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Beyond the functionality: Next dimension method of evaluating “feel” in skincare experience.

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1. Introduction

Cosmetic products offer useful benefits like skin improvement and also provide positive emotional value. This includes the pleasant experience during use, often called the "feel." While "feel" involves multiple senses, this study focuses mainly on the important touch aspect – how a product physically interacts with the skin and hands during application. This tactile feeling strongly influences consumer preference and product loyalty[1]. Although crucial, scientifically understanding and evaluating the touch "feel" remains a challenge. Our work concentrates on closely examining this specific touch experience during application.

Evaluating the "feel" of skincare is complex, involving both active touch from the applying hands and passive touch on the receiving face during typical self-application. How these distinct inputs combine to form the overall impression remains unclear[2]. A key reason for this knowledge gap is the inherent difficulty in experimentally separating these simultaneous sensations in a natural context. This measurement challenge has significantly hindered research into the underlying integration mechanisms. Investigating the specific integration of active and passive touch during self-application first requires overcoming this fundamental hurdle.

To address this measurement challenge, we employed an experimental design using monozygotic (MZ) twin pairs. We utilized the high similarity in genetic, physiological, and likely perceptual and neural substrates between MZ twins[3]. Crucially, while their sensory processing pathways are highly similar, they do not share direct tactile information. Therefore, we hypothesized that when one twin applies a product to the other's face, the 'applicator' twin experiences active touch similar to self-application on their own hand, while the 'receiver' twin experiences passive touch similar to being touched by their own hand. This setup allows for the separate assessment of active and passive touch sensations from highly similar individuals within the same ecologically relevant event, potentially simulating dissociated aspects of self-touch perception.

This research aims to elucidate active/passive tactile integration during cosmetic use via this twin-based approach. Separately measuring 'applicator' (active) and 'receiver' (passive) evaluations provides distinct inputs to model their integration. We analyze how these components combine for the overall 'feel,' informing sensory integration understanding within the Affective Engineering framework[4]. Acknowledging potential twin differences in sensory perception or judgment, we examine within-pair homogeneity's influence, selecting higher homogeneity pairs for detailed analysis. By addressing the measurement difficulty, this study seeks insights into touch integration for sensory/cosmetic science, potentially aiding product development considering distinct touch roles.

2. Materials and Methods

2.1. Participants

This study involved three distinct groups of participants recruited for different stages of the research: the extraction of evaluation terms, the main impression evaluation experiment involving identical twins, and a comparative impression evaluation experiment involving non-twin pairs. All participants provided written informed consent.

Ten healthy adults (6 males, 4 females), participated in the session to extract relevant evaluation terms for skincare feel. Their ages ranged from 28 to 45 years (mean ± SD: 34.0 ± 6.11 years).

Fifteen pairs of healthy female identical (monozygotic) twins (total N = 30) participated in the main impression evaluation experiment. Their ages ranged from 20 to 49 years (mean ± SD: 35.3 ± 9.61 years). Participants were recruited from individuals registered at the Twin Research Center, University of Osaka, who self-reported as monozygotic twins. The experimental design and procedure were approved Ethics Committee.

Five pairs of healthy female non-twin individuals (total N = 10) participated in the comparative impression evaluation experiment. Their ages ranged from 28 to 49 years (mean ± SD: 35.4 ± 7.38 years). To control for age effects between pairs as much as possible, non-twin pairs were formed by minimizing the standard deviation of the age difference within each pair across the entire non-twin group.

2.2. Cosmetic materials

Five skin creams were selected based on their composition and physical properties. Their general compositions were shown in **Table 1**.

Table 1. The general composition of 5 skin creams used in this study

(%)	Cream A	Cream B	Cream C	Cream D	Cream E
Water-soluble ingredients	25	15	21	21	24
Oil-soluble ingredients	6.1	34	25	21	3.2
Surfactants	1.1	7.0	1.5	3.0	0.020
Polymer thickener	0.76	0.10	0.25	0.40	0.76
Preservative/Acidity regulator	0.66	0.53	0.38	0.44	0.66
Distilled water			balance		

2.3. Evaluation Grid Method (EGM)

To identify relevant terms describing the subjective experience and "feel" of skincare products, we employed EGM[5], a structured interview technique. This method aims to elicit an individual's personal evaluation structure by uncovering the hierarchical relationships between concrete product attributes and more abstract personal values (i.e., means-end chains[6]).

