Preregistration: Sensory Mapping of Experimental Tribological Formulations

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1 Primary Objective and Research Questions

This research program aims to construct a comprehensive sensory performance map across a broad range of biocompatible tribological compounds. By estimating posterior distributions across a variety of performance parameters, we will be able to generate a multidimensional representation of perceived performance which will be refined through successive studies to isolate robust latent psychological variables of sensation. This iterative process allows for the characterization of perceptual tradeoffs and, ultimately, the probabilistic prediction of sensory performance parameters based on formulation composition. The main research questions for the present study are as follows:

1. What is the performance profile of each prototype across the seven performance parameters (e.g., stay-in-place, longevity, coherence)?
2. To what degree do prototypes A and B differ from one another with respect to overall satisfaction?
3. To what degree do prototypes A and B differ from participants' usual compound with respect to overall satisfaction?
4. Does exposure to novel tribological formulations produce a pre–post change in overall satisfaction with participants' usual compounds?
5. Which of the seven performance parameters contribute to overall satisfaction across both prototypes?
6. Does previous experience with biocompatible tribological compounds correlate with ability to make precise judgments of prototype performance parameters (i.e. lower variance in parameter estimates)?
7. Does previous experience correlate with greater accuracy in predicting cohort-level overall satisfaction for each prototype?

2 Study Scope & Objectives

2.1 Parameter Estimation

Primary Objective We will generate posterior estimates, specifically the posterior means and 95% Highest Density Intervals (HDIs), for all performance parameters to establish a performance benchmark.

2.2 Confirmatory Hypotheses

H1: Overall satisfaction differs between prototype A and prototype B.

H2: At least one prototype will show an increase in overall satisfaction compared to the participant's reported satisfaction with their usual compound.

H3: Overall satisfaction with the participant's usual compound will decrease between the pre-treatment measurement and the post-treatment measurement.

2.3 Exploratory Analyses

E1: We will investigate the associations between each performance parameter and overall satisfaction to determine which dimensions most strongly influence preference.

E2: We will investigate whether participants with higher self-reported experience level demonstrate higher accuracy in predicting group-level overall satisfaction averages (i.e. well calibrated testers).

E3: We will investigate if well calibrated testers also provide performance parameter estimates with lower variance compared to the group mean.

E4: All other analyses not explicitly listed are considered post-hoc analyses. These may be reported to identify unanticipated patterns but will be clearly labeled as post-hoc discoveries in the final manuscript.

2.4 Design Considerations

Previous research using psychorheological assessments show standard deviations ranging from 1.3 to 3.1 across various tactile dimensions (Greenaway, 2010; Kikegawa et al., 2019). While these studies help inform our sampling plan, the current study differs in three important ways.

First, previous works were conducted in laboratory settings where room temperature and relative humidity were controlled and participants were given instructions on how to evaluate and manipulate the materials. The current study will use field evaluations where participants are free to interact in their preferred manner. This is expected to increase variability in the performance

parameter estimates but this is an acceptable consequence of prioritizing ecological validity where several of the primary outcomes are measures of overall satisfaction which are influenced by idiosyncrasies in usage preferences.

Second, where prior studies have investigated psychorheological properties under a static or low friction regime, the present prototypes will be evaluated under dynamic and friction sensitive applications where repetitive shear conditions are present. Because interaction conditions differ, perceptual responses to these properties may vary, where properties are weighted differently depending on the conditions in which they are evaluated. For example, perceived slickness may be more salient in the high shear condition compared to low shear.

Third, the present prototypes employ novel formulations that leverage more modern materials designed to address the high repetitive shear conditions encountered during field use. While these formulations share substantial overlap in base chemistry with more conventional cosmetic skin conditioning products, they are optimized for tribological performance, such that physical sensation during use is primary rather than skin conditioning effects.

3 Sampling Plan

3.1 Existing Data

Registration will be completed prior to data collection.

