

Evidence Integration: Triangulation Across Measurements That See Different Things

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Abstract

Scientific confidence often increases when different methods, data sources or measurement systems with different error structures support the same bounded conclusion. This is triangulation, not simple replication and not numerical averaging of heterogeneous evidence. The inferential value comes from partial independence of the routes: weaknesses in one method should not be expected to generate the same result in another for the same reason. This article defines evidence integration as structured comparison of non-equivalent evidence streams. It distinguishes triangulation from proxy substitution, meta-analysis and repeated measurement, and introduces a convergence matrix that records what each method measures, its principal assumptions, its characteristic failure modes and the claim component it constrains. Convergence can reduce the plausibility of explanations tied to one method-specific artefact, whereas disagreement can localise hidden assumptions or reveal that the methods are not targeting the same quantity. Integration is strongest when heterogeneity is designed rather than accidental.

Keywords: triangulation; evidence integration; converging evidence; complementary methods; measurement; causal inference

1. More evidence is not automatically more independent evidence

Ten measurements made with the same instrument and preprocessing pipeline can provide precision without much protection against a shared systematic error. Triangulation instead seeks evidence streams with different and preferably unrelated sources of bias. Lawlor, Tilling and Davey Smith formalised this logic in aetiological epidemiology: causal confidence can be strengthened when different approaches, each with different assumptions, point toward the same conclusion [1]. Munafo and Davey Smith similarly emphasise that robust research benefits from multiple lines of evidence rather than replication alone [2].

2. Triangulation is not proxy substitution

Different measurements are useful only if their relation to the target claim is explicit. HEB-004 owns the hidden-proxy failure in which one convenient measurement is silently treated as the quantity of interest. INF-011 instead asks how deliberately non-equivalent measurements can constrain different parts of the same claim. Their non-equivalence is a feature only when the mapping between each measure and the claim is specified.

3. Independence of failure modes

The most informative combination is not necessarily the pair of methods with the most similar outputs. It is often the pair whose biases arise from different mechanisms. If optical spectroscopy and a gravimetric assay agree, for example, the integration is stronger when optical calibration error would not be expected to reproduce a gravimetric artefact. By contrast, two instruments using the same reference material, preprocessing algorithm or sampling route may share a hidden dependency.

4. Convergence matrix

- For each evidence stream, state the immediate measurand or observable.
- State which component of the scientific claim it constrains.
- List its principal assumptions and dominant failure modes.
- Identify dependencies shared with other streams: specimens, calibration, preprocessing, model, operator or selection process.
- Predict what pattern of disagreement would be expected if one stream were biased.
- Interpret convergence only after these relationships are explicit.

5. Agreement and disagreement

Agreement across genuinely different routes can weaken explanations based on one route-specific artefact. It does not prove that all routes are valid or that the preferred explanation is unique. Disagreement is not automatically failure; it can reveal scale dependence, temporal mismatch, different estimands, heterogeneous populations or a violated assumption. The first response to disagreement should therefore be to determine whether the methods were actually expected to estimate the same claim component.

6. Relation to causal inference

In causal research, different identification strategies can be triangulated when their biases are plausibly different. Randomised experiments, natural experiments, negative controls, instrumental-variable analyses and longitudinal adjustment do not become interchangeable. Their value lies in asking whether a common causal conclusion survives routes with different vulnerability profiles [1]. The causal claim still requires the assumptions of each design to be stated [3].

7. Relation to replication and meta-analysis

Replication repeats or closely reproduces an evidential route to test reproducibility. Meta-analysis statistically combines estimates under a model of comparability and heterogeneity. Triangulation can use replicated or meta-analytic evidence but has a different objective: to compare routes that see the problem differently. Numerical pooling is neither required nor always appropriate.

8. Minimum reporting

- Name each evidence stream and its immediate measurand.
- State which assumptions are shared and which are method-specific.
- Explain why the streams are expected to constrain the same claim.
- Do not count repeated measurements from one route as independent triangulation.
- Report disagreements and investigate whether they reflect bias, heterogeneity or different targets.
- Avoid a generic “multiple methods agree” statement without a failure-mode analysis.

References

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Data and materials statement

No new experimental dataset was generated for this article. The article is a methodological analysis based on the cited literature and the frozen ownership architecture of the INF series.