Participants were first presented with five skin cream representing different skincare experiences and asked to rank them based on overall 'pleasant feel'. This ranking prompted reflection on their evaluation criteria.

Next, participants articulated the reasons for their ranking, often through comparisons between stimuli, to elicit their core evaluation criteria ("original constructs"). These criteria were recorded, reframing negative terms into positive ones. Subsequently, for each elicited construct, the "laddering" technique was applied. This involved systematically probing to understand its connection to higher-level abstract concepts (e.g., asking "Why is that important?") and lower-level concrete attributes (e.g., asking "What specifically defines that?").

This iterative process revealed the hierarchical structure connecting specific sensory attributes to broader subjective values for each participant. All elicited constructs and their hierarchical relationships were recorded and organized using the web-based E-Grid system[7], facilitating the identification of key evaluation terms.

2.4. Subjective Evaluation Experiment

A subjective evaluation experiment was conducted to investigate the sensory integration process and the influence of participant homogeneity on the perceived "feel" of five different skincare creams under three conditions: Self, Active, and Passive. Both the twin group and the non-twin group participated in this experiment, following a within-subjects design where each participant experienced all stimuli and conditions. The three experimental conditions were defined as follows:

- **Self:** Self-application to the right cheek.
- **Active:** Applicator applied to receiver's cheek, rating hand sensations.
- **Passive:** Receiver rated facial sensations simultaneously with Active condition.The experiment took place in a controlled environment maintained at 22°C and 50% relative humidity. For each evaluation, 250 μL of a skincare cream material was provided to the participants.Subjective ratings were collected for multiple evaluation items using a 6-point Likert scale (1 = Strongly disagree, 6 = Strongly agree, in Japanese).

2.5. Statistical Analysis

Data were analyzed using factor analysis(FA; scree plot criterion, maximum likelihood, Varimax rotation), multiple regression analysis(MRA; stepwise method, $p < .05$ for entry/removal) and structual equation modeling(SEM) using SPSS/Python.

3. Results

3.1. Elicited Evaluation Terms for Skincare Feel

The EGM elicited various constructs related to the subjective experience of skincare feel. These constructs were categorized into higher-level values and lower-level consequences as **Table 2**. The constructs were subsequently classified into lower-level and higher-level categories based on discussions among several co-authors. Experts in cosmetic sensory perception were involved in this classification process. We used this 19 constructs for the terms of subjective evaluation.

Table 2. Evaluation constructs elicited by the EGM.

Higher-level constructs	1 Comfort	2 Absence of discomfort	3 Satisfaction
Lower-level constructs	1 Moisturizing feeling	2 Feeling of absorption	3 Easy to use
	4 Feeling efficacy	5 Good skin compatibility	6 Supple feeling
	7 Watery sensation	8 Smooth feeling	9 Good spreadability
	10 Coating feeling	11 Less tackiness	12 Glides smoothly
	13 Not slimy	14 Soft texture	15 Feeling of skin contact
	16 Low irritation		

3.2 Homogeneity Assessment and Grouping of Twin Participants

While monozygoticl twins share nearly identical genetic backgrounds, potential minor variations in subjective perception or response tendencies between pair members could influence the study's aim of treating them as perceptually equivalent units. Therefore, to rigorously assess the suitability of each pair for our novel sensory separation approach and enable more precise analysis, we quantitatively evaluated the degree of within-pair homogeneity.

To assess the homogeneity of subjective ratings within twin pairs, we screened participants based on the absolute difference in ratings between paired individuals across all trials (all materials, conditions, and skin cream):

1. **The overall mean absolute difference (Mean Abs. Diff.):** The grand average of absolute rating differences.
2. **The proportion (or count) of large absolute differences (Prop. Diff. ≥ 4):** The proportion of trials where the absolute difference was ≥ 4.
3. **The mean variance of absolute differences across conditions (Mean Cond. Var.):** The average variance of absolute differences calculated across the three conditions for each material/item combination.

