Peer-Review

Kim, Eli. 2026. “Noise-Dependent Limits of Dynamical Decoupling: Fidelity and Variance Dynamics in Single-Qubit Systems.” *Journal of High School Science* 10 (2): 159–75. https://doi.org/10.64336/001c.161307.

There is nothing novel in your contribution but it is a solid, clean and well designed experiment under ideal conditions that shows that carefully timed “echo” pulses can partially protect quantum information from noise, but they cannot prevent the fundamental loss of energy that ultimately destroys qubits.

I would like you to add another metric to your results - call it the variance of purity decay across stochastic trials for each type of pulse intervention (see chat gpt file attached). You already have Monte Carlo data; you will just need to operationalize that data further to provide an answer to the question "Do some kind of pulses make decoherence dynamics more predictable/reliable?”

Most papers treat the variance as error bars or uncertainty. It becomes novel if you show at least one of the following:

1.You show a non-trivial tradeoff
Example:
Pulse Sequence A → higher mean purity but higher variance
Pulse Sequence B → slightly lower mean but much lower variance
That’s new insight, even if the metric isn’t new.

2.Show variance behaves differently from mean
Example:
Mean purity similar across sequences
Variance very different
→ reveals robustness differences not captured by averages

3.Show variance encodes physics
Example:
Phase noise → high variance
T_1 noise → lower variance but monotonic decay
→ connects variability to noise mechanisms

4.Show scaling behavior
Example:
variance vs pulse number
variance vs noise strength
→ that’s closer to publishable analysis

Even if you don’t, that is still a defensible non-obvious contribution that will have addressed an implicit assumption.

Very well done. Thank you for addressing my comments so comprehensively. There remains one missed opportunity (in my original review) and one deficiency.

1.are these variance differences e.g., 0.18 → 0.06, statistically significant ? Please bootstrap CI for variance
-If CIs do not overlap much → strong evidence of difference
-If they overlap substantially → difference likely not robust
-If one CI is much tighter → insight into stability, not just magnitude

2.there remains one opportunity to further strengthen the manuscript with relatively modest additional analysis. The current treatment collapses purity decay into aggregate statistics over time. As a result, the temporal structure of stochasticity—how variance evolves during the decoherence process—is not visible. Including a time-resolved analysis (e.g., variance or CV of purity as a function of evolution time or pulse number for at least one representative noise regime) would significantly enhance the mechanistic insight. Such a figure would help distinguish whether pulse sequences primarily suppress early-time divergence, late-time spread, or both, and would more tightly connect the statistical observations to dynamical behavior.

Before I accept this manuscript, please provide the following:

1.Either a word or a libreoffice writer document of your manuscript properly formatted to the Journal's guidelines. Please ensure that any equations/figures etc. carry over without ideosyncracies.

2.Please find an appropriate place in the manuscript (results) and include this paragraph which fully articulates and captures what you have done with the revisions. Also include content in the Abstract and conclusions.

"Dynamical decoupling sequences do not merely reduce average error, but reshape the temporal and statistical geometry of noise in a way that determines whether quantum information remains operationally usable. In particular, the time-resolved variance results show that CPMG converts a regime of progressive stochastic divergence (baseline: +267% variance growth) into one of bounded, near-stationary fluctuations (+89%), implying that the error process transitions from effectively non-stationary to approximately stationary under dense pulse control . This has a nontrivial consequence: even if two strategies yield similar endpoint fidelity or comparable mean purity at certain times, the one with suppressed variance growth ensures that intermediate quantum states remain within a predictable error envelope, which is essential for composability in multi-step circuits. Conversely, the convergence of variance across all strategies in the T_1-dominated regime indicates that amplitude damping imposes a floor not just on mean coherence but on controllability of stochasticity itself—that is, beyond a certain point, the system loses not only information but also the ability to stabilize its uncertainty, rendering pulse-level interventions fundamentally incapable of improving reliability. Taken together, the results suggest a hierarchy: (1) in T_2-dominated regimes, pulse sequences act as stochastic regulators that enforce temporal consistency; (2) in mixed regimes, they transiently shape but cannot bound variability; and (3) in T_1-dominated regimes, both mean performance and higher-order statistical structure collapse to hardware-limited behavior. This reframes the role of dynamical decoupling from error "correction" to noise-structure engineering, where the key design objective is not simply maximizing fidelity, but ensuring that error remains temporally uniform, bounded, and therefore schedulable within larger quantum algorithms."

Response to Reviewer Comments

Journal of Humanities and Social Sciences

Manuscript: "Noise-Dependent Limits of Dynamical Decoupling: Fidelity Recovery and T_1-Constrained Decoherence in Single-Qubit Systems"

Author: Eli Kim

Comment 1 (verbatim):
Either a word or a libreoffice writer document of your manuscript properly formatted to the Journal's guidelines. Please ensure that any equations/figures etc. carry over without idiosyncrasies.

Response:
The manuscript has been reformatted and submitted as a .docx file compatible with Microsoft Word and LibreOffice Writer (RevisionIV_Eli_Kim_JHSS_Submission.docx). It adheres to the journal's formatting requirements, including font, margins, alignment, and heading structure. Equations have been standardized to ensure consistent rendering, and all figures, captions, and tables have been formatted for clarity and consistency. Page numbers, headers, and a properly formatted Works Cited section with DOI links have also been included. The submitted file is the finalized formatted version.

Comment 2 (verbatim):
Please find an appropriate place in the manuscript (results) and include this paragraph which fully articulates and captures what you have done with the revisions. Also include content in the Abstract and conclusions.

Response:

The requested paragraph has been inserted verbatim at the end of the “Summary of Results” subsection in the Results section, immediately following the time-resolved variance analysis to which it refers. This placement ensures that the interpretive claims are directly supported by the preceding results.

In addition, related material has been incorporated into both the Abstract and the Conclusion. The Abstract now includes a new concluding paragraph that summarizes the regime hierarchy and introduces the noise-structure engineering perspective. The Conclusion includes a corresponding paragraph that restates this framework and emphasizes its implications for quantum circuit design, particularly the importance of bounded variance for reliability. The reviewer-supplied paragraph itself was included without modification, and all additions are consistent with its terminology and framing.

Thank you for addressing my comments. Accepted.