Review of: "On Probabilities in Quantum Mechanics"

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In my opinion, the preprint “On Probabilities in Quantum Mechanics” by I.S. Helland touches on an important aspect of our understanding of basic quantum mechanical concepts: to which degree algebraic and functional (Schroedinger's equation, unitarities, commutators, Hilbert space of states, superposition principle, etc.) and statistical tools (Born's rule, probabilistic interpretation of QM, both idealistic and real measurements, wave function collapse, reproducibility of statistical predictions about quantum systems, etc.) in the quantum-mechanical description are interconnected and interdependent. In fact, this is an old but still very important philosophical discussion which originates from the “founders' ” (e.g., N. Bohr's and M. Born's) times. This is due to the fact that the deep nature of these interconnections and interdependences is still unclear after nearly a century of quantum mechanics development, despite the numerous attempts made by many researchers.

Indeed, all aspects of the quantum mechanical description of nature which rely on operator algebra and the Hilbert space of states, together with all various quantum interference phenomena (including, e.g., the famous “double-slit” experiment) - do not require any statistical interpretation (or any hypothetical or real observer or observers) to exist at all. On the other hand, all the statistical and measurement tools one could extract from one's common experience (definition of probabilities, definition of interaction between the measured system and the meter, Bayesian rules for probabilities, etc.) have nothing in common with the above-mentioned quantum operator algebra as well as with the superposition principle for complex quantum probability amplitudes. Probably, only the Born's rule for quantum probabilities densities calculation (as the squared absolute value of the corresponding complex quantum amplitude or wave function) is the only statement which joins two “sets” of quantum concepts into one consistent, experimentally confirmed quantum theory. However, the “overlap” between these two sets of different (algebraic and statistical) concepts has always remained somewhat “foggy” and not well defined. As a result, this overlap (between two sets - algebraic and statistical - of QM concepts) continues to fluctuate in different theories of quantum mechanics interpretation.

For example, Feynman's approach to this overlap was to derive all statistical predictions of quantum mechanics from the interference effects between an infinite number of classical trajectories, though taking the exponential form of the evolution operator as well as Born's rule for probabilities calculation for granted. This means that within Feynman's approach, one can observe an attempt to derive all statistical predictions of quantum mechanics from pure interference effects ruled by quantum mechanics algebra. And even in this case, he needed a certain central assumption (Born's rule) as an “external” axiom.

Thus, in my opinion, Helland's approach of “ideal measurements” (or what he calls “theoretical variables” (see e.g., [Helland, 2024a] in the reference list of the preprint) and related algebra represents somewhat of an opposite to Feynman's approach: it is an attempt to say something about quantum operator algebra and the quantum evolution of states starting from some purely statistical concepts of “ideal measurements/variables” which form their own algebra. But here, it is important to notice that, as well as with Feynman's approach, Helland still needs Born's rule as an external important axiom which cannot be derived either solely from statistical arguments or solely from quantum operator algebra (exactly as it takes place with Feynman's integral over trajectories approach). In fact, what one needs in order e.g. to derive a statement about the fact of unitary evolution existence from the Born's rule (see [Helland, 2024a]) is a combination of scalar product symmetry considerations (statistical) and the projection of state vectors (algebraic) concept.

That is why, in my opinion, Helland's approach of “ideal observables” and the related analysis of reproducibility of measurements by different parties looks like an attempt to translate into “statistical language” the phenomena which should be attributed to purely quantum interference-related (i.e., algebraic and functional) aspects of the quantum mechanical description of nature: e.g., the question here is why one needs “observers” and hypothetical “ideal measurements” and “ideal variables” in order to interpret e.g. spectra of eigenvalues or “collective” quantum interference phenomena which happen simultaneously and non-locally even to a single particle (e.g., in “double-slit” experiments) without the presence of any “observers”? - For me, such an attempt of additional statistical interpretation of such phenomena looks like an unnecessary complication of the consistent (though not single-language) quantum theory.

Instead, in order to bring a possible new sense into the overlap of algebraic and statistical fundamentals of quantum theory, I would concentrate on the analysis of the “quantum fluctuations” phenomenon, i.e., on the phenomenon of causal interconnections between the basic quantum mechanical (algebraic) property of “non-commutativity” (of operators) and the related Heisenberg uncertainty (statistical) principle.

Nevertheless, I think that Helland's works play an important role as a part of the continuing discussions about necessary and unnecessary elements in the quantum mechanical description of nature.

As for this preprint, it seems to be part of a long line of related Helland's papers (where the most significant to this discussion seems to be a paper [Helland, 2024a]). However, besides its theoretical meaning, which I tried to highlight above, this preprint looks a bit “hanging in the air” since it looks as a part of a conversation between two specialists being occasionally heard by a third person. What is the meaning (in a nutshell) of a number of following terms: Khrennikov's approach, Ozawa's theorem, and Helland's own theory from [Helland, 2024a] and other related papers? - I mean that if this preprint has been written in order to attract more readers than the author and persons he argues with, then a brief overview of the related context is extremely necessary. In my opinion, this is a main flaw of this preprint. That is why I think that to be considered as a separate concise publication, this preprint needs major revision, paying attention to all those aspects I've highlighted above.