The distributions of these parameters across all pairs are illustrated in **Figure 1**. The numbers displayed above each bar in the histograms indicate the participant IDs falling within that bin.

Using these parameters, pairs were classified into two groups based on rating homogeneity. Pairs were assigned to the high-homogeneity group (High-H; n=7 pairs, 14 individuals) if they met all of the following three criteria:

1. Mean Abs. Diff. **≤ 1.2**
2. Prop. Diff. ≥ 4 **≤ 1 (time)**
3. Mean Cond. Var. **≤ 1**

Pairs that did not meet all three criteria were classified into the low-homogeneity group (Low-H; n=8 pairs, 16 individuals)."

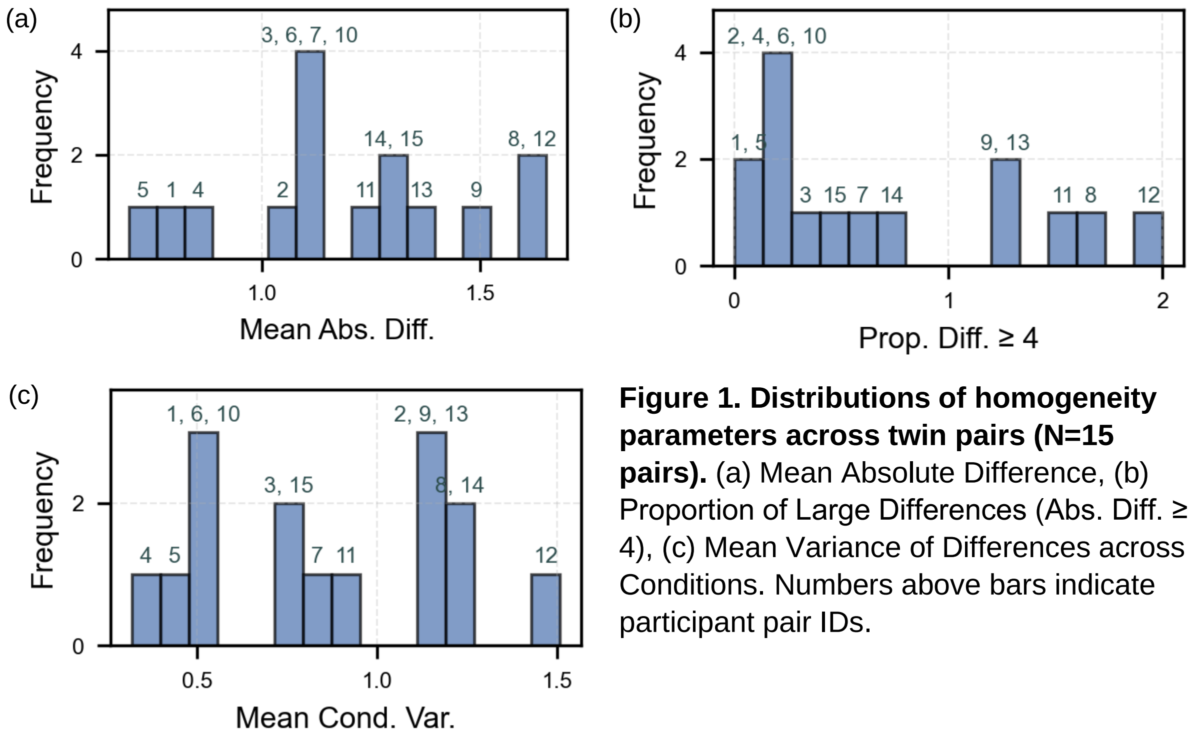

Figure 1. Distributions of homogeneity parameters across twin pairs (N=15 pairs). (a) Mean Absolute Difference, (b) Proportion of Large Differences (Abs. Diff. ≥ 4), (c) Mean Variance of Differences across Conditions. Numbers above bars indicate participant pair IDs.

