Schrödinger's Cats Superposition and Measured Time[1]
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Extended abstract: *The wave equation represents all the different probabilities of an atom's decay time as a superposition. Schrödinger's thought experiment creates a one-to-one correlation between all the equal atoms' decay time and the many cats' death times. This paper correlates the wave equation's superposition of states to a time distribution of multiple individual measurement results of equal atoms/cats.*

This correlation identifies that observing the cats only at one hour is very imprecise. The distribution of dead cats may be seen as a cumulative probability distribution centered at one hour. When the observations are in the middle of a two-hour distribution, all that is known is: in half the observations a cat is dead and in half the observations a cat is alive, but they are not the same cats. This is the maximum possible imprecision in this maximum two-hour experiment. This imprecision causes any single cat to appear to be both alive and dead, a paradox. This paradox disappears and the concept of a measurement scale's precision becomes clearer, when the scale's precision is increased by observing each cat every 10 minutes.

Schrödinger's thought experiment plays on a misconception in Representational Measurement Theory (RepMT, applied in all physics). RepMT assumes a measurement scale is exact in theory. Schrödinger's thought experiment identifies that the precision of the measurement scale does have an effect on measurement results in theory. Changing this subtle misconception in RepMT (by proposing Relative Measurement Theory) resolves the apparent differences (i.e., measurement problems) between classical and quantum mechanics.

The Wikipedia position on Schrödinger's cat:[2] "Fundamentally, the Schrödinger's cat experiment asks how long quantum superpositions last and when (or *whether*) they collapse [into experimental measurement results]. Different interpretations of the mathematics of quantum mechanics have been proposed that give different explanations for this process, but Schrödinger's cat remains an unsolved problem in physics." This paper proposes that revising metrology[3] into Measurement Mechanics,[4] rather than a different interpretation of quantum mechanics, explains Schrödinger's cat experiments.

1. Schrödinger's experiment creates a paradox.

> "One can even set up quite ridiculous cases. A cat is penned up in a steel chamber, along with the following diabolical device (which must be secured against direct interference by the cat): in a Geiger counter, there is a tiny bit of radioactive substance, *so* small, that *perhaps* in the course of one hour one of the atoms decays, but also, with equal probability, perhaps none; if it happens, the counter tube discharges and through a relay releases a hammer which shatters a small flask of hydrocyanic acid. If one has left this entire system to itself for an hour, one would say that the cat still lives *if* meanwhile no atom has decayed. The first atomic decay would have poisoned it. The ψ function of the entire system would express this by having in it the living and dead cat (pardon the expression) mixed or smeared out in equal parts." [5]

The paradox: How can a cat be alive and dead at the same time?

2. This paradox is explained by examining multiple experiments.

In quantum mechanics the wave function (ψ) of an atom represents a superposition (time independent) of all of the possible states of an atom's decay. Fig. 1 presents multiple experiments over time. The vertical axis represents the cumulative probability of any atom/cat and the horizontal axis represents time, where the physical states of multiple different atoms/cats occur. The superposition (ψ) represents all these states independent of time.

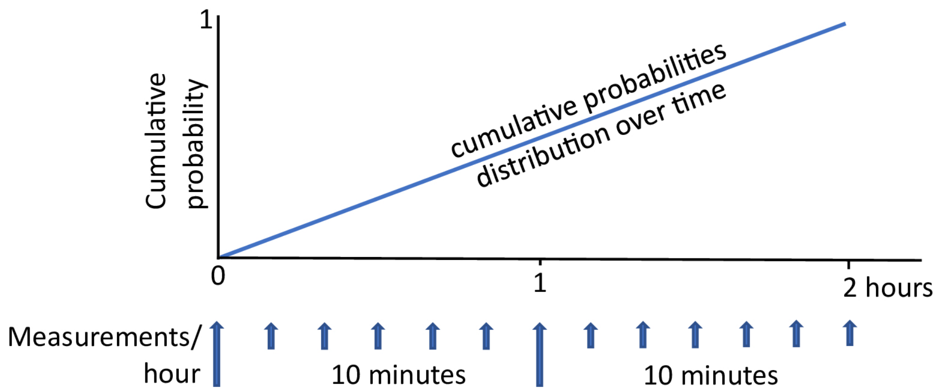
3. Results from multiple experiments form a probability distribution.

