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Reply to arXiv:2111.13357 (“The Quantum Eraser Non-Paradox”)

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In a recent criticism (arXiv:2111.13357) of our paper arXiv:2111.09347, Drezet argues that we have forgotten to consider superpositions of detector eigenstates. However, such superpositions do not occur in the models our paper is concerned with. We also note that no one has ever observed such detector superpositions.

In our recent paper [1], we propose a quantum mechanical experiment that leads to a temporal paradox for local-realist hidden variables models which rely on backward causation (“retrocausality”). We argue that resolving the paradox requires giving up the idea that in such models a choice can influence the past, and that it instead requires a violation of Statistical Independence without retrocausality. Throughout our paper, we state explicitly and repeatedly that we are concerned with local realist models, rather than the Bell-nonlocal/contextual models typically referred to as Standard Quantum Mechanics or any mathematically equivalent interpretations thereof.

In a local realist hidden variable model the wave-function is an ensemble of ontic states. The outcome of a measurement is always a detector eigenstate. Which of the detector eigenstates is realised – i.e., which measurement outcome occurs – is determined by the hidden variables. In such models, the outcome of a measurement is never a superposition of detector eigenstates. The entire purpose of such models is to make sure that the outcome of a measurement is always a detector eigenstate. We know from Bell’s theorem and the observed violations of the inequality which follows from it that such models must violate Statistical Independence, hence they are either superdeterministic or retrocausal. These models are the focus of our paper.

In a recent criticism of our paper, Drezet [2] argues that we have forgotten to consider superpositions of detector eigenstates. However, such superpositions do not occur in the models our paper is concerned with. We may also note that no one

has ever observed such a thing.

We know detectors of the sort we describe act classically (they give out classical single clicks for photon detections, rather than superpositions of clicks). Given that we do not consider many worlds, many histories, or relational interpretations of quantum mechanics, there is no need to describe these detectors as quantum objects.

We want to emphasise that we certainly do not claim that our experiment poses a problem for quantum mechanics. It does not, as we have clearly stated in our paper. It is rather unsurprising that [2] obtains a result compatible with quantum mechanics using quantum mechanics – in whatever interpretation, retrocausal or otherwise.

In the local hidden variables models which we consider, the measurement outcome is always a determined detector eigenstate. To explain the experiment without the feedback loop, a non-detection at D_1 must mean the photon pair was created at the lower slit, and its entangled partner had a 50:50 chance of being reflected:transmitted (and so going to U_3 and U_4 half of the time each). With the feedback loop, the photon would always have to go to U_4 . We expect this to be incompatible with observation as it contradicts the quantum mechanical result.

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[1] Colm Bracken, Jonte R Hance, and Sabine Hossenfelder. The quantum eraser paradox. *arXiv preprint arXiv:2111.09347*, 2021. URL: <https://arxiv.org/abs/2111.09347>.

[2] Aurélien Drezet. The quantum eraser non-paradox: a comment on arxiv:2111.09347v1. *arXiv preprint arXiv:2111.13357*, 2021. URL: <https://arxiv.org/abs/2111.13357>.

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