3.3. Factor Analysis for High-Homogeneity Twins (High-H; n=7 pairs)

FA was conducted on the subjective rating data from the High-H for each condition (Self, Active, Passive). **Figure 2** showed the factor loading matrix for each conditions.For all three conditions (Self, Active, Passive), a three-factor solution was deemed appropriate.

Self	Factor1	Factor2	Factor3
Good spreadability	0.896	0.229	0.302
Glides smoothly	0.886	0.147	0.335
Soft texture	0.826	0.207	0.384
Smooth feeling	0.818	0.375	0.289
Easy to use	0.806	0.325	0.291
Watery sensation	0.756	0.317	0.354
Low irritation	0.685	0.492	0.173
Good skin compatibility	0.68	0.308	0.548
Less tackiness	0.679	-0.058	0.489
Supple feeling	0.113	0.902	0.043
Moisturizing feeling	0.222	0.883	0.028
Feeling efficacy	0.268	0.808	0.25
Feeling of absorption	0.499	0.335	0.796
Not slimy	0.245	0.011	0.402
Factor (%)	42.8	22.6	14.8
Cumulative (%)	42.8	65.4	80.2

Active	Factor1	Factor2	Factor3
Good spreadability	0.941	0.210	0.187
Glides smoothly	0.921	0.226	0.249
Smooth feeling	0.906	0.272	0.150
Soft texture	0.895	0.216	0.228
Watery sensation	0.851	0.311	0.254
Easy to use	0.808	0.315	0.249
Low irritation	0.745	0.402	0.277
Good skin compatibility	0.675	0.534	0.35
Less tackiness	0.665	0.212	0.593
Feeling efficacy	0.328	0.826	0.301
Moisturizing feeling	0.143	0.757	0.039
Supple feeling	0.177	0.597	-0.091
Feeling of absorption	0.568	0.582	0.415
Not slimy	0.257	0.001	0.750
Factor (%)	48.1	20.4	12.0
Cumulative (%)	48.1	68.5	80.5

Passive	Factor1	Factor2	Factor3
Glides smoothly	0.882	0.323	0.227
Smooth feeling	0.876	0.273	0.305
Good spreadability	0.865	0.313	0.322
Soft texture	0.861	0.325	0.243
Watery sensation	0.854	0.334	0.230
Easy to use	0.707	0.517	0.383
Low irritation	0.690	0.291	0.417
Less tackiness	0.648	0.418	0.136
Feeling of absorption	0.522	0.731	0.400
Good skin compatibility	0.611	0.627	0.399
Feeling efficacy	0.431	0.584	0.394
Not slimy	0.187	0.521	0.187
Supple feeling	0.226	0.286	0.929
Moisturizing feeling	0.348	0.352	0.695
Factor (%)	44.3	19.8	18.2
Cumulative (%)	44.3	64.0	82.3

Figure 2. The High-H twin's factor loading matrix for each conditions. Left: Self condition, Center: Active condition, Right: Passive conditions. Factor (%) and Cumulative (%) means factor contribution ratio and cumulative contribution ratio each others.

The interpretation and naming of these factors were shown in **Table 3**.

Table 3. Factor interpretations for the High-H twin group.

High-H	Factor1	Factor2	Factor3
Self	Physical properties	Skin texture	Non-stickiness
Active	Physical properties	Skin texture	Non-stickiness
Passive	Physical properties	Skin texture	Moisturization

3.4. Factor Analysis for Low-Homogeneity Twins (Low-H; n=8 pairs)

Similarly, FA was conducted for the Low-H group. A three-factor solution was again appropriate for all conditions **(Figure 3**). Factor interpretations are presented in **Table 5**. For all three conditions (Self, Active, Passive), a three-factor solution was deemed appropriate.

