To reveal the correlation of sensory attributes in different types of cosmetics

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Abstract :
Background: sensory evaluation has been widely used in skin care products development in the last decades. In order to suit the expectations of consumers, it is critical for cosmetic developers to thoroughly investigate and highlight the correlation of sensory features between various types of cosmetic products. **Methods:** four kinds of skin care cosmetics (toner, serum, emulsion and cream) were evaluated by 8~10 panelists who were professionally trained with high acuity and accuracy. Then, the relationship of attributes among four kinds of skin care cosmetics were studied by the principal component analysis (PCA) and heat maps of sensory attributes. **Results:** among with four kinds of skin care cosmetics, there were a negative correlation between transparency and product thickness, product thickness and absorption rate, skin freshness and product thickness. Moreover, the results of principal component analysis presented that among the four skin care cosmetics, there are three, four, two, and three components greater than 1, and the variances of these components in the corresponding principal components were 68.787%, 72.497%, 63.604%, and 64.219%, respectively. **Conclusion:** the same type of cosmetic products had obvious three key factors, correlating several sensory attributes. Furthermore, similar correlation could be found by principal component analysis in different type of skin care products such as toner, serum, emulsion and cream.
Keywords: sensory evaluation, sensory attributes, correlation, principal component analysis.

Introduction:

During the development of skin care products, sensory evaluation has been commonly used in recent years. Bunches of sensory attributes are set to help researchers not only to link consumer real needs, but also to deeply understand products behaviors [1]. However, setting more attributes makes it more difficult for sensory panelists to define and more confusing for consumers to fill out the designed questionnaire. Thus, a considerable proportion of failed products come from the mismatch between sensory properties and consumer needs [2-3]. To address these limitations, we propose to use the principal component analysis method and heat maps to explore the correlation of several sensory attributes. For example, from product conception to post-launch monitoring, this kind of analysis could help researchers to deeply understand products behaviors from consumer feedback both on products sensory and effects [3-4]. Additionally, the analysis could also provide reference for researchers to design the right questionnaire when choosing sensory attributes.

Materials and Methods:

There were 9 characteristic attributes for toner products, and a total of 20 toners were tested. Likewise, 15 attributes of 16 serum products were examined. 17 emulsion products with 14 attributes and 28 cream products with 15 attributes were tested. Four kinds of skin care cosmetic products (toner, serum, emulsion and cream) were assessed by 8~10 professionally trained panelists with high sensitivity and veracity. These panelists estimated the same kind of cosmetic weekly, with up to six samples at each time.

Before starting the study, the inside of forearms were divided into 3 quadrants, with each panelist applying one of the formulations in one of the quadrants randomly according to the random table, and taking six samples at each time. After the application, scorings were made for selections of attributes related to appearance, touch sensation and the skin effect. Then, the panelists answered the sensory evaluation questionnaire containing the following main attributes: transparency, ease of apply, skin smoothness, absorption rate, hydrating effect, persistent hydration, and so on. The attributes were scored according to table 1 (common sensory characteristics attributes of the four kinds of skin care cosmetics (toner, serum, emulsion and cream)).

Table 1. Standard for scoring

Attributes	**Scores**	**Scorings Description**
Transparency	0~10	0-opacity，10-fully transparent
Fragrance		0-dissatisfied，10-satisfied
Thickness		0-very thin，10-very thick
Adhesive		0-difficult to adhesive，10-easy to adhesive
Easy to apply		0-difficult to apply，10-easy to apply
Watery sensation		0-no watery sensation，10-obvious watery sensation
Oily sensation		0-no oily sensation，10-obvious oily sensation
Absorption rate		0-very slow，10-very fast
Hydrating effect (immediately)		0-no Hydrating effect (immediately)， 10-obvious Hydrating effect (immediately)
Skin fineness		0-not at all fineness，10-very fineness
Skin softness		0-not at all softness，10-very softness
Skin nutritious		0-not at all nutritious，10-very nutritious
Skin freshness		0-not at all freshness，10-very freshness
Stickness		0-not at all stickness，10-very stickness
Persistent hydration（2min）		0-no Persistent hydration（2min）， 10-obvious Persistent hydration（2min）
Persistent nutritious（2min）		0-no Persistent nutritious（2min）， 10-obvious Persistent nutritious（2min）

Statistical analysis

To evaluate the correlation and export its Heatmap among all studied attributes in different types of cosmetics, the Pearson correlation was used with the assistance of the software Origin 2021. Heatmap shows a data matrix where coloring gives an overview of the numeric differences [5]. The redder the color, the stronger the positive correlations were showed between the two sensory attributes. On the contrary ,the blue color represented the negative correlations between the two sensory attributes.

