About the nature of quantum information

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Despite formal precision, the concept of information has received varied and incompatible interpretations (Lombardi, Holik, and Vanni 2016). During the last decades, new interpretive problems have arisen with the advent of quantum information; those problems combine the difficulties in the understanding of the concept of information with the well-known foundational puzzles derived from quantum mechanics itself. Although there were many works on the matter before, Benjamin Schumacher's article "Quantum Coding" (1995) is usually considered the first precise formalization of the quantum information theory. In this context, the question 'What is quantum information?' is still far from having the answer which the whole quantum information community agrees with. In fact, the positions about the matter range from those who seem to deny the existence of quantum information (Duwell 2003), to those who conceive it as a new kind of information absolutely different from classical information (Jozsa 1998, Brukner, and Zeilinger 2001).

The aim of this talk is to consider some arguments traditionally put forward to support the idea that quantum information is qualitatively different from classical information.

- Contrary to some claims (Timpson 2013), there are not two kinds of information sources, classical and quantum. The quantum system that produces quantum states is part of the transmitter; the quantum state is not a message but a signal encoding the message (Lombardi, Fortin, and López 2016). This remark is in agreement with the very title of Schumacher's article: "Quantum Coding" and not "Quantum Information".
- If quantum information were conceived as what is generated by a quantum source, nothing would change in the discourse about quantum information if one replaced the term 'quantum information' by the term 'quantum state': the concept of quantum information would collapse with that of quantum state.
- Some authors link the very meaning of 'information' with the coding theorems: if Shannon's noiseless coding theorem and Schumacher's noiseless coding theorem are different, then the corresponding concepts of information are also different (Timpson 2008). But, in this case, information would not be defined for single messages. Moreover, it would be not possible to talk about information in situations that do not involve coding, as in traditional telephony where the transmitter operates as a mere transducer.

- The von Neumann entropy $S(\rho)$ is not a measure of the information produced by a source of information. What the von Neumann entropy measures are the optimal quantum resources needed to encode the information, that is, the number of quantum systems required, in average, to encode the messages produced at the source of information.
- Some authors (e.g. Brukner and Zeilinger 2001) claim that Shannon theory cannot be applied to quantum contexts since it assumes a classical notion of measurement, according to which measurement discovers actually preexisting values of the system's properties. However, there is nothing in Shannon's theory that requires actual sequences of states in the source of information in order to define its entropy. In fact, Shannon entropy only depends on the statistical features of the source, and not on the nature of its states.

On the basis of these arguments, we conclude that there are no reasons to admit the existence of quantum information as qualitatively different from classical information: there is only one kind of information, physically neutral, which can be encoded by means of classical or of quantum states.

References

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