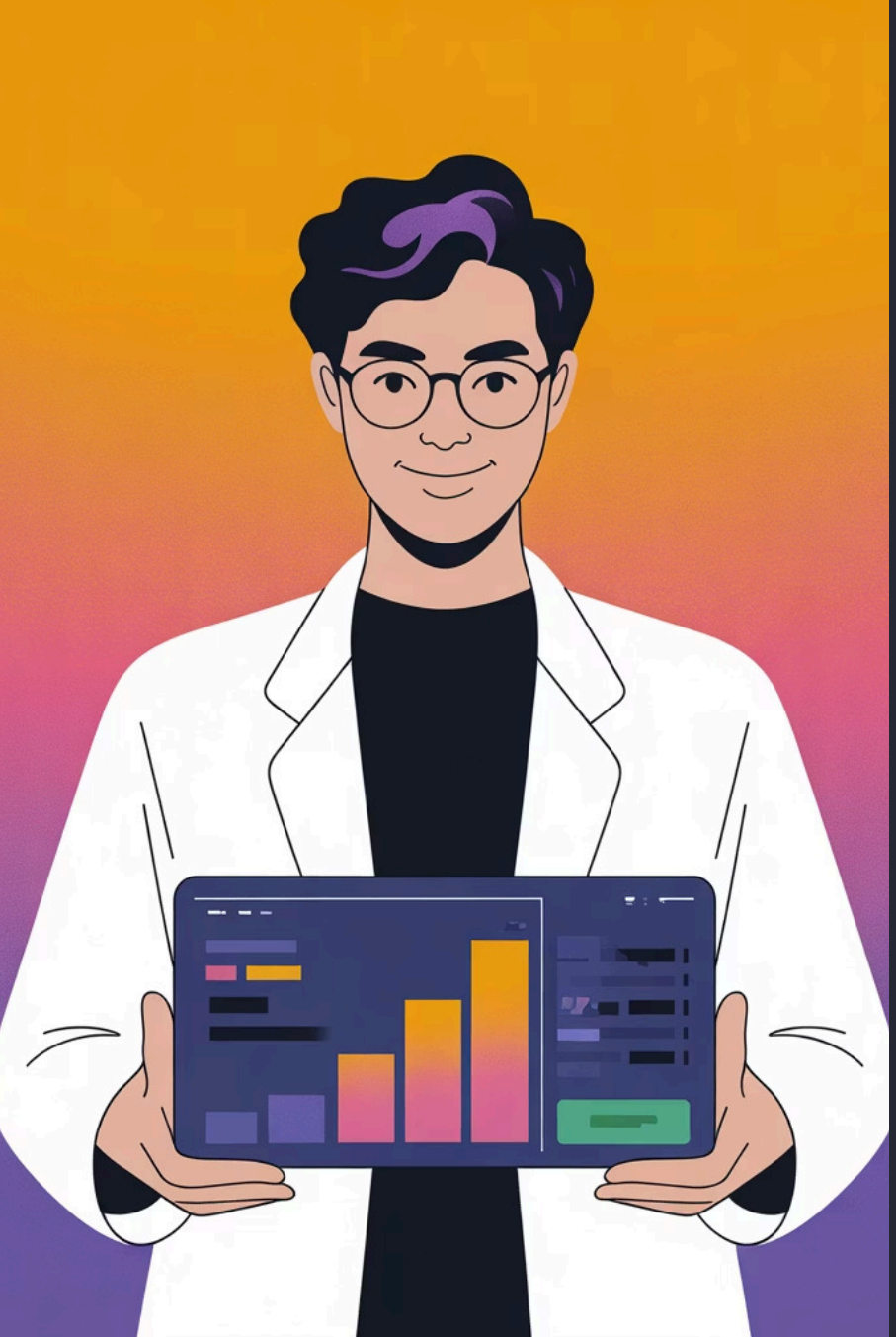

Rigorous Meta Ads Experimentation: A Methodological Framework with Simulated Proof-of-Concept

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This thesis presents a comprehensive methodological framework for conducting statistically rigorous paid social media experiments, complemented by a simulated proof-of-concept application calibrated to direct-to-consumer industry benchmarks. The framework prioritizes decision quality through integrated statistical protocols and economic guardrails, addressing systematic failures in contemporary digital advertising experimentation.