These data were tested to indicate the correlation of several sensory attributes by the principle of factor analysis in principal component analysis (PCA), using the statistical software SPSS 26. PCA is a method where a multivariate data set is linearly transformed into a set of uncorrelated variables, ordered in descending manner by the variance explained [6].

Results:

(1) According to the correlation heat maps of attributes (Figure1), among with four kinds of skin care cosmetics, there were negative correlations between transparency and thickness, thickness and absorption rate, thickness and skin freshness. On the contrary, hydrating effect (immediately) and skin softness, hydrating effect (immediately) and thickness showed positive correlations.

(2) In the interpretation of total variance from toner, serum, emulsion, cream (Table2), the results of principal component analysis presented that among the four skin care cosmetics, there are three, four, two, and three components greater than 1, and the variances of these components in the corresponding principal components were 68.787%, 72.497%, 63.604%, and 64.219%, respectively.

(3) The first principal component of toner contained thickness, hydrating effect (immediately), skin softness, persistent hydration (2min). The second principal component of toner contained absorption rate, skin freshness. The thirdly principal component of toner was Transparency (table e1, e2). For the serum (table f1, f2), there were hydrating effect (immediately), skin fineness, skin softness, persistent hydration (2min), skin nutritious, persistent hydration (2min) as the first principal component. The second principal component of serum were thickness, easy to apply, watery sensation, oily sensation and skin freshness. The thirdly principal component of serum was stickness and the last principal component were transparency, absorption rate. Relative to emulsion (table g1, g2), hydrating effect (immediately), skin fineness, skin softness, persistent hydration (2min), persistent nutritious(2min), skin nutritious belonged to the first principal component. The sensory attributes which were easy to apply, watery sensation, oily sensation, skin freshness, stickness, thickness and absorption rate belonged to second principal component. For the cream (table h1, h2), the first principal component was the same as the emulsion. While the cream's second principal component was the same as the serum's. Besides the thirdly principle component was absorption rate. Among all the extracted principal components, the first principal component of these four kinds of cosmetics contained the sensory attributes which were

hydrating effect (immediately), skin softness and persistent hydration. These results were summarized in Table 3.

