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Application of Check-All-That-Apply (CATA) Questions for Sensory Characterization of Cosmetic Emulsions by Untrained Consumers

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Synopsis

The sales potential of cosmetic products is greatly determined by skin feel and skin sensory performance. To please the target audience, it is important to gather information about consumers' perception of products' sensory characteristics. In this study, six different emulsions were formulated. Samples represented three different types of emulsions, including steric-stabilized oil-in-water (O/W), liquid crystal–stabilized O/W, and water-in-oil emulsions, providing different skin feel and aesthetics. Emulsions within the same group differed in the emollients, providing similar sensory attributes. The aim was to have 50 consumers evaluate the emulsions' sensory characteristics. Using a check-all-that-apply (CATA) survey, consumers provided information about their perception of appearance, rub-out, pick-up, and afterfeel. Consumers effectively discriminated between the emulsions. Statistical analysis showed significant differences for 15 sensory attributes in the before, during, and after phases. Our findings suggest that emulsifiers, and not emollients, have the dominant role in determining the aesthetics of a skin care emulsion, similar to previous findings. The fact that untrained consumers provided similar results as trained panelists suggests the validity of the CATA survey and its reliability as a screening tool in the product development process. CATA questions may serve as a viable complimentary to descriptive sensory analysis performed by trained panelists.

INTRODUCTION

The sales potential of cosmetic products is greatly determined by skin feel and skin sensory performance (1,2). Sensory characteristics, including appearance, rub-out, pick-up, and afterfeel, can help build an emotional relationship with the consumer, trigger excitement, and help consumers purchase the product again and again, which is the primary

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goal of developing products (3,4). The emotional connection and excitement can be established from the initial look and feel of a product. In fact, the emotional connection is made when the product is first experienced, usually in the first few seconds after opening the container. The look, smell, and tactile properties can either draw the consumers in or turn them away. These properties must be engineered to be in harmony with each other and to appeal to a target group.

It is important to emphasize that there is no perfect aesthetic that is right for every application or every target audience (4). Therefore, gaining information about the target audience's opinion of a certain product is critical for successful product development and marketing. This type of information can be obtained using descriptive sensory analysis (DSA) with a group of trained panelists or with naive consumers who are the ultimate purchasers of a product.

DSA is a technique that was developed to quantify perceptual properties of samples so that their sensory profiles can be directly compared (5). DSA is a powerful tool in the cosmetic and personal care industry because it can provide relevant information about aesthetics and sensory experience of raw material ingredients and skin care products (1), which can then be used to provide guidance in new product formulation, product reformulation, ingredient substitutions, optimization of manufacturing processes, and claim substantiation (5,6). DSA being used to evaluate skin care products is now a standard practice in the American Society for Testing and Materials. This ASTM E 1490-11 guide outlines procedures for two different approaches for quantitatively describing the sensory characteristics of skin creams and lotions and measuring their similarities and differences (6); (i) a technical expert (i.e., trained panelist) and (ii) a consumer behavior approach. Both approaches usually provide detailed, accurate, reliable, and consistent results (5). However, these approaches are expensive and time-consuming. Therefore, it is difficult for the industry, which often faces resource and time constraints, to routinely apply this technique in the product development process. Because of these constraints, interest in developing reliable and quick methods for sensory characterization of products has been increasing (7). Consumer-based methods are gaining popularity (8,9). Examples of techniques developed in the last couple of decades include sorting (10), flash profiling (11), napping (12), pivot profiling (13), and check-all-that-apply (CATA) questions (14).

CATA questions have a structured question format.The principle is that each volunteer receives a questionnaire (i.e., a list of terms) by which they characterize each product. Their task is simply to select all the terms they consider appropriate to describe the product (15). Advantages of CATA surveys are that they are focused on consumers and not trained panelists, easy to create, quick and easy for participants to answer (16,17), and require no participant training. Furthermore, a well-structured questionnaire does not put special burden on participants, and response rate generally reaches the maximum. Some studies have compared the sensory maps generated by CATA questions with those provided by DSA with trained panelists, reporting similar results (18–20). Therefore, CATA surveys using untrained consumers could provide similar results to quantitative descriptive analysis performed by trained panelists.

Modifying the sensory characteristics of cosmetic creams and lotions is often required during the product development process to appeal to the target group. A common practice when the sensory characteristics of a given product need to be modified is to change (remove/add) the oily components (i.e., emollients) in the formula. However, significant changes cannot be expected from such a modification, as it has been demonstrated using trained panelists that the emulsifier choice plays the dominant role in determining the aesthetics of a skin care emulsion (21,22). Emulsifiers determine the skin feel during the initial phases of skin sensory evaluation, including assessment of appearance, pick-up, and rub-out. Emollients have a substantial role during the later phases (afterfeel) of skin sensory evaluation. Afterfeel parameters are a mix of effects from emulsifier and emollient selections (22).