Why Paid Social Tests Often Fail

Common Failure Modes

Contemporary paid social experimentation suffers from predictable, systematic failure modes that undermine decision quality. Attribution drift occurs when measurement windows shift mid-experiment, creating non-comparable treatment effects. Underpowered sample sizes lead to inconclusive results and false negatives, while mid-test creative edits invalidate statistical assumptions.

Platform-specific constraints compound these issues. Audience overlap between treatment arms violates independence assumptions. Pacing algorithms and frequency capping introduce confounding variables that distort delivery patterns and user exposure.

The Critical Gap

Perhaps most problematic is the practice of *metric shopping*—selecting success metrics post-hoc based on which show favorable results rather than pre-specifying decision criteria.

Research Gap: Few published frameworks integrate statistical rigor with unit economics, creating a disconnect between inference validity and business decision quality.

What This Work Contributes

Decision Framework

Single decision metric (**CPA**) with comprehensive integrity gates: sample ratio mismatch detection, delivery balance (45–55%), frequency delta control (≤0.2), and tracking quality assurance protocols.

Statistical Sensitivity

Rigorous power analysis and minimum detectable effect (MDE) planning procedures. Optional CUPED (Controlled-experiment Using Pre-Experiment Data) variance reduction for improved sensitivity without biasing estimands.

Economic Guardrails

ROAS threshold enforcement and landing page performance vitals monitoring (Largest Contentful Paint <2.5s, Cumulative Layout Shift <0.1) to ensure statistical wins translate to business value.

Scope Declaration: This is a *methods paper* presenting a theoretical framework validated through simulated datasets calibrated to D2C benchmarks. No live advertising traffic or proprietary data was analyzed. The simulation demonstrates protocol application and decision logic using realistic effect sizes and variance structures.

The Protocol at a Glance

The framework consists of five interdependent pillars that collectively ensure experimental validity and decision quality. Each stage includes specific deliverables and quality gates that must be satisfied before progression.

Pre-register

Formalize hypotheses, specify decision metrics, define success criteria, and document all analytical procedures before data collection begins.

Design (One Lever)

Isolate single treatment variable with mutually exclusive, collectively exhaustive arms. Mirror pacing and budget allocation across conditions.

Integrity Gates

Execute five validation checks before analysis: ROAS threshold, delivery balance, frequency control, page vitals, and SRM detection.

Analysis

Test conversion rate for inference; decide based on cost per acquisition plus guardrails. Apply variance reduction techniques if warranted.

Scale & Monitor

Deploy winning variant with continuous performance monitoring to detect degradation, fatigue effects, or seasonality impacts.

Metrics and Gates for Decision-Grade Outcomes

Primary Measurement Framework

Decision Metric: Cost Per Acquisition (CPA) in INR—the economic metric that directly impacts unit economics and profitability at scale.

Inference Metric: Purchase Conversion Rate (CVR)—calculated as purchases divided by link clicks. This provides statistical power for detecting meaningful differences while maintaining interpretability.

Attribution Standard: Fixed 7-day click, 1-day view attribution window applied consistently across all experimental arms to ensure comparability and eliminate measurement drift.