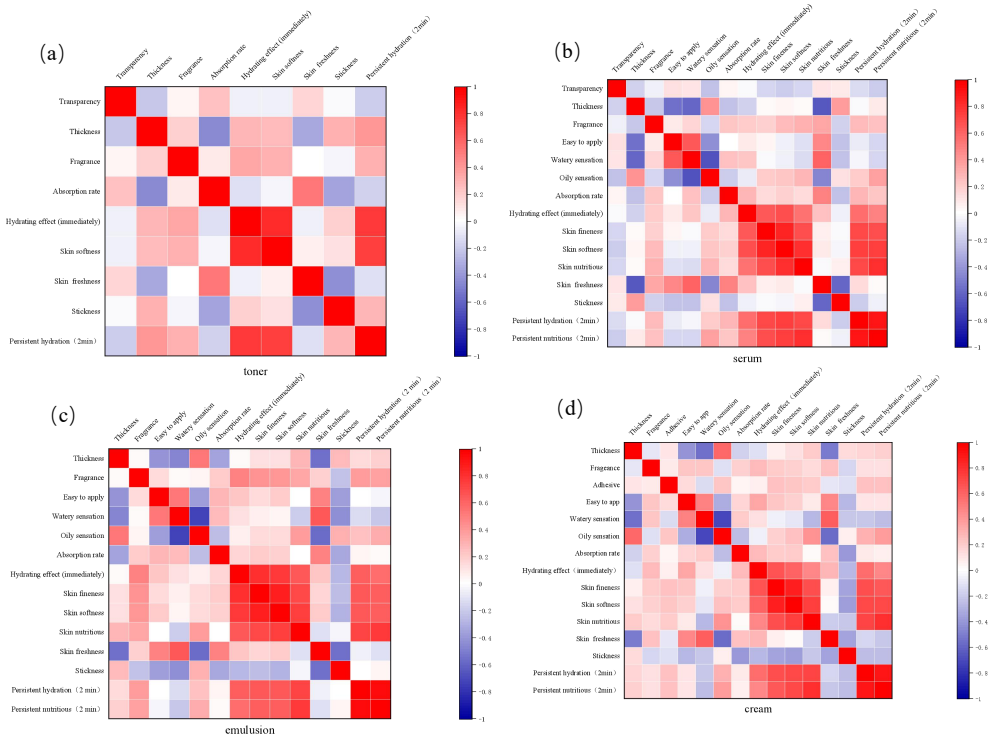

Figure1. Correlation heat maps of attributes about four kinds of skin care cosmetics （a-Toner，b-Serum，c-Emulsion，d-Cream）

Table 2. The interpretation of total variance from products（e1、e2-Toner，f1、f2-Serum，g1、g2-Emulsion，h1、h2-Cream）

Component Matrixa（Toner）			
	Component		
	1	2	3
Transparency	-0.241	0.293	0.855
Thickness	0.636	-0.335	-0.082
Fragrance	0.39	0.384	0.107
Absorption rate	-0.429	0.705	0.059
Hydrating effect (immediately)	0.826	0.386	0.038
Skin softness	0.779	0.469	-0.022
Skin freshness	-0.341	0.722	-0.177
Stickness	0.453	-0.467	0.479
Persistent hydration（2min）	0.868	0.241	-0.057
Extraction Method: Principal Component Analysis.			
a 3 components extracted.			

（e1）-Toner

Total Variance Explained

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	3.165	35.163	35.163	3.165	35.163	35.163
2	2.007	22.304	57.467	2.007	22.304	57.467
3	1.019	11.32	68.787	1.019	11.32	68.787
4	0.862	9.575	78.362			
5	0.608	6.756	85.119			
6	0.549	6.099	91.218			
7	0.398	4.421	95.639			
8	0.23	2.558	98.196			
9	0.162	1.804	100			

Extraction Method: Principal Component Analysis.

（e2）-Toner

Component Matrixa

	Component			
	1	2	3	4
Transparency	-0.207	0.214	0.458	0.583
Thickness	-0.018	-0.79	-0.004	0.118
Fragrance	0.367	0.324	-0.227	0.145
Easy to apply	-0.063	0.701	0.291	-0.43
Watery sensation	-0.023	0.843	0.242	-0.137
Oily sensation	0.261	-0.719	-0.249	-0.123
Absorption rate	0.322	0.416	-0.29	0.594
Hydrating effect (immediately)	0.726	0.237	0.3	0.079
Skin fineness	0.862	-0.031	0.21	-0.158
Skin softness	0.921	-0.055	0.125	-0.084
Skin nutritious	0.867	-0.145	0.113	-0.014
Skin freshness	0.169	0.862	-0.254	0.072
Skin freshness	-0.11	-0.506	0.649	0.172
Persistent hydration（2min）	0.898	0.004	-0.084	0.044
Persistent nutritious（2min）	0.894	-0.163	-0.071	0.018

Extraction Method: Principal Component Analysis.

a 4 components extracted.

（f1）-Serum

Total Variance Explained

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	4.868	32.455	32.455	4.868	32.455	32.455
2	3.774	25.159	57.613	3.774	25.159	57.613
3	1.211	8.071	65.684	1.211	8.071	65.684
4	1.022	6.813	72.497	1.022	6.813	72.497
5	0.861	5.741	78.238			
6	0.786	5.243	83.48			
7	0.521	3.473	86.953			
8	0.452	3.016	89.969			
9	0.408	2.72	92.689			
10	0.279	1.862	94.55			
11	0.239	1.596	96.147			
12	0.217	1.447	97.593			
13	0.193	1.285	98.878			
14	0.114	0.76	99.639			
15	0.054	0.361	100			

Extraction Method: Principal Component Analysis.

（f2）-Serum

Component Matrixa

	Component	
	1	2
Fragrance	0.555	0.173
Thickness	0.196	-0.69
Easy to apply	0.126	0.678
Watery sensation	-0.065	0.825
Oily sensation	0.285	-0.754
Absorption rate	0.171	0.55
Hydrating effect (immediately)	0.847	0.208
Skin fineness	0.887	0.125
Skin softness	0.892	0.14
Skin nutritious	0.869	-0.206
Skin freshness	0.085	0.868
Skin freshness	-0.198	-0.646
Persistent hydration（2min）	0.856	-0.142
Persistent nutritious（2min）	0.846	-0.218

Extraction Method: Principal Component Analysis.

a 2 components extracted.