3.2 Data Collection Procedures

Participants will be recruited through a pre-screening survey which will be advertised in online communities with informal domain relevant experience (i.e. familiarity with biocompatible tribological compounds and their psychorheological properties). Eligibility criteria are as follows: must be 18 years of age or older, United States resident, provide informed consent for use of the data collected, acknowledge that their participation is voluntary, and commit to providing feedback within two weeks of receiving the prototype samples.

The pre-screen survey will collect baseline information for the following variables: experience level, typical use frequency, usual compound type, reapplication frequency, past irritation experiences, and overall satisfaction with current compound. 100 participants will then be randomly selected and mailed the prototype samples. Once received participants will self-select which prototype to evaluate first and will be provided instructions to use each at least twice and each on separate days, as well as the performance parameters to be evaluated. Participants will complete the main survey after evaluating both prototypes and will record the order in which the prototypes were tested.

3.3 Sample Size

100 participants will be selected from the eligible pool via a simple random sample. The anticipated final sample size is $N \approx 70$, accounting for a 30% attrition rate due to either non-responses, failed

attention checks or failure to adhere to testing protocols.

3.4 Sample Size Rationale

The final sample size remains sufficient to meet our two primary design goals. First, to reliably detect practically meaningful differences in performance parameters between the two prototypes and allow for sufficient precision for estimating each prototype's performance parameters. And second, to practically discriminate between both prototypes with respect to the various overall satisfaction measures and irritation comparison to participant's usual compound.

We define a minimum detectable effect (MDE) of 0.8 scale points as practically significant for prototype prioritization. As discussed in the design considerations section, prior studies report standard deviations of approximately 1–3 scale points across tactile dimensions. Because the present study differs in evaluation context and interaction conditions, we are using a plausible but conservative value of $\sigma = 2.5$ for study planning purposes. This value falls within the range of variability reported in previous work while accounting for the aforementioned study differences. The standard deviation used for analysis will be estimated from the observed data. By adopting a conservative estimate of $\sigma = 2.5$, a frequentist paired samples power analysis (used as a study design heuristic) shows that $N = 70$ provides approximately 80% power at $\alpha = 0.05$ (two-sided) to detect mean differences at the specified MDE.

The same variance assumption implies an expected standard error of 0.30, which corresponds to a 95% interval half-width of roughly 0.6 points. This is considered practically meaningful for building a preliminary performance profile for both prototypes. If upon reaching the target sample size, the 95% HDIs for primary prioritization metrics remain wider than the half-width required, or if the Bayes Factors for comparisons remain in the anecdotal evidence range, sequential sampling will be employed not to exceed a total number of shipments of 150.

4 Variables

4.1 Manipulated Variables

Prototype formulation (prototype A vs prototype B)

4.2 Measured Variables

Prescreen Questions

1. Experience with tribological compounds (Novice/Moderate/Experienced/Advanced)
2. Typical frequency of use per week (0–1, 2–3, 4–6, Daily)
3. Usual compound type (Albolene, Petrolatum, Coconut oil, Silicone-based, Water-based, Other) and optional free response to provide brand name.
4. Usual compound reapplication need during use (1–10)

5. Usual compound irritation (Yes/No/Sometimes)
6. Usual compound overall satisfaction (1–10)
7. Optional free response to describe usual compound properties or experiences

Main survey

Asked per prototype

1. Session duration (<10, 10–30, 30–60, >60 minutes)
2. Performance parameters (1–10) (startup slipperiness, staying in place/runoff, longevity, resistance to displacement, absorption, motion/texture resolution, coherence)
3. Fit for intended application or usage style (1–10)
4. Overall satisfaction (1–10)
5. Negative effects (Yes/No)
6. Four optional qualitative feedback questions

Post-exposure cohort-level questions

1. Whether each prototype was used twice before rating (Yes/No/Not sure)
2. Whether prototypes were tested on different days (Yes/No/Not sure)
3. Preference (First/Second/Both/Neither)
4. Prediction of the average satisfaction for first and second prototype (1–10) plus confidence in prediction (Low/Med/High)
5. Whether usual compound changed since prescreen (No/Yes + text)
6. Satisfaction with usual compound after prototype exposure (1–10)
7. Influence of packaging on overall satisfaction (None/Some/A lot)
8. Intention to switch to prototype (Yes/No/Maybe)

5 Analysis Plan

5.1 Estimands

Primary Objective For each performance parameter (startup slipperiness, staying in place, longevity, resistance to displacement, absorption, motion/texture resolution, and coherence), the estimands of interest are the population mean ratings for each prototype and will be reported with the posterior distributions and 95% HDIs.