Five Integrity Guardrails

01

ROAS Threshold

Minimum return on ad spend requirement

02

Delivery Balance

45–55% traffic split tolerance

03

Frequency Control

Delta ≤0.2 between arms

04

Page Vitals

LCP <2.5s, CLS <0.1

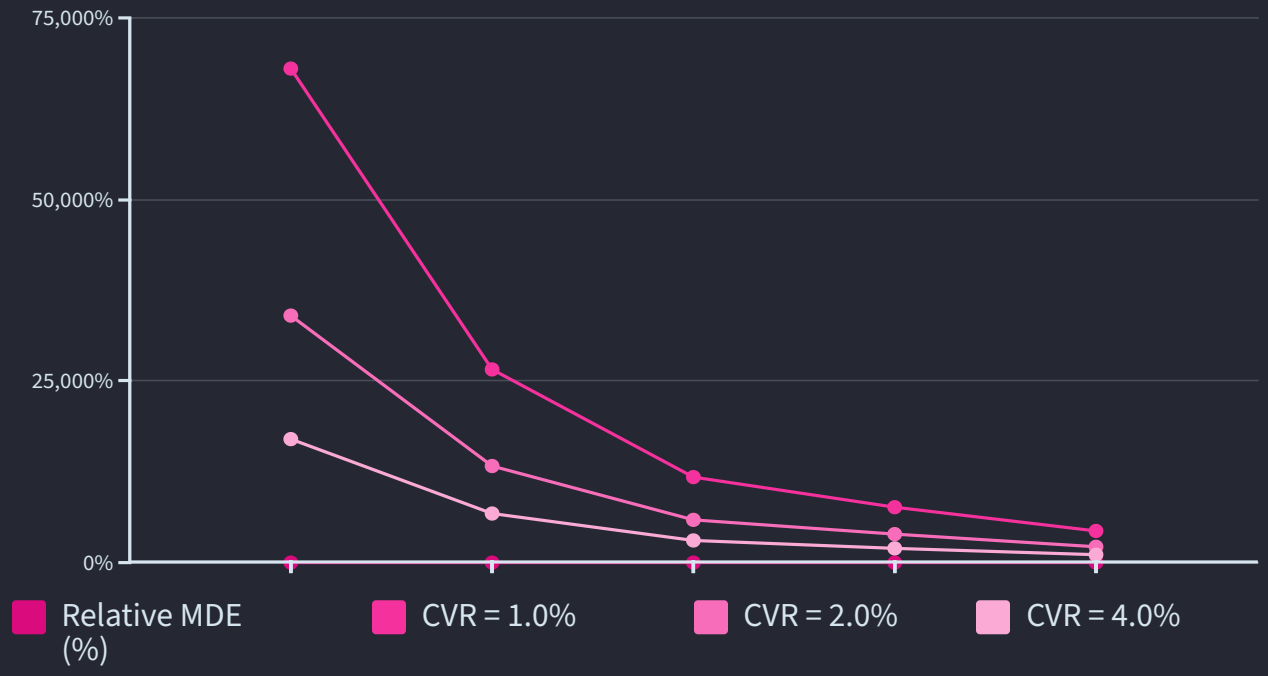
05

SRM Detection

Chi-square test p≥0.01

References: Kohavi et al., 2020; Deng et al., 2013; Meta Attribution Documentation

Sizing for Decision Intent



Power Curve Analysis: Required link clicks per arm to achieve 80% power (α=0.05, two-tailed) for detecting relative improvements across baseline CVR scenarios. Highlighted trace shows CVR=4.0% baseline requiring approximately 2,950 clicks per arm to detect a 12% relative improvement.

References: Deng et al., 2013; Johari et al., 2017

Design Implications

The framework employs two-proportion z-tests for CVR comparison, with sample size requirements determined by baseline conversion rate and minimum detectable effect size aligned with business materiality thresholds.

CUPED Enhancement: Controlled-experiment Using Pre-Experiment Data reduces outcome variance by incorporating pre-period covariates, improving statistical power without introducing bias to the treatment effect estimand.

This approach prevents underpowered experiments that yield inconclusive results, enabling confident go/no-go decisions within reasonable testing windows.

Simulated Proof-of-Concept

Scenario Construction

Seven experimental scenarios (T1–T7) were simulated to represent realistic paid social testing situations: creative variations, call-to-action messaging, audience targeting strategies, and placement optimization.

Each scenario was calibrated using D2C industry benchmarks for click-through rates, conversion rates, cost structures, and variance patterns. Simulated sample sizes ranged from 5,000 to 15,000 link clicks per arm, reflecting typical Meta Ads campaign scale.

