1. Research Objective

This research proposes a **Continuous Biological State Vector Modeling Framework** integrated into a generative AI–based menstrual phase tracker.

The core hypothesis is:

> Continuous biological state modeling improves personalization, biological grounding, and contextual relevance compared to categorical phase-based prompting.

The study compares four generation strategies:

1. Generic prompting (baseline)
2. Phase-aware prompting
3. Phase + contextual memory-aware prompting
4. Phase + continuous biological state vector prompting

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2. System Overview

The Menstrual Phase AI-Powered Tracker is a structured generative AI system that provides personalized health recommendations based on menstrual cycle information.

The system collects:

- Menstrual phase
- Mood
- Energy level (1–10)
- Sleep quality (1–10)
- Symptom indicators (cramps, bloating, back pain, headache, etc.)
- Optional historical pattern data

The novelty lies in transforming these inputs into a **continuous biological state representation** before prompt injection.

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3. Core Innovation: Continuous Biological State Vector

Instead of representing the user state as:

Phase = Luteal

The system computes a multidimensional biological state vector:

Example:

Biological State Vector B =
[Estrogen Influence, Progesterone Influence,
Energy Stability, Emotional Volatility,
Inflammation Likelihood]

Each component is normalized between 0 and 1.

3.1 State Vector Formulation

Let:

E = Energy level (normalized 0–1)
S = Sleep quality (normalized 0–1)
M = Mood intensity (mapped to numerical scale)
Sym = Weighted symptom score
P = Phase index

Then example formulations:

Energy Stability = 0.6E + 0.4S

Emotional Volatility = f(M, sleep deficit, symptom stress indicators)

Inflammation Likelihood = weighted sum of cramps + back pain + headache

Hormonal Influence Scores:
Mapped based on cycle phase:

Menstrual → high inflammation tendency
Follicular → rising estrogen

Ovulatory → peak estrogen
Luteal → rising progesterone

These hormonal mappings are deterministic and biologically grounded.

The final vector:

$B = [H_e, H_p, E_s, V_e, I_l]$

Where:
H_e = Estrogen influence
H_p = Progesterone influence
E_s = Energy stability
V_e = Emotional volatility
I_l = Inflammation likelihood

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4. Prompting Strategies Compared

Strategy 1: Generic Baseline

Prompt includes only raw user text.
No structured biological awareness.

Example:
“User feels irritable and has back pain. Provide advice.”

Strategy 2: Phase-Aware Prompting

Prompt includes explicit menstrual phase.

Example:
“Menstrual Phase: Ovulatory
Mood: Irritable
Symptoms: Back pain
Provide biologically grounded advice.”

This introduces categorical biological grounding.

Strategy 3: Phase + Memory-Aware Prompting

Adds historical patterns:

"User historically experiences irritability during ovulation.
Sleep has decreased over the past 3 days."

Adds temporal personalization.

Strategy 4: Phase + State Vector Prompting (Proposed)

Injects continuous biological state:

"Biological State Profile:
Estrogen Influence: 0.78
Progesterone Influence: 0.22
Energy Stability: 0.52
Emotional Volatility: 0.68
Inflammation Likelihood: 0.73

Generate recommendations aligned with this physiological state."

This shifts from categorical reasoning to continuous adaptive modeling.

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5. Experimental Design

5.1 Dataset

- 80–120 structured synthetic menstrual health scenarios
- Balanced across 4 phases
- Variation in energy, sleep, symptoms, mood

Optional extension:

- Real anonymized user data (if available)

Each scenario is evaluated across all 4 strategies.

5.2 Evaluation Panel

- 3 independent evaluators
- At least one domain-informed evaluator
- Blind evaluation (raters unaware of generation strategy)

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6. Evaluation Metrics

6.1 Human-Rated Metrics (1–5 Scale)

1. Relevance
2. Specificity
3. Biological Grounding
4. Personalization Quality
5. Safety Score

Inter-rater reliability measured using:

- Cohen's kappa
- Intraclass correlation coefficient (ICC)

6.2 Quantitative Metrics

1. Semantic Differentiation Score

For same phase but different state vectors:

- Compute embedding similarity between outputs.
- Higher divergence indicates adaptive personalization.

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2. Alignment Consistency

Measure frequency of:

High inflammation score → anti-inflammatory advice
Low energy stability → rest-oriented suggestions

Compute alignment ratio.

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3. Violation Rate

If a biological constraint layer is implemented:

Count number of biologically inappropriate suggestions.

Compute percentage reduction after constraint validation.

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4. Sensitivity Stability Test

Slightly perturb one state vector dimension.
Measure semantic shift magnitude.

Ensures smooth adaptive behavior.

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7. Statistical Analysis

Use:

- Repeated Measures ANOVA (for 4-strategy comparison)
- Post-hoc pairwise t-tests with Bonferroni correction
- Effect size (Cohen's d)
- 95% confidence intervals

Significance threshold:
$p < 0.05$

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8. Expected Output Differences

Generic:
Broad wellness advice.

Phase-aware:
Phase-specific hormonal explanations.

Phase + Memory:
Pattern-sensitive advice.

State Vector:
Quantitatively adaptive, nuanced variation between users within same phase.

Example:

Two ovulatory users:

User A:
Energy Stability = 0.8
Inflammation = 0.2

Advice → social engagement, high productivity.

User B:
Energy Stability = 0.3
Inflammation = 0.7

Advice → reduce strain, gentle activity, anti-inflammatory diet.

This differentiation is measurable.

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9. Research Contribution

This work contributes:

1. A continuous biological state modeling framework for generative menstrual health systems.
2. A structured comparative evaluation of categorical versus continuous personalization.
3. Quantitative validation of adaptive prompt conditioning.
4. A reproducible evaluation protocol for phase-aware health AI systems.

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10. Publication Strength

This becomes publishable if:

- ≥ 80 scenarios
- ≥ 3 raters
- Statistical rigor
- Clear mathematical formulation
- Transparent evaluation protocol

It is unlikely that this exact structured evaluation of continuous biological state modeling in generative menstrual AI systems has been formally published.

The components exist independently.
The integrated experimental comparison likely does not.