Although consumer profiling techniques have become more relevant, only a few studies reported about the application of such techniques to cosmetic and personal care products. The aim of this work was to have consumers evaluate the sensory characteristics of six cosmetic emulsions before, during, and after application using a CATA survey. The six emulsions represented three different types of emulsions with different skin feel and esthetic attributes; however, emulsions within the same group were similar. As mentioned previously, it is known from the literature (21,22) that different types of emulsions provide different skin feel, even when the same emollient is used. We set out to examine whether consumers can feel these differences and differentiate between samples based on their sensory characteristics. If consumers can differentiate between the samples based on their sensory characteristics and the differences can be clearly attributed to the formulation technology and composition of the products, it means that a carefully designed CATA survey using consumers could serve as an easy, quick, economical, and useful approach in the characterization of cosmetic emulsions during the product development phase. In addition, if our study using untrained consumers indicates that emulsifiers are the primary determinants of skin feel and aesthetics of cosmetic emulsions, a concept that was previously proven using trained panelists, it would confirm the validity of CATA surveys and indicate their reliability as screening tools.

MATERIALS AND METHODS

MATERIALS

Heptyl undecylenate (LexFeel® Natural; Inolex, Philadelphia, PA) was used as the light emollient, whereas clear olive oil (AC Clear olive oil; Active Concepts LLC., Lincolnton, NC) was used as the rich emollient. A combination of polyglyceryl-10-hexaoleate and polyglyceryl-6-polyricinoleate (Pelemol® P-1263; Phoenix Chemical, Inc., Somerville, NJ), as well as lauryl PEG-9 polydimethylsilcoxyethyl dimethicone (KF 6038; ShinEtsu Silicones, Akron, OH), polyglyceryl-10-stearate (Polyaldo® 10-1-S; Lonza, South Plainfield, NJ), cetyl alcohol (Making Cosmetics, Snoqualmie, WA), and a combination of sorbitan stearate and sorbityl laurate (Arlacel™ LC; Croda, Edison, NJ) were used as emulsifiers for the emulsions. Propanediol (Zemea®; DuPont Tate & Lyle Bio Products Company, LLC, Loudon, TN) was used as the humectant. A mixture of propylene glycol, diazolidinyl urea, methyl paraben, and propyl paraben (Germaben™ II; Ashland, Bridgewater, DE) was used as the preservative. Finally, deionized water of 18 MΩ purity was used as the vehicle/solvent for the aqueous phase. The exact composition of the emulsions is shown in Tables I–III.

Table I
Ingredients and Percentage of Ingredients in the Steric-stabilized O/W Emulsions

Ingredient—INCI name	Emulsion 1 % (w/w)	Emulsion 2 % (w/w)
Heptyl undecylenate	15	10
Olive oil	—	5
Polyglyceryl-10-stearate	5	5
Cetyl alcohol	3	3
Water	71	71
Propanediol	5	5
Propylene glycol (and) diazolidinyl urea (and) methyl paraben (and) propyl paraben	1	1

METHODS

Emulsions. Six cosmetic emulsions were formulated, namely, two water-in-oil (W/O) emulsions, two steric-stabilized oil-in-water (O/W) emulsions, and two liquid crystal–stabilized O/W emulsions. These three groups differed in the type and amount of emulsifiers used. In each group, one emulsion contained a single emollient that is generally perceived as light in terms of skin feel, whereas the second emulsion contained a combination of the light emollient and a small amount of olive oil as a second emollient, which provides a rich skin feel. Tables I–III show the composition of each emulsion. The overall emollient phase volume of the emulsions was held constant, and the emulsifiers were used at the recommended use levels for stability.

Each sample (2 g) was provided to the participants in a 3 g clear plastic jar with a white cap. Identification numbers were marked on each cap as well as on the bottom of each jar. All samples were stored at ambient conditions in the testing room for at least an hour before conducting the study.

CONSUMER PANEL

Fifty consumers, of ages ranging between 18 and 55 years, were recruited for the study. Consumers from both genders and any ethnicity were invited to participate in the study.

Table II
Ingredients and Percentage of Ingredients in the Liquid Crystal–Stabilized O/W Emulsions

Ingredient—INCI name	Emulsion 3 % (w/w)	Emulsion 4 % (w/w)
Heptyl undecylenate	15	10
Olive oil	—	5
Water	75	75
Sorbitan stearate (and) sorbityl laurate	4	4
Propanediol	5	5
Propylene glycol (and) diazolidinyl urea (and) methyl paraben (and) propyl paraben	1	1

Table III
Ingredients and Percentage of Ingredients in the W/O Emulsions

Ingredient—INCI name	Emulsion 5 % (w/w)	Emulsion 6 % (w/w)
Heptyl undecylenate	15	10
Olive oil	—	5
Polyglyceryl-10-hexaoleate (and) polyglyceryl-6-polyricinoleate	1	1
Lauryl PEG-9 polydimethylsilcoxyethyl dimethicone	1	1
Water	77	77
Propanediol	5	5
Propylene glycol (and) diazolidinyl urea (and) methyl paraben (and) propyl paraben	1	1

The majority of the participants were female (78%). Eighty-four percent of the participants were aged between 18 and 29. Ethnicities included Caucasian/White/European (58%), Asian/Pacific Islander (30%), and African American/African/Black/Caribbean (8%). An important note is that the majority of consumers (74%) were regular users of hand or body lotions. "Regular" was defined as product use at least two to three times a week.

This study was approved by the University of Toledo Institutional Review Board (approval number IRB# 201211).

