A Probabilistic Measurement Model of Essence: Invariance, Entropy Minimization, and Contextual Stability

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Abstract

This paper introduces a new psychological construct, essence, defined as the most stable representation of a stimulus under contextual perturbation. Building on classical measurement theory, stochastic choice models, and information-theoretic principles, we present an axiomatic framework in which essence emerges as the unique representation minimizing uncertainty across contexts. We show that the axioms of continuity, invariance, symmetry, and additive decomposability uniquely identify Shannon entropy as the appropriate uncertainty measure. The resulting Essence Representation Theorem formalizes essence as the entropy-minimizing representation within a probabilistic representation space. We further demonstrate how essence relates to stochastic transitivity, robustness under contextual transformation, and interoceptive coherence measured through heart rate variability (HRV). This framework extends classic work by Falmagne, Luce, and Krantz by providing a new invariant for psychological representation grounded in probabilistic structure and information theory.

1. Introduction

Psychological representations are rarely fixed. Contextual factors—affective, perceptual, linguistic, or task-induced—can perturb the way a stimulus is internally encoded. Classical measurement theory addresses structure-preserving mappings from observable data to numerical representations. Stochastic choice theory models variability in preferences across repeated trials or conditions. However, the field lacks a formal account of representation stability under contextual perturbation.

This paper introduces a new construct, essence, defined as the representation of a stimulus that is maximally invariant across contexts. Intuitively, essence is the core representation that persists despite contextual noise.

2. Representational Framework

Let S be a stimulus, C be a context, R(S) the set of possible representations, and $P(\cdot|S,C)$ the distribution over representations. Contexts perturb the representation unpredictably but not arbitrarily. Essence is the representation $E(S) \in R(S)$ that minimizes uncertainty across these distributions.

3. Axioms for Essence

Axiom 1. Representational Space: For each S, $R(S) \neq \emptyset$ and $P(\cdot|S,C)$ is proper.

Axiom 2. Stochastic Contextuality: Representations are selected probabilistically.

Axiom 3. Contextual Equivalence: Identical distributions imply equivalent contexts.

Axiom 4. Additive Decomposability: Independent contexts yield additive uncertainty.

Axiom 5. Continuity: Small changes in P yield small changes in U.

Axiom 6. Maximality: Uniform distributions maximize uncertainty.

Axiom 7. Minimization Principle: Essence minimizes U(P).

4. Essence Representation Theorem

Theorem: The only uncertainty measure satisfying Axioms 4–6 is Shannon entropy, $U(P) = -k \Sigma P(r) \log P(r)$. Essence is the representation minimizing entropy across contexts.

5. Proof Sketch

Axiom 4 forces additivity; Axiom 6 requires maximality at uniformity; Axiom 5 requires continuity. Shannon's representation theorem identifies entropy as the unique measure satisfying these conditions.

6. Stochastic Transitivity and Stability

Low-entropy representations satisfy weak stochastic transitivity: $P(E(S) > r1) \geq P(E(S) > r2)$ whenever $r1 \succ r2$. Essence thus operates as a probabilistic anchor.

7. Physiological Validation (HRV)

HRV reflects interoceptive stability. High HRV states should exhibit lower representational entropy and stronger convergence on essence. This yields empirically testable predictions.

8. General Discussion

Essence theory provides a new primitive for cognitive representation, offering a formal bridge between measurement theory, information theory, and stochastic modeling. It opens new avenues for studying stability, invariance, and interoceptive-cognitive interactions.

References

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