Critical Note: This is *simulated data* generated for methodological demonstration. No actual advertising campaigns were conducted, and no proprietary or confidential data was accessed.

Integrity Validation

Sample Ratio Mismatch

Example T1: χ^2 test p=0.42 (pass threshold ≥0.01). Traffic split: 49.8% / 50.2%, well within tolerance.

Delivery Balance

All simulated scenarios achieved 45–55% delivery split, ensuring comparable exposure conditions across treatment arms.

Frequency Control

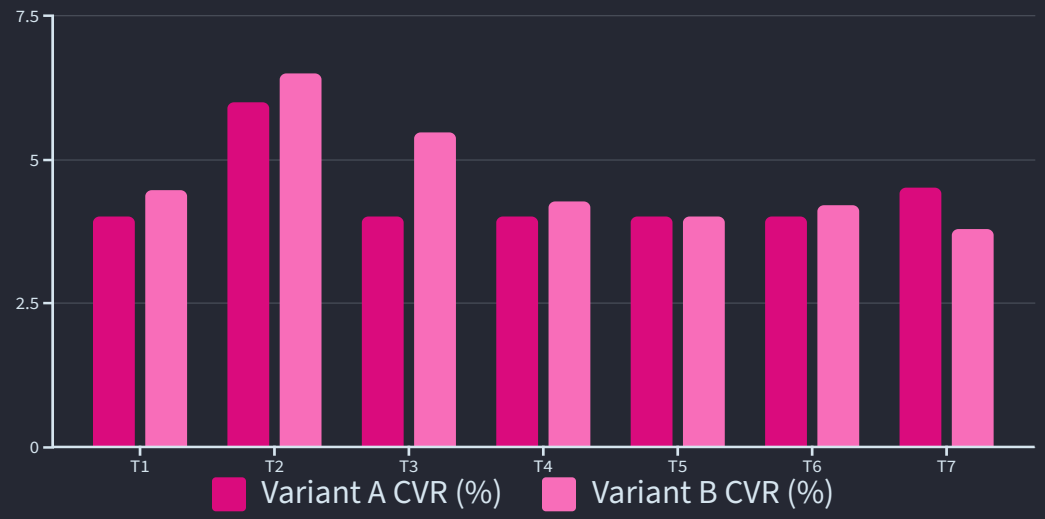
Maximum frequency delta Δ=0.05 across all tests, well below the 0.2 threshold that could indicate differential user fatigue.

All integrity gates passed before proceeding to effect analysis. In production environments, gate failures would trigger investigation and potential experiment invalidation before examining outcomes.

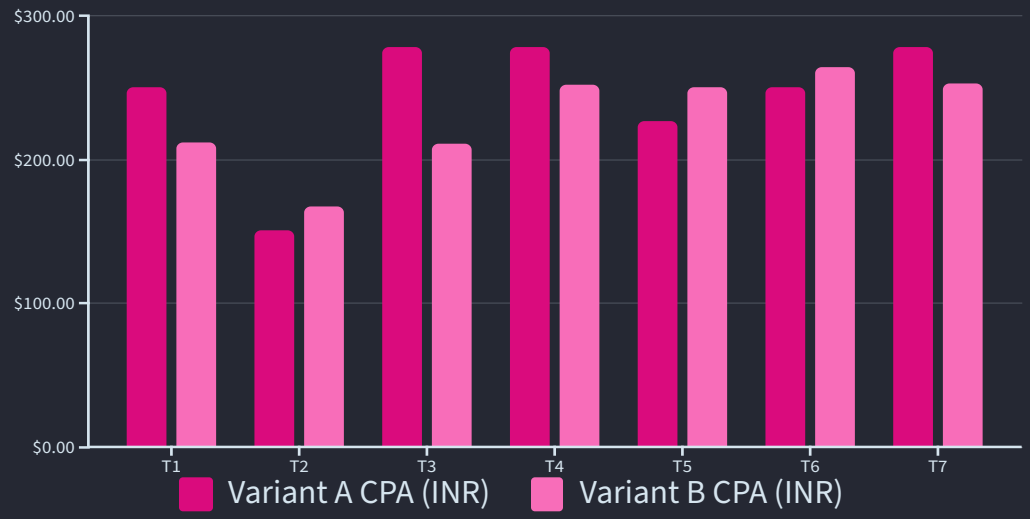
⚠️ **Simulated Data:** All results on subsequent slides are generated from calibrated simulations and do not represent actual campaign performance.