Confirmatory Hypotheses The estimands of interest for H1–H3 are the population means of the within-participant differences defined as follows. For participant i ($i = 1, \ldots, N$), let A and B denote the two prototypes received.

H1: Define within-participant differences in overall satisfaction between prototypes as

$$\Delta^{\text{sat}}_{AB,i} = \text{Sat}_{B,i} - \text{Sat}_{A,i}$$

H2: Define within-participant differences in overall satisfaction between each prototype and usual compound as

$$\Delta^{\text{sat}}_{A,i} = \text{Sat}_{A,i} - \text{Sat}_{\text{usual},i}$$
$$\Delta^{\text{sat}}_{B,i} = \text{Sat}_{B,i} - \text{Sat}_{\text{usual},i}$$

H3: Define within-participant differences in overall satisfaction of usual compound pre-exposure compared to post-exposure as

$$\Delta^{\text{usual}}_{i} = \text{Sat}_{\text{usual, post},i} - \text{Sat}_{\text{usual, pre},i}$$

5.2 Statistical Models

Primary Objective For each sensory performance parameter and each prototype $p \in \{A, B\}$, ratings are modeled on the raw 1–10 scale as

$$Y_{i,p} \sim \mathcal{N}(\mu_p, \sigma_p^2)$$

Weakly informative priors are placed on model parameters

$$\mu_p \sim \mathcal{N}(5, 5^2), \quad \sigma_p \sim \text{HalfNormal}(3)$$

Confirmatory Hypotheses We will use Bayesian paired-samples t-tests on within-participant differences and use Bayes Factors to compare evidence for the presence of a difference between means. For participant i, the observed difference is modeled as

$$\Delta_i \sim \mathcal{N}(\mu_\Delta, \sigma_\Delta^2)$$

Inference will be conducted on the standardized effect size using a Cauchy prior with scale $r = 1/\sqrt{2}$.

$$\delta = \frac{\mu_\Delta}{\sigma_\Delta}$$

H1: A paired-samples Bayesian t-test will be conducted on $\Delta^{\text{sat}}_{AB,i}$.

H2: Separate paired-samples Bayesian t-tests will be conducted on $\Delta_{A,i}^{\text{sat}}$ and $\Delta_{B,i}^{\text{sat}}$. The hypothesis is considered supported if at least one prototype yields strong evidence for improvement over baseline.

H3: A paired-samples Bayesian t-test will be conducted on Δ_i^{usual}.

5.3 Sensitivity Analysis

Following guidelines set forth by Van Doorn et al. (2021), we will conduct a multiverse analysis testing prior robustness across Cauchy scale parameters $\gamma \in \{0.5, 0.707, 1.0\}$ for all hypothesis tests. Results will be considered stable if the Jeffreys (1961) interpretation category for the Bayes factor is consistent across all prior specifications.

5.4 Exclusion Criteria

Participants will be excluded from analysis if they select an invalid code when reporting prototype sequence, indicating an attention check failure. Any participant who reports that their usual compound changed between the pre- and post-exposure surveys will be excluded from analyses involving pre–post comparisons of the usual compound (H3), but will remain eligible for all other analyses.

5.5 Other Analyses

While primary estimates will utilize simple Bayesian models for immediate decision-making, we reserve the option to re-analyze the performance parameter data using a hierarchical model to better account for participant-level variance. All other analyses not preregistered will be reported as post-hoc exploratory analyses.

References

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