Self	Factor1	Factor2	Factor3
Variable	0.902	0.251	0.0770
Good spreadability	0.881	0.349	0.00878
Smooth feeling	0.850	0.221	0.196
Watery sensation	0.809	0.393	0.179
Easy to use	0.773	0.249	0.237
Glides smoothly	0.756	0.312	0.159
Soft texture	0.686	0.517	0.276
Good skin compatibility	0.618	0.552	0.359
Feeling of absorption	0.602	0.482	0.351
Low irritation	0.411	0.775	0.199
Feeling efficacy	0.239	0.701	0.165
Moisturizing feeling	0.243	0.643	0.165
Supple feeling	0.444	0.142	0.814
Less tackiness	-0.00764	0.265	0.726
Factor (%)	41.7	21.0	12.6
Cumulative (%)	41.7	62.7	75.3

Active	Factor1	Factor2	Factor3
Good spreadability	0.935	0.299	0.0159
Smooth feeling	0.913	0.307	0.0136
Glides smoothly	0.887	0.245	0.0937
Easy to use	0.859	0.274	0.162
Soft texture	0.808	0.346	0.0329
Watery sensation	0.784	0.284	0.267
Low irritation	0.699	0.362	0.0352
Good skin compatibility	0.678	0.496	0.380
Moisturizing feeling	0.273	0.806	-0.0181
Supple feeling	0.274	0.779	-0.144
Feeling efficacy	0.396	0.687	0.272
Feeling of absorption	0.514	0.596	0.557
Less tackiness	0.414	0.101	0.651
Not slimy	-0.0960	-0.0658	0.517
Factor (%)	44.3	21.4	9.64
Cumulative (%)	44.3	65.6	75.3

Passive	Factor1	Factor2	Factor3
Good spreadability	0.892	0.166	0.0904
Smooth feeling	0.884	0.268	0.0375
Watery sensation	0.875	0.032	0.0996
Easy to use	0.874	0.310	0.0795
Glides smoothly	0.862	0.246	0.139
Good skin compatibility	0.764	0.421	0.217
Feeling of absorption	0.724	0.391	0.182
Soft texture	0.671	0.443	0.136
Low irritation	0.601	0.512	0.184
Feeling efficacy	0.400	0.761	0.158
Moisturizing feeling	0.201	0.742	0.125
Supple feeling	0.132	0.703	-0.0682
Less tackiness	0.352	-0.0153	0.933
Not slimy	-0.000853	0.109	0.614
Factor (%)	43.6	19.2	10.5
Cumulative (%)	43.6	62.8	73.3

Figure 3 The Low-homogeneity twin's factor loading matrix for each conditions. Left: Self condition, Center: Active condition, Right: Passive conditions. Factor (%) and Cumulative (%) means factor contribution ratio and cumulative contribution ratio each others.

The interpretation and naming of these factors were shown in **Table 4**.

Table 4 Factor interpretations for the Low-H twin group.

Low-H	Factor1	Factor2	Factor3
Self	Physical properties	Skin texture	Non-stickiness
Active	Physical properties	Skin texture	Non-stickiness
Passive	Physical properties	Skin texture	Non-stickiness

3.5. Multiple Regression Analyses(MRA) for High-Homogeneity Twins (High-H)

To investigate how sensory information from active and passive touch contributes to the overall subjective experience ('Self' perception) within the High-H twin group, a two-stage MRA was performed using the factor scores.

Stage 1: Predicting Self-Comfort: The factor scores for higher-level constructs ('Comfort', 'Absence of discomfort', 'Satisfaction') under the Self condition were highly correlated (data not shown). Therefore, 'Comfort' (Self_Comfort) was used as the dependent variable representing overall positive affect. A regression model predicting Self_Comfort from lower-level Self factors (Self_factor1: Physical properties, Self_factor2: Skin texture) was significant (Adjusted $R^2 = 0.603$; **Figure 4a**).

Stage 2: Predicting Self-Factors from Active/Passive Factors:

- Self_factor1 (Physical properties) was significantly predicted by Active_factor1 (Physical properties) (Adjusted $R^2 = 0.632$; **Figure 4b**).
- Self_factor2 (Skin texture) was significantly predicted by Active_factor2 (Skin texture), Active_factor3 (Non-stickiness), and Passive_factor2 (Skin texture) (Adjusted $R^2 = 0.465$; **Figure 4c**). The relationship with Passive_factor2 was negative.