Simulated Outcomes — Highlights

Conversion Rate Effects



Cost Per Acquisition



Statistical Significance: T1 shows +0.46 percentage point lift (p=0.009), T3 demonstrates +1.46 pp improvement (p<0.001), while T7 reveals -0.70 pp decline (p<0.001). Tests T4–T6 remain inconclusive at α=0.05.

Economic Analysis: Lower CPA indicates more efficient customer acquisition. T1 and T3 show both CVR improvement and CPA reduction—strong promotion candidates. T2 presents a trade-off case examined in detail on the next slide.

⚠️ **Simulated Data:** These results demonstrate decision logic application, not actual campaign performance.

How Promotions Are Decided

Integrity Gate Validation

Verify SRM, delivery balance, frequency control, page vitals, and ROAS threshold before proceeding to analysis.

CVR Inference Test

Conduct two-proportion z-test on conversion rates to establish statistical significance and effect direction.

CPA Decision + Guardrails

Evaluate cost per acquisition alongside all guardrail metrics to determine promotion worthiness.

Promote / Reject / Defer

Execute decision based on integrated evidence: scale winner, reject harmful variant, or extend test if inconclusive.

T2 Trade-off Case

Variant B shows borderline CVR improvement (6.50% vs 6.00%, p=0.07) but *worse* CPA (₹167 vs ₹151). **Decision:** Retain cheaper Variant A despite marginal CVR trend.

Principle: Statistical significance alone is insufficient—economic superiority must be demonstrated.

T4–T6 Inconclusive

These scenarios fail to reach statistical significance at α=0.05 with current sample sizes. **Options:** Extend test duration, increase budget for larger sample, or refine treatment design.

The framework prevents premature decisions based on noise rather than signal.

T7 Harmful Variant

Variant B shows significant CVR *decline* (-0.70 pp, p<0.001) despite nominally lower CPA. **Decision:** Reject—the CVR harm outweighs any cost benefit.

This illustrates why testing CVR while deciding on CPA plus guardrails prevents optimization myopia.

What It Gives, Limits, and Next Steps

Framework Value Proposition

Reproducibility

Pre-registration, documented decision criteria, and standardized evidence packages enable replication and audit trails.

Decision Quality

Integrated CPA optimization with guardrails ensures statistically significant findings translate to profitable business outcomes.

Speed to Confidence

Rigorous power analysis and optional CUPED variance reduction accelerate conclusive results, reducing opportunity costs.

Known Limitations

Simulation Constraints

Calibrated simulations cannot capture all real-world complexities: competitive dynamics, creative fatigue curves, or cross-channel interactions.

Incrementality Measurement

The framework addresses relative treatment effects, not absolute incrementality. Geo-experiments or conversion lift studies remain necessary for measuring true causal impact.

Temporal Dynamics

Creative fatigue, seasonality effects, and competitive response require continuous monitoring beyond initial experiment conclusions.

Validation Plan

Proposed next steps include staged pilot implementation with industry partners to measure: (1) decision velocity improvements versus ad-hoc testing approaches, (2) post-scale CPA and ROAS stability relative to baseline periods, and (3) false positive rate reduction through integrity gate enforcement. Feedback on design choices, statistical assumptions, or guardrail thresholds is welcome.

This is a methodological framework with a simulated application. Feedback welcome.

References: Kohavi et al., 2020; Deng et al., 2013; Johari et al., 2017; Miller, 2015; Meta Experiments & Attribution Documentation; Web Vitals Standards; Gordon et al., 2019; Lewis & Rao, 2015