Dynamics of quantum measurement and the quantum measurement problem

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To elucidate ideal measurements, one must explain how individual events emerge from quantum theory which deals with statistical ensembles, and how different may end up with different final states. This so-called "measurement problem" is tackled with two guidelines. On the one hand, the dynamics of the macroscopic apparatus A coupled to the tested system S is described mathematically within a standard quantum formalism, where "q-probablities" remain devoid of interpretation. On the other hand, interpretative principles are introduced to account for the expected features of ideal measurements. Most of the five principles, which relate the quantum formalism to physical reality, are straightforward and refer to macroscopic variables. The process can be identified with a relaxation of S+A to thermodynamic equilibrium, not only for a large ensemble $\mathcal{E}$ of runs but even for its sub-ensembles. The different mechanisms of quantum statistical dynamics that ensure the relaxation are exhibited. The additional information provided by the sub-ensembles remove Schrödinger's quantum ambiguity of the final density operator for $\mathcal{E}$ which hinders its direct interpretation, and bring out a commutative behaviour of the pointer observable at the final time. The latter property supports the introduction of a last principle, needed to switch from the statistical ensembles and sub-ensembles described by quantum theory to individual experimental events. It amounts to identify some formal "q-probabilities" with ordinary frequencies, but only those which refer to the final pointer indications. The desired properties of ideal measurements, in particular the uniqueness of the result for each individual run and von Neumann's reduction, are thereby recovered with economic interpretations. The status of Born's rule involving both A and S is re-evaluated, and contextuality is made obvious.