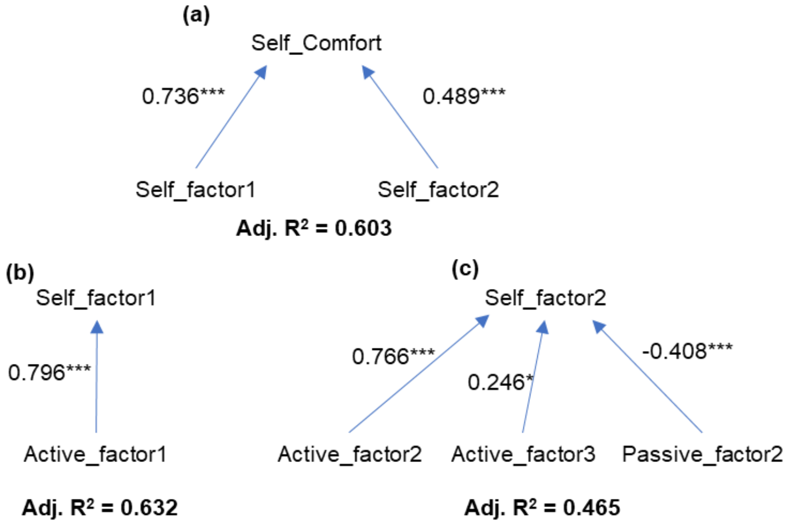

Figure 4. Path diagram of the two-stage multiple regression analysis for the High-homogeneity (High-H) twin group. (a) Stage 1 predicting Self_Comfort. (b, c) Stage 2 predicting Self_factor1 and Self_factor2 from Active/Passive factors. Numbers are standardized beta coefficients. *p < .05, **p < .01, ***p < .001.

3.6. Multiple Regression Analyses(MRA) for Low-Homogeneity Twins (Low-H)

MRA were also conducted for the Low-H twin group.

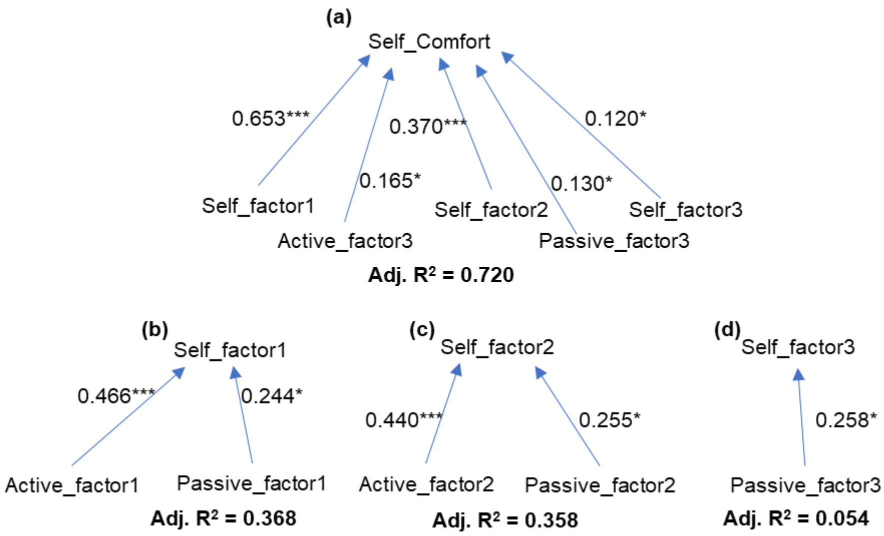

Figure 5. Path diagram of multiple regression analyses for the Low-homogeneity (Low-H) twin group. (a) Predicting Self_Comfort. (b-d) Predicting Self_factor1, Self_factor2, and Self_factor3 from Active/Passive factors. Numbers are standardized beta coefficients. **p* < .05, ***p* < .01, ****p* < .001.

- **Predicting Self_Comfort:** Using factors from all conditions as potential predictors, the final model included Self_factor1, Self_factor2, Active_factor3, Self_factor3, and Passive_factor3 (all positive predictors) (Adjusted R^2 = 0.720; **Figure 5a**).
- **Predicting Self_factor1 (Physical properties):** Predicted by Active_factor1 and Passive_factor1 (Adjusted R^2 = 0.368; **Figure 5b**).
- **Predicting Self_factor2 (Skin texture):** Predicted by Active_factor2 and Passive_factor2 (Adjusted R^2 = 0.358; **Figure 5c**).