CONSUMER TEST

First, each consumer was asked to fill out a prescreening questionnaire to ensure they were eligible for the study. The prescreening questionnaire's intent was to gather demographic information, including age group, gender, and race/ethnicity; and to identify any exclusion criteria, including skin rashes, calluses on hands/fingers, hypersensitivity, tingling in fingers, any medication use that affects senses, especially touch, and any previous allergic reactions or adverse reactions to any lotions or creams. In addition, the prescreening questionnaire also gathered information about the regularity of skin care product use. If no exclusion criterion was identified, consumers could participate in the study. After providing more details about the study and allowing the participants to ask questions, an informed consent form was signed by each participant. Participants were shown the CATA survey before actually completing it, and had the chance to ask if something was not clear or if they did not completely understand a term.

Participants were asked to clean their forearms and hands with a mild skin cleanser of one of the leading brands to remove any products that were present on their skin before the study. After cleaning, they dried their skin thoroughly with nonfragranced, nonmoisturized, and nonsoftened absorbent paper towels.

The six emulsions were presented to participants in individual plastic jars, and they were asked to evaluate each product on their forearm. Participants were instructed to apply the samples as they typically would in real-world conditions. They were also asked to apply different samples to different areas on their forearm to avoid product build-up or interference between products. In addition, they were asked to fill out a paper-based CATA survey for each product. Testing was administered in a research laboratory under artificial daylight type of illumination at room temperature (between 22° and 24°C).

CATA SURVEY

CATA surveys (Figure 1) were administered to have consumers evaluate sensory properties of emulsions before, during, and after application. First, participants were asked to look at each emulsion in the jar and check characteristics they felt appropriate from the first section of the survey. Then they had to apply each sample to the forearm and fill out the second part of the survey. Finally, they had to test the application site again after 3 min and fill out the third part of the survey.

The CATA survey consisted of a list of 30 words/word groups divided into three groups; (i) the first section (six terms) was related to the appearance of the products; (ii) the second section (16 terms) was related to the sensory characteristics and skin feel (rub-out, pick-up, and immediate skin feel) provided by the products; and (iii) the third section (eight terms) was related to the afterfeel provided by the products after 3 min. When creating the survey and selecting terms, the terminology and words used in the consumer behavior descriptive analysis described in the ASTM E1490-11 guidelines were taken into consideration. Participants were asked to select as many words as they felt appropriate to describe each of the products.

Similar terms that can be considered synonyms were listed together, such as "thick/creamy" and "silky/smooth." The purpose of this type of listing was to decrease the number of terms used and also to make it easier for consumers to select the appropriate terms. In addition, a number of antonym terms were in the CATA survey, for instance, "thick/creamy" and "thin/milky," "easy to spread/slippery," "hard to spread/dragging," and "light" and "heavy."

When I look at the product in the jar it looks:

☐ Glossy/shiny ☐ Thick/creamy ☐ Bright white
☐ Dull/flat ☐ Thin/milky ☐ Off-white

When I apply the product to my skin the product feels:

☐ Cooling ☐ Warming
☐ Easy to spread/slippery ☐ Hard to spread/dragging
☐ Thick/creamy/firm ☐ Thin/milky
☐ Hard to rub in ☐ Easy to rub in
☐ Highly absorbent ☐ Slightly absorbent
☐ Watery/wet ☐ Oily/greasy
☐ Silky/smooth ☐ Gluey/sticky
☐ Light ☐ Heavy

3 minutes after application my skin feels/looks:

☐ Glossy/shiny ☐ Dull
☐ Oily/greasy ☐ Smooth/soft
☐ Wet/not fully dry ☐ Dry
☐ Sticky/tacky ☐ White

Figure 1. Questions of the CATA survey used in this study.

PHYSICAL EVALUATION OF THE EMULSIONS

A Discovery Hybrid Rheometer DHR-3 (TA Instruments, New Castle, DE) was used for measuring rheological properties of the different emulsions. A 40-mm 2° cone and plate geometry at 25.0° ± 0.1°C tested samples of 0.8 ml. Steady state viscosity was recorded at various shear rates (Table IV).

DATA ANALYSIS

Frequencies of mention for each term were determined by counting the number of participants that used a term to describe each emulsion. The Skillings–Mack test, which is the general form of the Friedman test (23), was implemented in STATA (StataCorp LLC, College Station, TX) for each term (within-subjects variable), considering samples (dependent variable) as the sources of variation to evaluate whether the CATA survey was able to detect differences in consumers' perception of the evaluated cosmetic emulsions. The robustness of the Skilling–Mack test was evaluated with a Cochran's Q test (24).

Hierarchical cluster analysis (HCA) was carried out on the CATA survey to identify groups of emulsions that shared similar preferences based on consumers' opinions (25). A multiple factor analysis (MFA) was performed on the frequency table containing responses to the CATA survey to investigate the relationship between the six emulsions and the 30 terms used in the CATA survey (26). All factorial analyses were performed using R language (R Core Team, 2013). Emulsions were compared in pairs using a two-sample analysis of variance (ANOVA) test.

RESULTS AND DISCUSSION

VISCOSITY MEASUREMENTS

The viscosity of each emulsion is reported at a single shear rate (1 s^{-1}) and varied more than 10-fold (Table IV). Emulsions 1 and 2 contained cetyl alcohol as a co-emulsifier. Because of the waxy nature of cetyl alcohol, this component also acted as a thickener, increasing the viscosity of the emulsions. Emulsions 3 and 4 contained a combination of sorbitan stearate and sorbityl laurate, an off-white, flaky ingredient that produced emulsions with a self-bodying effect (27). Emulsions 5 and 6 contained two liquid emulsifiers, which did not add to the viscosity of the emulsion.

