Counterfactuals-based Stress Test for Theory Choice
in the Geometric Trinity of Gravitation

Abstract

Thesis: I argue that a Woodwardian counterfactuals-based stress test provides a superior basis for realists for epistemic choice in the geometric trinity of gravitational theories compared to current approaches.

Background: Read (2025) provides a succinct overview of the philosophical issues surrounding the geometrical trinity of gravitational theories. General relativity (GR) explains gravitational effects via spacetime curvature, the teleparallel equivalent of general relativity (TEGR) does so in terms of torsion but a flat spacetime, while symmetric teleparallel equivalent of general relativity (STEGR) takes spacetime to be flat with no torsion, while spacetime non-metricity gives rise to gravitational effects. See Hehl et al. 1995; Jimenez et al 2019; Bahamonde et al. 2023; Heisenberg 2024 for a detailed review of the trinity.

TEGR and GR are not theoretically equivalent (Weatherall & Meskhidze 2024, March et al 2025) but the three theories have the same empirical content. Accordingly, they constitute a case of ontological underdetermination in that each has a distinct ontology while producing all the same empirical results (Lyre & Eynck 2003, Wolf et al 2024, and others). Mulder (2024) and Read (2025) offers a summary of the various approaches to resolve the underdetermination. These include: appeal to geometric conventionalism (Durr and Read 2024 and Roberts 2025); common core (March et al. 2024a, Weatherall and Meskhidze 2024, and Wolf et al. 2024b); same representational capacities in the context especially of boundary conditions (Wolf and Read 2023); extra-empirical virtues such as simplicity or aesthetically pleasing (Le Bihan and Read 2018); and overarching solutions such as general metric-affine gravity (MAG). Knox (2011), Golonev (2024) and Zhou (2025) deny that there is any underdetermination. Mulder & Read (2024) counter Knox. Knox & Golonev prefer GR, and Zhou, according to Mulder (2024) is closest to achieving MAG.

For a realist, theory choice should be guided by a criterion which is truth-tracking, even though the realist recognizes that the indicated choice may not turn out to be correct. In other words, realists are fallibilists. I will argue that the approaches outlined in the previous paragraph to resolve the underdetermination do not explicitly or implicitly demonstrate truth tracking, or do so unsatisfactorily.

Counterfactuals-based Criterion: I propose a different criterion based on Woodward's (2006, 2018b) use of interventions to determine the strength of dependence relations between the posits and postulates of a theory and its observations or predictions. The stronger the relation, the stronger should be the epistemic preference for the theory.

Woodward describes two notions – invariance and insensitivity. Given a purported cause p, invariance refers to the stability of the relationship between p and its putative effect q under a special process called intervention. To the extent that the dependence relationship between p and q continues to hold under different interventions, the dependence relationship between q and p is invariant. Insensitivity is a related notion, but refers to changes in background conditions rather than interventions. Woodward formulates the issue as one where if p causes q, then what would be the sensitivity of q to p' in the neighborhood of p, and similarly for the sensitivity of ~p and ~q. To the extent that the relationship continues to hold for the former (and not for the latter) the dependence is insensitive to changes in background conditions. Woodward (2018b) defends his invariance based account from various critiques including circularity and subjectivity. He says that the invariance test provides a naturalistic, scientifically respectable, and non-mysterious account (Woodward 2018b, 160). I claim that a theory which survives the invariance test demonstrates a stronger dependence relationship between its posits and observations, and thus is more likely to be truth-tracking. Woodward (2018a) extends his invariance-based account to non-causal dependence relations.

Geometric Trinity Subjected to Woodwardian Counterfactuals-based Stress Test: If a theory in the trinity accommodates the intervention, it passes the test. If it cannot, because of limitations within the theory or because it needs a supplemental theory then it does not pass the test. I propose three Woodwardian interventions as counterfactuals (i) change in the number of dimensions of spacetime, (ii) violation of the weak equivalence principle, and (iii) local Lorentz violations.

Change in dimensions: I show that GR fares poorly for number of dimension $d<4$, while TEGR is responsive. STEGR performs not so well for $d>4$ with superfluous degrees of freedom.

Violation of the Weak Equivalence Principle: In GR, the equivalence principle is essential. Aldrovandi et al (2004a, 2004b) derive an equation which allows different values for gravitational and inertial masses. They reproduce the action for TEGR, but without assuming the weak equivalence principle. STEGR too falters when accommodating WEP violation.

Local Lorentz violations: GR cannot handle these natively, but requires extra fields. TEGR can accommodate these via appropriate spin connection. Local Lorentz violations are harder to introduce in STEGR.

Based on these considerations, the epistemic choice of theory veers towards TEGR. One criticism could be the choice of interventions seems to favor TEGR. At the very least, the exercise demonstrates the power of the counterfactuals-based stress test principle.

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