In each experimental run of Schrödinger's diabolical device another atom decays and another unfortunate cat dies with a one-to-one correlation. In Schrödinger's thought experiment, any atom has a 0.5 probability of radioactive decay after 1 hour. The radioactive decay of many individual atoms generates a Poisson cumulative probability distribution which is an S curve.[6] Fig. 1 represents this S curve as a diagonal line (for drawing simplicity). Changing the S curve to a diagonal line does not significantly impact his thought experiment.

4. Assuming a 2-hour probability distribution.

Each experimental run ends with one cat's death. Many experimental runs produce the diagonal line representing both the ψ function's cumulative probabilities and a distribution of multiple measurement results over time. Assuming this distribution of each experimental run's result is linear over time, the 2-hour total distribution time is twice the mean 1-hour time. This common assumption causes the maximum imprecision.

Fig. 1 Experimental results distribution over 2-hours



At the bottom of Fig. 1 the two long bold upward arrows indicate when a human measures each cat in each run. The first time is when a cat is penned into the diabolical device (0 hour) and the second time is at 1-hour, the middle of the 2-hour range of the distribution. Each cat's actual time of death is one point on the diagonal line, but is only measured with a precision of ± 1-hour.

5. The ± 1-hour imprecision of each cat's time of death.

This thought experiment is paradoxical because the one hour measurement unit time interval establishes the precision (± 1-hour) of each measurement result, making Schrödinger's measurements the most imprecise possible, when a 2-hour distribution is assumed. It is imprecision, not superposition, that makes it impossible to determine whether a single cat is alive or dead. All that can be known is: half of the many cats, when observed at 1-hour, are alive. And half, when observed at 1-hour, are dead, <u>but not the same cats.</u>

6. More precise measurements results requires more precise units.

All measurement results consist of a numerical value and a measurement unit.[7] In Schrödinger's thought experiment the numerical value is the binary representation of alive or dead and the measurement unit is one hour. Consider changing Schrödinger's statement, "If one has left this entire system to itself for an hour,...", to 10 minutes. The eleven short bold arrows at the bottom of Fig. 1 show this change. Decreasing the measurement unit/scale interval results in more precise measurements.

In Measurement Mechanics, the smallest measurement scale intervals, including their individual precision, determines the precision of an experimental measurement result. With the shorter time interval, the observed time of death occurs within ±10 minutes of the actual time of death. Dividing the 10 minute reference units into even smaller, but still equal intervals, further increases the precision of each measurement of each cat's time of death.

7. Including calibration in a new theory of measurement.

In Measurement Mechanics, a measurement result is a numerical value which is the sum of a set of the smallest intervals on a measurement instrument's scale. This numerical value has an accuracy and each interval has a precision determined by calibration to a unit reference/standard or factor thereof. The smaller and closer to equal the smallest intervals on a measurement scale, the greater the precision of an experimental measurement result.

Applying Measurement Mechanics, the precision of each of the smallest intervals of a scale is determined by calibration. Calibration, most rigorously, divides each smallest interval on a measurement instrument's scale into yet smaller calibration resolution intervals and applying the calibration resolution intervals, compares each interval on the scale to a unit reference/standard or factor thereof, which is exact. Then the precision of each interval on the measurement scale is determined.

Each smallest scale interval has in practice and the units, or factors thereof, represented as intervals on the scale, each have in theory, a precision which must, in theory, be greater than or equal to +/- the calibration resolution when there is no noise (external to the measurement system) or distortion (internal to the measurement system). Summing each interval with its random +/- precision generates a measurement result. Over many repetitive measurement results this summation of each interval +/- random interval precision, generates a normal (Gaussian) probability mass distribution. Measurement Mechanics explains, and is verified by, experimental results.[8]

8. The existing measurement theory assumes a measurement instrument's scale is invariant.

As currently applied in all physics, Representational Measurement Theory (RepMT)[9] treats calibration as an empirical process (does not impact theory) that only adjusts an experimental measurement instrument's intervals precisely enough for a measurement in practice. RepMT assumes each interval of a measurement scale is invariant.

