine that the whole of reality can be reduced to local matters of fact about objects exemplifiying (local, monadic) properties plus spatio-temporal relations, holds, but it is widely agreed that this is not the case in the quantum domain, for so-called entangled states are possible there.

But if this is true, why exactly should one accept the failure of Humean supervenience in cases such as entangled fermions, but stick to the classical picture when it comes to the more general statistical scenarios? I want to suggest that there is no real reason for doing so, and that it is instead reasonable to think that what is generally agreed to hold for certain quantum systems holds generally, and therefore *all* state-dependent properties of quantum particles in many-particle systems (entangled and non-entangled) are properties expressing correlations and nothing more than that.[10] Let us call *inherent-holistic* those properties of wholes (composed of two or more parts) that

a) Are not reducible to properties of the parts of those wholes and

b) Convey information about such parts without also conveying specific information about any specific part.

The conjecture being put forward thus amounts to the claim that *all quantum state-dependent properties are inherent-holistic properties*.[11] The explanatory efficacy of this conjecture with respect to quantum statistics can be appreciated by simply translating in the suggested terms the relevant many-particle scenarios and noticing that, if all that is described are *correlations*, particle exchanges do not and cannot give rise to new states (i.e., new descriptions). Therefore, one readily obtains an account of the evidence that doesn't involve claims about the identity and individuality of things.

In more detail, once the view of quantum-mechanical state-dependent properties as inherent-holistic properties is adopted, the fact that the statistics only deals with

[9] These correlations can be taken as categorical irreducible relations, as suggested by Muller, Saunders and Seevinck, but also as (monadic or relational) dispositions for measurement outcomes. Which option is to be preferred doesn't matter here, anyway.

[10] It may be objected that one should presuppose supervenience whenever possible, and so non-factorisable entangled states should be deemed 'metaphysically special'. However, 1) I think the explanatory efficacy of a presupposition to the effect that (A) fails in general, plus the fact that such a presupposition allows one to stick to commonsense at a more important level (that of the ontological status of particles and larger physical systems) suffices to resist the objection; moreover, 2) it is possible to implement criteria for evaluating the non-reducibility of global to local properties that make quantum non-supervenience independent of, and non-reducible to, entanglement and non-factorisability: Seevinck (2004) proposes one such criterion, based on the local resources available to agents (so suggesting a shift from an ontological to an epistemological justification for claims of (non-)supervenience and holism).

[11] This might be restricted to identical particles but whether or not one does so is not crucial here.

correlations straightforwardly explains permutation symmetry without questioning the status of identities, modality, probabilities, classical distinguishability etc., for permuting the specific entities involved in a correlation doesn't affect the latter, but the latter is all the relevant physical description is about. This also accounts for the impossibility of non-symmetric states, another puzzle raised by QM: these latter states require separate well-defined (and distinct) states and properties for individual particles, which is exactly what the present proposal rules out.

The above suggestion basically consists of an extension of the sort of holism outlined by Teller (1986), (1989) and Healey (1991) for entangled states to non-entangled states.[12] As promised, it avoids the question of whether haecceitism holds in the quantum domain. For, clearly, if the suggested picture is correct, there are no manifest haecceitistic differences in the quantum case, but these are explained on the basis of a conjecture involving the relevant *properties* (not identities/(non-)individualities); while it remains a possibility that, *were* particles to possess monadic intrinsic state-dependent properties, they *would* indeed exhibit haecceitistic behaviour.

The proposal also requires something: first, that genuine multi-particle wholes be distinguished from mere bunches of particles considered together (we don't want to attribute inherent, holistic properties to any set of several particles described as a whole via the formalism, but only to those which exhibit the peculiar statistical behaviour that was deemed problematic in the first place); this, however, appears a sensible distinction to make anyway; secondly, and more importantly, that in such systems only *total-system symmetric operators* correspond to genuine observables (not single-particle operators, not even when an eigenvalue for the corresponding (alleged) observable is possessed with probability 1). This entails, if anything, a slight modification to the eigenstate-eigenvalue link, but the latter is certainly not an indispensable part of the theory, and just represents a possible interpretative rule.