Table IV
Viscosity of Each Emulsion at 1 s^{-1}

Sample	Viscosity (mPa·s)
Emulsion 1	17,500
Emulsion 2	17,500
Emulsion 3	6,100
Emulsion 4	8,000
Emulsion 5	1,200
Emulsion 6	1,800

Viscosities were very similar for the same types of emulsions (i.e., Emulsions 1 and 2, Emulsions 3 and 4, and Emulsions 5 and 6), because only the emollients, which were both liquid ingredients, differed. Thus, the presence of olive oil did not change the viscosity of the thickest emulsion (Emulsion 1), whereas modestly increasing the viscosity of the other two emulsion types.

CATA SURVEY

Frequency of mention of terms. Table V shows the number of consumers who used terms of the CATA survey to describe each of the evaluated cosmetic emulsions. As for the appearance of the emulsions, most emulsions were considered "glossy/shiny" and "bright white." Regarding the viscosity of the emulsions, term selection depended on the particular samples. Emulsions 1 and 2 (i.e., steric-stabilized O/W emulsions) had a high viscosity; they were thick creams and did not flow in the container. They were perceived as "thick/creamy" by most consumers, which was in line with the viscosity measurements discussed previously. Emulsions 3 and 4 (i.e., liquid crystal–stabilized O/W emulsions) had a medium viscosity, compared with the rest of the emulsions. Perception of their viscosity was not uniform; unlike in the case of the other emulsions, most of the consumers considered Emulsion 3 as "thin/milky," whereas Emulsion 4 was perceived primarily as "thick/creamy." Consumers could not decide whether they should select "thick/creamy" or "thin/milky." Some consumers noted that they perceived the viscosity to be "in between" the two terms. Notes were not used in the data analysis. Emulsions 5 and 6 (i.e., W/O emulsions) had a low viscosity; they were lotions and were able to flow easily in the container. These emulsions were considered "thin/milky" by most of the consumers, which again was in agreement with the viscosity measurements.

As for the second section of the CATA survey, which was related to rub-out, pick-up, and immediate afterfeel, the terms "easy to spread/slippery," "light," "gluey/sticky," "cooling," "light," "silky/smooth," and "easy to rub in" were most frequently associated with the evaluated emulsions. The least mentioned terms were "warming" and "hard to spread/dragging," suggesting that most consumers thought none of the evaluated emulsions had these properties.

Regarding the afterfeel after 3 min, which was the third section of the CATA survey, the most frequently selected terms were "smooth/soft," "glossy/shiny" and "dry." The least mentioned term was "white." Results of Cochran's Q test, which was performed to evaluate the robustness of the Skillings–Mack test, were identical to those of the Skillings–Mack test. Statistical analysis showed significant differences for 15 of the 30 terms of the CATA survey (Table V), which suggests that the CATA survey was able to detect differences in consumers' perception of the emulsions. In addition, all three categories had statistically significant terms, which indicate that consumers were able to distinguish between emulsions based on more than appearance.

In the first section of the CATA survey, significant terms were those related to the viscosity of the products. Probable rationale includes the following: (i) viscosity is a property that can be qualitatively determined by eye, and (ii) significant viscosity differences were present in the three sets of emulsions. In the second section of the CATA survey, more than half of the terms were significant. For example, most consumers selected "hard to spread/dragging" for Emulsion 6, which was a W/O emulsion containing olive oil. W/O

Table V
Frequency of Mention of Each Term of the CATA Survey for Each Emulsion

		Emulsion					
Category	Term	1	2	3	4	5	6
Before application (appearance)	Glossy/shiny	36	33	39	41	39	41
	Dull/flat	10	10	4	3	5	6
	Thick/creamy***	49	45	15	27	0	6
	Thin/milky***	1	1	31	18	49	43
	Bright white	33	34	33	35	28	33
	Off-white	11	8	6	8	14	10
During application (rub-out, pick-up, and immediate afterfeel)	Cooling	23	25	27	27	33	28
	Warming	2	2	0	1	1	1
	Easy to spread/slippery***	36	38	48	49	45	38
	Hard to spread/dragging***	7	7	0	0	4	13
	Thick/creamy/firm***	39	39	2	6	2	10
	Thin/milky***	7	3	39	35	40	31
	Hard to rub in*	16	9	13	17	12	23
	Easy to rub in	29	28	28	25	29	19
	Highly absorbent	19	17	10	17	14	14
	Slightly absorbent	18	18	20	22	22	18
	Watery/wet***	9	6	39	25	33	22
	Oily/greasy***	27	28	6	13	14	19
	Silky/smooth*	32	24	38	32	24	29
	Gluey/sticky***	11	15	1	4	7	13
	Light***	18	19	45	38	37	31
	Heavy***	22	16	0	4	3	10
After application (afterfeel after 3 min)	Glossy/shiny	25	24	23	29	29	27
	Dull	14	10	15	11	10	14
	Oily/greasy**	20	24	8	16	13	16
	Smooth/soft**	36	27	44	34	29	32
	Wet/not fully dry	16	19	10	14	19	15
	Dry	21	16	20	21	18	20
	Sticky/tacky	7	12	3	10	7	11
	White	4	4	4	2	2	1