- **Predicting Self_factor3 (Non-stickiness):** Predicted only by Passive_factor3 (Adjusted R^2 = 0.054; **Figure 5d**).

Compared to the High-H group, the Adjusted R^2 values for predicting Self factors from Active/Passive factors (Stage 2 equivalent) were generally lower in the Low-H group.

3.7. Factor Analysis and Multiple Regression analyses for non Twins (n=5 pairs)

FA was conducted on the subjective rating data from the non twin group for each condition, structurally similar to the Low-H group (data not shown). Then MRA were conducted:

- **Predicting Self_Comfort:** The model included only Self_factor1 (Adjusted R^2 = 0.346; Figure 6a).
- **Predicting Self_factor1 (Physical properties):** Predicted by Active_factor1 and Active_factor2 (Adjusted R^2 = 0.662; Figure 6b).

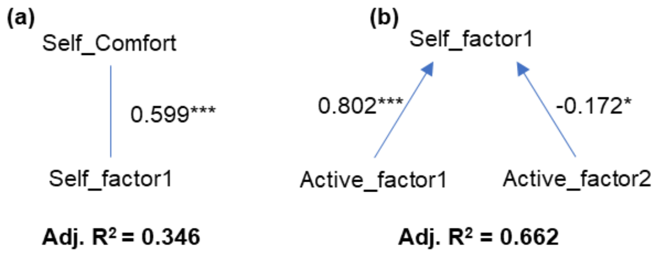

Figure 6. Path diagram of multiple regression analyses for the non-twin group. (a) Predicting Self_Comfort. (b) Predicting Self_factor1 from Active/Passive factors. Numbers are standardized beta coefficients. **p* < .05, ****p* < .001.

For the non-twin group, the regression model corresponding to Stage 1 – predicting the higher-level (abstract) construct 'Comfort' – resulted in a lower Adjusted R^2 value compared to the twin groups. This indicates that the model possessed less explanatory power for the more abstract domain of evaluation within this participant group.

3.8. Integration Patterns of Active and Passive Touch by SEM

To further elucidate the integration mechanism of active and passive touch, SEM was employed, particularly focusing on the High-H group data. A hypothesized model testing the relationships between Active, Passive, and Self factors was evaluated. The model fit indices (CFI, AGFI, RMSEA) and significant path coefficients are presented in **Figure 7**.

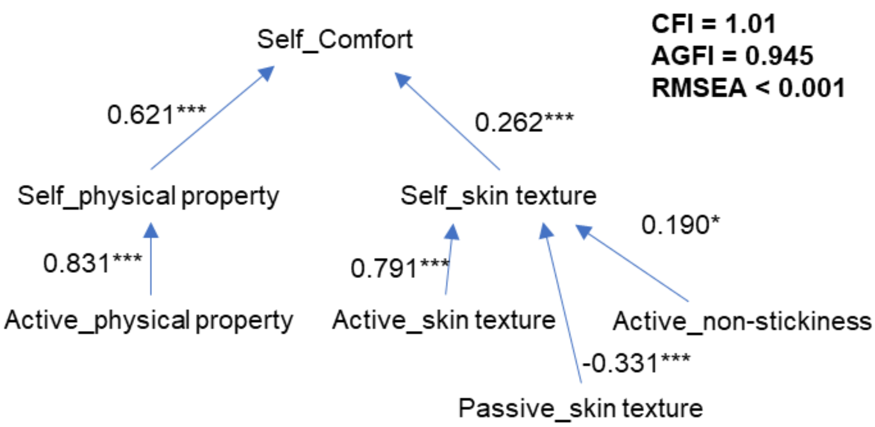

Figure 7. Integration structure of active and passive touch. **p* < .05, ****p* < .001.