More details can be found elsewhere (Morganti (2009)). Here, the main point to be made is that, if the foregoing is correct, there is no reason for thinking that 5) is actually true; hence, even if one takes 4) as true, the claim that QM contradicts the view that individuality is determined by the possession of primitive intrinsic identities doesn't follow. Indeed, an explanation of quantum statistics can be provided that, among other

---

[12] Views of which, of course, it doesn't need to share the specific details. Most notably, with respect to Teller's proposal, it is not necessary here to assume that the inherent holistic properties are 'non-Humean' relations.

things, leaves identity and individuality completely untouched. As a consequence, primitive intrinsic individuality becomes (remains?) a viable option for quantum particles (even for naturalists about metaphysics), even in the supposedly 'extreme' form represented by (Ockhamian, not Scotian) primitive identities.

4. Conclusions

The argument - summarised by 1)-C) above - in favour of the conclusion that quantum particles are not individual objects can legitimately be said to fail entirely. The only true part in it is 4), which is, however, a general metaphysical thesis that, by itself, cannot have any bearing with respect to the metaphysical import of quantum mechanics. Hence, we can certainly reject C) as the conclusion of a valid but unsound argument, and believe (even if we are naturalists about metaphysics) that quantum particles are individuals and are not, after all, *very* different from their classical counterparts and, more generally, the objects we interact with in our everyday life. In particular, primitive intrinsic identity and individuality need not, claims to the contrary notwithstanding, be looked at with suspicion by the scientifically-minded philosopher.

References

Belousek, D.W., (2000): *Statistics, Symmetry, and the Conventionality of Indistinguishability in Quantum Mechanics*, in *Foundations of Physics*, 30, 1-34.

Brighouse, C., (1994): *Spacetime and Holes*, in Hull, D., Forbes, M. and Burian, R.M. (eds.): *PSA 1994*, Vol. 1, 117-125.

Butterfield, J., (1989): *The Hole Truth*, in *British Journal for the Philosophy of Science*, 40, 1-28.

French, S. and Krause, D., (2006): *Identity in Physics: A Historical, Philosophical, and Formal Analysis*, Oxford Univeristy Press, Oxford.

French, S. and Redhead, M., (1988): *Quantum Mechanics and the Identity of the Indiscernibles*, in *British Journal for the Philosophy of Science*, 39, 233-246.

Healey, R., (1991): *Holism and Nonseparability*, in *Journal of Philosophy*, 88, 393-421.

Ladyman, J., (2007): *Scientific Structuralism: On the Identity and Diversity of Objects in a Structure,* in *Proceedings of the Aristotelian Society*, Supplementary Volume 81, 23–43.

Ladyman, J. and Bigaj, T., (2010): *The Principle of the Identity of Indiscernibles and Quantum Mechanics*, in *Philosophy of Science*, 77, 117-136.

Morganti, M., (2009): *Inherent Properties and Statistics with Individual Particles in Quantum Mechanics*, in *Studies in History and Philosophy of Modern Physics*, 40, 223-231.

Muller, F.A. and Saunders, S., (2008): *Discerning Fermions*, in *British Journal for the Philosophy of Science*, 59, 499-548.

Muller, F.A., and Seevinck, M.P., (2009): *Discerning Elementary Particles*, in *Philosophy of Science*, 76, 179-200.

Saunders, S., (2006a): *Are Quantum Particles Objects?*, in *Analysis*, 66, 52-63.

Saunders, S., (2006b): *On the Explanation for Quantum Statistics*, in *Studies in History and Philosophy of Modern Physics*, 37, 192-211.

Seevinck, M.P., (2004): *Holism, Physical Theories and Quantum Mechanics*, in *Studies in History and Philosophy of Modern Physics*, 35, 693-712.

Stachel, J., (2004): *Structural Realism and Contextual Individuality*, in Ben-Menahem, Y. (ed.), *Hilary Putnam*, Cambridge University Press, Cambridge, 203-219.

Teller, P., (1986): *Relational Holism and Quantum Mechanics*, in *British Journal for the Philosophy of Science*, 37, 71-81.

Teller, P., (1989): *Relativity, Relational Holism, and the Bell Inequalities*, in Cushing, J. and McMullin, E., (eds.): *Philosophical Consequences of Quantum Theory: Reflections on Bell's Theorem*, University of Notre Dame Press, Notre Dame, Indiana, 208-223.

Teller, P., (2001): *The Ins and Outs of Counterfactual Switching*, in *Noûs*, 35, 365-393.