***Indicates significant differences ($p \leq 0.001$); **Indicates significant differences ($p \leq 0.01$); *Indicates significant differences ($p \leq 0.05$), according to Skillings–Mack test.

emulsions are known to be sticky/tacky, further emphasized by olive oil, which has its own tacky skin feel. When looking at the term "gluey/sticky," emulsions with olive oil (Emulsions 2, 4, and 6) were considered more gluey/stickier than the emulsions without olive oil, which is in alignment with the expectations (28). Consumers perceived Emulsions 3 and 4 as "light" at rates of 90% and 76%, respectively, which is usually how liquid crystal–stabilized O/W emulsions are perceived. An interesting finding was that 74% and 61% of consumers, respectively, perceived Emulsions 5 and 6 (W/O emulsions) as "light." This may be explained by the light nature of the main emollient, which was present in a higher concentration in all emulsions. The perceptions of steric-stabilized emulsions were divided; they were considered "light" by about half of the participants and "heavy" by the other half. In the third section of the survey, two terms were significant, namely "oily/greasy" and "smooth/soft." As for "oily/greasy," emulsions with olive oil were considered oilier, which can be expected because of olive oil's tacky nature. The emulsions without olive oil had the highest frequencies of mention for "smooth/soft," which makes sense, considering that emulsions with olive oil were considered "oily/greasy" and "sticky/tacky."

Antonym terms, for instance "thick/creamy" and "thin/milky," "easy to spread/slippery" and "hard to spread/dragging," and "light" and "heavy," are examined next. Instances of individual consumers selecting both 'attribute A' and 'not attribute A' were uncommon (3%), which suggests that most of the consumers understood the terms, were attentive of filling out the survey, and did not randomly select terms, which correlates with prior findings (20,29). These examples clearly suggest that term selection for the CATA survey was appropriate, as consumers were able to detect differences based on the emulsions' sensory characteristics.

Our findings also suggest that CATA surveys can serve as a useful tool in the product development process when formulators have multiple viable prototypes for a particular product. Recruiting consumers from the target group and having them fill out a CATA survey can be an easy, fast, and convenient approach for companies and can provide guidance for formulators as to which prototype(s) should be moved into the subsequent steps of product development.

MFA

The MFA with balancing sets of variables explained 72.16% of the total inertia in the first two dimensions (Figure 2). With such a high explanatory power, it was worth representing the results in a reduced dimensional space, where it was possible to examine visually associative links among groups of variables.

Contributions represent the extent to which each variable contributes to building the corresponding axis, which helps in the interpretation. A variable with a large value contributes more to the definition of the specific dimension. Contributions (CTR) are shown in Figure 2A in three colors. Terms in black had the highest contribution (CTR > 8), terms in medium gray had medium contribution (CTR 3–8), and terms in light gray had the lowest contribution (CTR < 3). The following variables contributed to the first dimension the most: "glossy/shiny (appearance)," "dull/flat (appearance)," "thick/creamy (appearance)," "think/milky (appearance)," and "oily/greasy (afterfeel)." As for the second dimension, the following variables contributed the most: "bright white (appearance)," "off-white (appearance)," "glossy/shiny (afterfeel)," "dull (afterfeel)," "smooth/soft (afterfeel)," and "wet/not fully dry (afterfeel)." From the results, it seems that consumers perceived dull creams as smooth/soft and off-white as glossy/shiny.

Figure 2A shows the representation of terms of the CATA survey in the MFA dimensions. Correlation shows the relationship between the variables (i.e., terms of the CATA survey). The terms "thick/creamy/firm," "oily/greasy," "oily/greasy (afterfeel)," "warming," "dull/flat," "heavy," "thick/creamy," "gluey/sticky," and "highly absorbent" had a correlation of 0.8 or higher in the first dimension, whereas "easy to spread/slippery," "thin/milky," "glossy/shiny," "watery/wet," "light," and "thin/milky (pick-up and rub-out)" had a correlation of −0.8 or lower in the first dimension. Consumers felt that light creams were easy to apply, wetter than heavy creams, and thin and glossy, whereas heavy creams were