（g1）-Emulsion

Total Variance Explained

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	5.029	35.918	35.918	5.029	35.918	35.918
2	3.876	27.686	63.604	3.876	27.686	63.604
3	0.9	6.428	70.032			
4	0.831	5.936	75.968			
5	0.698	4.984	80.952			
6	0.607	4.336	85.288			
7	0.52	3.717	89.005			
8	0.436	3.111	92.116			
9	0.289	2.066	94.182			
10	0.243	1.739	95.921			
11	0.227	1.622	97.544			
12	0.199	1.422	98.966			
13	0.107	0.762	99.728			
14	0.038	0.272	100			

Extraction Method: Principal Component Analysis.

（g2）-Emulsion

Component Matrixa

	Component		
	1	2	3
Thickness	0.217	-0.699	-0.213
Fragrance	0.227	0.371	-0.098
Adhesive	0.338	-0.061	-0.38
Easy to apply	0.193	0.672	0.187
Watery sensation	-0.224	0.818	0.14
Oily sensation	0.404	-0.737	-0.11
Absorption rate	0.188	0.451	-0.649
Hydrating effect (immediately)	0.671	0.413	0.187
Skin fineness	0.869	0.174	0.033
Skin softness	0.894	0.115	0.007
Skin nutritious	0.869	-0.127	0.154
Skin freshness	-0.096	0.826	0.018
Stickness	-0.374	-0.447	0.49
Persistent hydration（2min）	0.884	-0.051	0.144
Persistent nutritious（2min）	0.888	-0.123	0.136

Extraction Method: Principal Component Analysis.

a 3 components extracted.

（h1）-Cream

Total Variance Explained

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	4.978	33.185	33.185	4.978	33.185	33.185
2	3.628	24.189	57.374	3.628	24.189	57.374
3	1.027	6.845	64.219	1.027	6.845	64.219
4	0.991	6.605	70.823			
5	0.882	5.881	76.705			
6	0.66	4.403	81.107			
7	0.582	3.88	84.988			
8	0.482	3.214	88.201			
9	0.452	3.013	91.214			
10	0.387	2.583	93.797			
11	0.304	2.026	95.822			
12	0.235	1.565	97.388			
13	0.212	1.414	98.801			
14	0.117	0.782	99.583			
15	0.063	0.417	100			

Extraction Method: Principal Component Analysis.

（h2）-Cream

Table 3. The results of principal component analysis for the four kinds of skin care cosmetic

	Toner	**Serum**	**Emulsion**	**Cream**
The first principal component	Thickness, Hydrating effect (immediately), Skin softness, Persistent hydration (2min)	Hydrating effect (immediately), Skin fineness, Skin softness, Persistent hydration (2min) , Skin nutritious Persistent nutritious(2min),	Hydrating effect (immediately), Skin fineness, Skin softness, Persistent hydration (2min), Persistent nutritious(2min), Skin nutritious	Hydrating effect (immediately), Skin fineness, Skin softness, Persistent hydration (2min), Persistent nutritious(2min), Skin nutritious
The second principal component	Absorption rate, Skin freshness	Thickness, Easy to apply, Watery sensation, Oily sensation, Skin freshness	Easy to apply, Watery sensation, Oily sensation, Skin freshness, Stickness, Thickness, Absorption rate	Thickness, Easy to apply, Watery sensation, Oily sensation, Skin freshness
The thirdly principal component	Transparency	Stickness	/	Absorption rate
The last principal component	/	Transparency, Absorption rate	/	/

Conclusion:

In this study, it could be concluded that the same type of cosmetic products had obvious three key factors, correlating several sensory attributes. Furthermore, similar correlation could be found by principal component analysis in different types of skin care products such as toner, serum, emulsion and cream.

Discussion:

Additionally, in the process of product development, cosmetic developers should fully understand the needs of consumers, grasp the relationship between these sensory attributes, and design sensory questionnaires reasonably, so as to design more satisfactory products and improve the possibility of product success. [7]. In parallel with the above study, it is vital for us to study which sensory attributes of the products are key to the consumer's purchase in different types of cosmetic products. Therefore, to find out which sensory attributes play an important role in popular products ,it is possible to design the sensory attributes questionnaires which include degree of preference in the future.

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