4. Discussion

This study introduced a framework using monozygotic twin pairs to investigate the interplay between active (hand) and passive (face) touch during skincare application. Our primary scientific goal was to gain insights into the sensory integration mechanism, while a secondary methodological goal was to evaluate a method capable of separating these intertwined inputs. The findings provide initial insights into this approach and underscore the influence of within-pair homogeneity on the obtained results.

4.1. Assessing the Influence of Pair Homogeneity on the Twin-Based Method

The twin evaluation method enabled the separate assessment of hand and face tactile information in an ecologically relevant context. Comparing across groups with varying homogeneity (High-H, Low-H, Non-twin) indicated the methodology's sensitivity to participant similarity. As hypothesized, lower homogeneity correlated with factor structures explaining less variance, suggesting reduced commonality in evaluation axes and greater individual differences within pairs.

Furthermore, the relationship between Active/Passive inputs and the predicted 'Self' evaluation appeared to differ across homogeneity levels. The explanatory power of models predicting 'Self' diminished at different processing stages depending on the group (e.g., affecting the sensory integration level in the Low-H group, and extending to higher-level value judgments in the Non-twin group). This pattern suggests a validity gradient for the application of this approach (High-H > Low-H > Non-twin) in terms of reflecting a consistent sensory integration process.

Interpreting results from lower homogeneity pairs requires caution. While some statistical metrics might appear strong, this may not signify a meaningfull integration pattern. Lower homogeneity introduces confounding factors: the 'applicator' and 'receiver' experience potentially different skin textures and application styles compared to true self-touch, alongside possible psychological influences. This inherent variability complicates the dissociation of active and passive inputs. Consequently, although the method is applicable across homogeneity levels, high-homogeneity pairs offer a clearer view of the targeted sensory integration dynamics. Assessing homogeneity is therefore crucial when using this method for such studies.

4.2. Illuminating Sensory Integration Dynamics via the Twin Methodology

Using SEM with high-homogeneity twins allowed investigating the integration mechanism. A key finding, enabled by separating inputs, was Passive_factor2's significant negative effect on Self_factor2 (related to facial vs. overall texture). This challenges simple additive models of self-touch integration. Interpreting this requires considering inherent active/passive touch differences. The applying hand yields discriminative information (Aβ afferents) via exploration [8]. The face passively receives input (Aβ and CT afferents) [9]. This negative influence might reflect integrating these different inputs (active/discriminative vs. passive/affective). This suggests dynamic adjustments or comparisons in self-touch integration, not simple summation. This underscores complex self-touch integration influenced by channel/sensorimotor factors; highlighting this complexity shows the method's utility in high-homogeneity pairs.

4.3. Significance, Limitations, and Future Directions

The primary contribution is modeling the integration of active (hand) and passive (face) tactile sensations during skincare self-application. Using a twin method to separate these inputs allowed empirically deriving and validating a quantitative model describing their interplay. This model revealed important integration characteristics, notably non-additive aspects. For instance, passive facial input negatively influencing perception challenges simple summation assumptions and highlights the model's captured complexity.

The twin methodology provided the crucial separated data for this model, enabling quantitative modeling of sensory integration within a relevant context. Practically, this validated model provides a framework for understanding consumer 'feel' perception. This understanding can inform cosmetic development and evaluation for optimized sensory experiences.

Limitations relate mainly to the model's current scope and generalizability (specific group/products); further research is needed to refine the model and confirm its applicability across different demographics, product types, and application conditions.

Future work should refine and extend this model, investigating underlying mechanisms[10], modulation by individual/stimulus factors, and predictive validity. Continued use/refinement of the twin method could support achieving a more comprehensive integration model.

5. Conclusion

This study investigated active/passive tactile integration during skincare use. We employed a methodology using MZ twins, leveraging their similarity to separately assess these inputs. Our analysis, focusing on high-homogeneity pairs where the method appeared most valid, revealed complex, non-additive self-touch integration. While effectiveness depends on homogeneity, this work demonstrates the method's potential utility for sensory science. Overall, this research highlights intricate self-touch perception. By applying the insights gained into the distinct contributions of active and passive touch to cosmetic evaluation and development, the industry can create products with a more refined 'feel', ultimately leading to enhanced satisfaction and a more pleasant self-application experience for consumers.

6. Refference

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