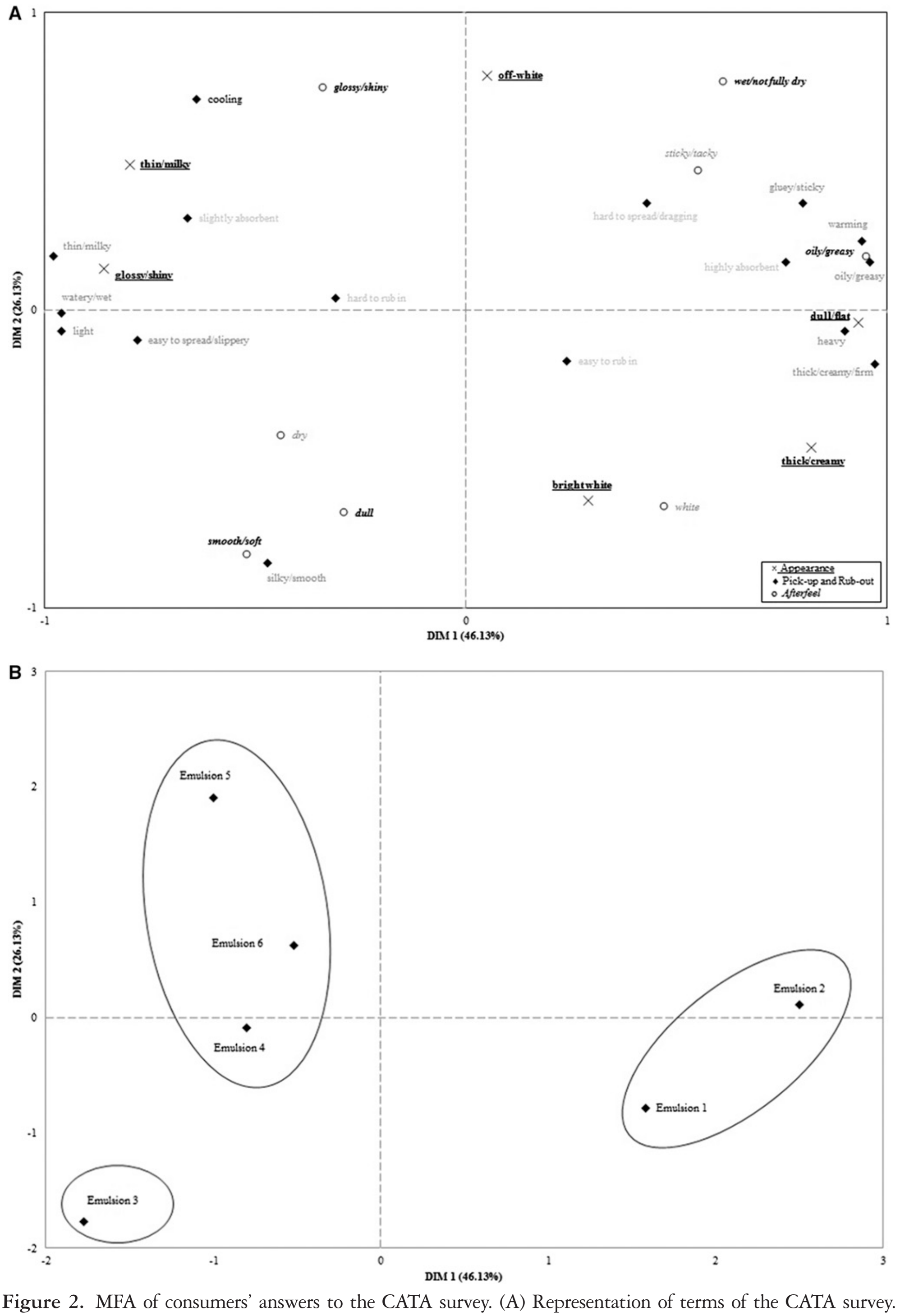

Figure 2. MFA of consumers' answers to the CATA survey. (A) Representation of terms of the CATA survey. Colors indicate contribution of factors to the dimensions. Terms in black had the highest contribution (CTR > 8), terms in medium gray had medium contribution (CTR 3–8), and terms in light gray had the lowest contribution (CTR < 3). (B) Representation of emulsion samples. Ellipses indicate the result of hierarchical cluster analysis.

oily/greasy, hard to spread, gluey, and dull in their appearance. The relationship between these terms is coherent considering that a light cream is expected to be easy to apply, whereas a heavy cream could be regarded as oily/greasy. Having these terms in this distribution suggests that consumers were able to distinguish between the emulsions based on their sensory properties. Looking at the second dimension, the terms "off-white," "wet/not fully dry," "glossy/shiny (afterfeel)," and "cooling" had a correlation of 0.7 or higher, whereas "bright white," "white," "dull," "smooth/soft," and "silky/smooth" had a correlation of −0.6 or lower.

The results from MFA suggest that the first dimension primarily discriminated emulsions based on rub-out and pick-up characteristics, including how thick or thin they felt on spreading on the skin (i.e., sensation of thickness/viscosity). Appearance attributes, including glossiness/dullness and thickness also determined this axis. The second dimension was primarily related to the appearance of the emulsions, including color and glossiness/dullness, as well as afterfeel after 3 min, including smooth and watery feeling, provided by the emulsions.

An intriguing finding was that the terms "warming" and "cooling" did not appear to be antonyms in this study. Warming, located at the positive values of both dimensions, was in the cluster characterizing heavy creams. Cooling, located at the negative values of the first dimension and positive values of the second dimension, was mainly used by consumers to characterize thin, glossy, off-white creams. As mentioned previously, "warming" was one of the least mentioned terms. It suggests that most consumers could not relate this term to any of the emulsions. Products can be designed to provide a warming sensation on the skin on application (30); however, none of the emulsions in this study were designed to have a warming sensation on the skin. This can explain the infrequent use of the term. Characteristics that none of the emulsions will likely have ("warming" in this case) may cause negligible noise in the data because some consumers may still select these terms as a sensory attribute for certain samples. However, the low incidence of such cases did not affect significantly the robustness and reliability of the results obtained. When looking at the frequency of mention of the term "cooling," it can be seen that cooling was used very frequently. Typically, W/O emulsions (often called cold creams) are known to be cooling, providing a cooling sensation as water evaporates from the skin after applying the product. However, "cooling" was selected a similar number of times for all emulsions. This suggests that consumers could not really distinguish products based on this characteristic.