In metrology and Measurement Mechanics only the reference/standard is invariant, not the intervals of a measurement instrument's scale. In Measurement Mechanics, all the intervals of a measurement scale become closer to equal by calibration.

9. Precision and uncertainty make equal intervals impossible.

RepMT incorrectly assumes the intervals of a scale are equal in theory (invariant), which incorrectly assumes the correlation between each interval and a reference/standard unit or factor can be exact in theory. Both assumptions ignore Measurement Mechanics precision (caused by calibration resolution intervals) and Heisenberg uncertainty (caused by Planck intervals).

Relative Measurement Theory identified and verified that the effect of calibration resolution intervals at classical scales is equivalent to the effect of Planck intervals at quantum scales.[10] Schrödinger's experiment identifies that the precision of a measurement instrument's scale in theory has an effect on measurement results, which identifies the equal intervals misconception in RepMT and validates the measurement equation proposed in Measurement Mechanics.

10. Relative Measurement Theory resolves the measurement problems.

Relative Measurement Theory formally identifies the preexisting relationship, caused by calibration, between two independent measurement instruments which appears in the Stern-Gerlach experiments.[11]

The inclusion of calibration in a measurement resolves all the differences (i.e., measurement problems) between quantum and classical measurements.

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[1] An earlier version of this paper appeared on the blog ScienceX June 17, 2020. https://sciencex.com/news/2020-06-schrdinger-cat.html?utm_source=nwletter&utm_medium=email&utm_campaign=daily-nwletter. Other early versions appear on the preprint site Qeios.com.
[2] Wikipedia (Nov 29, 2023) https://en.wikipedia.org/wiki/Schr%C3%B6dinger%27s_cat
[3] International Vocabulary of Metrology (VIM), third ed., BIPM JCGM 200:2012, http://www.bipm.org/en/publications/guides/vim.html December 2022. This provides the definitions of metrology.
[4] K. Krechmer, Measurement Mechanics, August 2024, preprint on Qeios https://www.qeios.com/read/EFJP80. Provides the proposed revisions to metrology definitions necessary to include calibration in measurement theory.
[5] E. Schrödinger, "The Present Situation in Quantum Mechanics". First published in German in Naturwissenschaften 23, 1935. This translation (J. D. Trimmer) first appeared in the *Proceedings of the American Philosophical Society*, 124, 323–38 (1980). This paragraph is all the information Schrödinger supplied on his thought experiment.
[6] https://en.wikipedia.org/wiki/Poisson_distribution, July 5 2026.
[7] J. C. Maxwell, *A Treatise on Electricity and Magnetism*, 3rd Ed., 1891, Dover Publications, New York, 1954, A measurement result (i.e., a quantity) is defined on p. 1.
[8] K. Krechmer, Measurement Mechanics. Section 3 provides a more detailed explanation of normal repetitive measurement distributions.
[9] D. H. Krantz, et al, Foundations of Measurement (RepMT), Academic Press, NYC, NY, 1971. This three volume work is considered to be the "magnum opus" on representational measurement theory by D. J. Hand, Measurement Theory and Practice, Arnold, London England, 2004, page 27. On page 32 of RepMT, Section 1.5, Roles of Theories of Measurement in the Sciences. “The construction and calibration of measuring devices is a major activity, but it lies rather far from the sorts of qualitative theories we examine here”
[10] K. Krechmer, Relative Measurement Theory, The unification of experimental and theoretical measurements, *Measurement*, Volume 116, February 2018, pages 77-82. The Appendix provides verification that precision and Heisenberg uncertainty are equivalent.
[11] K. Krechmer, Measurement Mechanics. Section 10 provides explanations of different measurement problems.