Figure 2B shows the representation of emulsions in the MFA dimensions. This figure suggests that consumers were able to categorize the emulsions into groups. The principal axis was highly correlated with variables that belong to two separate groups. It opposed Emulsions 1 and 2 from Emulsions 3–6. From the perspective of appearance, Emulsions 1 and 2 were characterized as dull, whereas Emulsions 3–6 were characterized as shiny. From the perspective of skin feel during application, Emulsions 1 and 2 were considered heavy and the rest of the emulsions as light. The off-white trait of an emulsion practically coincides with the main factor. The second dimension sorted the samples based on color and afterfeel into two groups, one including Emulsions 2, 5, and 6 and the other including Emulsions 1, 3, and 4.

Considering the color, a sharp discrimination was detected in the shade of the emulsions (i.e., bright white or off-white). As shown in Figure 2B, Emulsion 1 was located at the positive values of the first dimension and negative values of the second dimension, being described by consumers as bright white, thick/creamy, and easy to rub-in. On the other hand, Emulsion 5 was located at the negative values of the first dimension and positive values of the second dimension. It was described as cooling, glossy/shiny, and thin/milky. These results are in agreement with the viscosity measurements. The afterfeel characteristics also had a large discriminative power, which helped differentiate Emulsion 3 from Emulsion 5. Consumers felt that Emulsion 3 left their skin smooth/soft and dull, whereas Emulsion 5 made the skin glossy/shiny 3 min after application.

We also looked at which ingredient types were driving the skin feel and sensory characteristics, and how these were related to each other. Five supplementary groups of variables were added to the empirical investigation. They expressed the percentage of emollients, emulsifiers, water, and other ingredients in the emulsions, as well as the measured viscosity. One of the main purposes of factorial analyses is to make predictions via displaying external profiles in a created map. Thus, supplementary variables were not included in constituting the plane; but their relative position and relationship with the factors were shown geometrically. The results showed that the sensory characteristics were primarily driven by the emulsifiers, not the emollients. These findings empirically verify previous findings (21,22). Figure 3 shows that water and the emulsifiers are strongly related to the main factor. This factor has a strong inertia for two other clouds of variables, including appearance and pick-up/rub-out, meaning that numerous variables from these groups are related to this common factor. On the other hand, the relationship of emollients with both factors was statistically weak, as is shown by their location in the MFA dimensions. The other ingredients, including the humectant and preservatives, did not have any correlation to the skin feel characteristics at all because they were used in the same concentration in each emulsion.

Viscosity had a high correlation with the emulsifiers and water, suggesting that viscosity is determined by both of these ingredients (Figure 3). Viscosity was closely located to pick-up/rub-out, which indicates that viscosity has an important role in influencing these skin feel characteristics. On the other hand, the location of afterfeel and viscosity are farther from each other, suggesting a weaker relationship.

Cluster analysis. HCA under MFA was performed using two types of distance metrics (including Manhattan and Euclidean) and four agglomeration methods (including average, complete, single, and Ward linkage). All dissimilarity measures with both cluster methods resulted in the same classification (Figure 2B). The first cluster was composed of Emulsion 3. The second cluster included Emulsions 4, 5, and 6, and the third cluster was composed of Emulsions 1 and 2. According to this analysis, consumers categorized emulsions slightly differently as compared with the original grouping based on emulsion type (i.e., steric-stabilized O/W, liquid crystal–stabilized O/W, and W/O). Consumers grouped the steric-stabilized emulsions together. These emulsions were the thickest, considered "heavy" by consumers, and very dissimilar compared with the rest of the emulsions. The second group included two W/O emulsions and the liquid crystal–stabilized O/W emulsion with olive oil. The fact that two different types of emulsions, both containing olive oil, were grouped together suggests that consumers could detect similarities between these two products. This is a notable result, especially when we consider that the participants were untrained consumers.

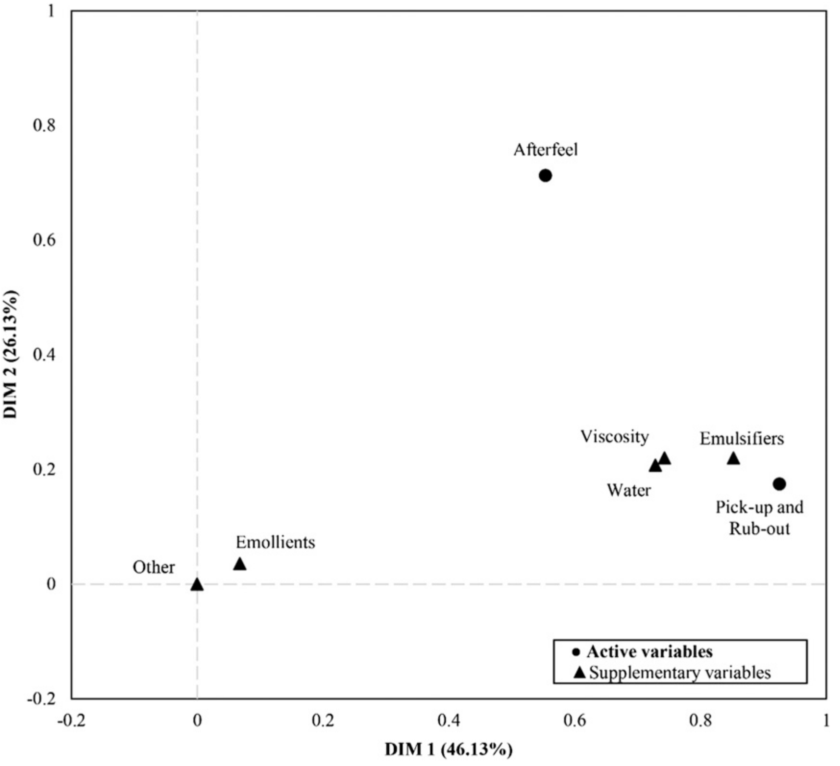

Figure 3. Representation of ingredient types and skin feel characteristics.

Looking at the results of the cluster analysis also helps to define the first dimension more accurately. A possible explanation for having three emulsions in this cluster is that consumers differentiated emulsions primarily based on the sensation of viscosity on application (i.e., under shear) and not just thickness as an attribute of appearance. Discriminating samples based on viscosity is not an easy task. According to a recent study (31), the ability to discriminate viscosity differences is attributed to experience. As mentioned previously, 74% of our participants were regular users of hand and body lotions. They more likely noticed differences in the sensation of viscosity. As mentioned previously under the frequency of mention of the terms, Emulsions 3 and 4 were regarded as "thin" in terms of rub-out and pick-up properties (during application) by the majority of consumers (78% and 70%, respectively). This also helps to explain the three-emulsion cluster. These observations are in correlation with the findings of the MFA.

Cluster analysis also helped to define the second dimension. We compared all possible combinations of each emulsion in pairs (Table VI). We looked for attributes that were related to either appearance or afterfeel and were similar for Emulsions 4 and 6, but different for Emulsions 3 and 5. The reason for this was that we wanted to identify attributes that could help better understand the second dimension. We identified two attributes, namely "off-white" and "wet/not fully dry." This confirms the findings of the MFA that the second dimension was mainly related to the appearance of the emulsions, including color and afterfeel after 3 min, including watery feeling provided by the emulsions.

Table VI
Comparison of Pairs of Emulsions for Statistical Differences

	Emulsion pairs														
Attributes	1–2	1–3	1–4	1–5	1–6	2–3	2–4	2–5	2–6	3–4	3–5	3–6	4–5	4–6	5–6
Appearance															
Glossy/shiny															
Dull/flat							*								
Thick/creamy		***	***	***	***	***	***	***	***	*	***	*	***	***	*
Thin/milky		***	***	***	***	***	***	***	***	**	***	**	***	***	*
Bright white															
Off-white											*				
Cooling				*											
Rub-out and pick-up															
Warming															
Easy to spread/slippery		***	***	*		**	***					**		***	
Hard to spread/dragging		**	**			**	**				*	***	*	***	*
Thick/creamy/firm		***	***	***	***	***	***	***	***			**			*
Thin/milky		***	***	***	***	***	***	***	***						*
Hard to rub in									**			*			*
Easy to rub in															*
Highly absorbent		*													
Slightly absorbent															
Watery/wet		***	***	***	**	***	***	***	***	**		***			*
Oily/greasy		***	**	**		***	**	**			*	**			
Silky/smooth						**					**				
Gluey/sticky		**				***	*				*	***		*	
Light		***	***	***	**	***	***	***	*		*	***			
Heavy		***	***	***	**	***	**	***		*		***			*
Afterfeel after 3 min															
Glossy/shiny															
Dull															
Oily/greasy		**				***		*							
Smooth/soft		*				***				**	***	**			
Wet/not fully dry						*					*				
Dry															
Sticky/tacky						*				*		*			
White															
Total (stars)	0	35	28	25	18	41	29	24	16	9	17	28	7	13	9

***Indicates significant differences ($p \leq 0.001$); **Indicates significant differences ($p \leq 0.01$); *Indicates significant differences ($p \leq 0.05$), according to two-sample ANOVA test.

CONCLUSIONS

A CATA survey provided useful information about consumers' perception of the skin feel and sensory characteristics of six cosmetic emulsions. Emulsions represented three main types of emulsions, differing in the amount and type of emulsifiers. Emulsions of the same type differed in the emollients, but all other ingredients were the same. We investigated the effect of emulsifier versus emollient on the skin feel and esthetic of emulsions. The identified sensory differences between the emulsions can be explained by differences in ingredients, suggesting that the method was valid. Our findings suggest that emulsifiers, not emollients, have the dominant role in determining the esthetics of a skin care emulsion, which is in line with previous findings (21,22). The fact that this study, using untrained consumers, resulted in similar findings as studies using trained panelists suggests the validity of the CATA survey, and its reliability as a screening tool in the product development process. It is recommended that formulators evaluate a wide range of emulsifiers and emulsifier combinations at the beginning of the formulating process to find the proper esthetic properties for a particular application. This is a more direct approach to engineering formulations that pleases the target audience and meets their needs and preferences.

Among the advantages of CATA surveys are that they provide a fast and convenient method for participants and no training is necessary after recruiting consumers. They can be recruited from the target group, which can add much value to the results, and recruitment can happen at any time. In this study, the 50 consumers were able to discriminate between the emulsions without any training. Another advantage of the CATA surveys is that consumers do not have to describe the products themselves; they simply have to select terms from a predetermined list, which is very helpful for those consumers who find it difficult to verbalize their perceptions. A study (29) investigated whether the number of words had a significant positive or detrimental effect on the outcome of CATA surveys. Findings showed that using more terms rather than less (10–17 vs. 20–28) did not appear to be detrimental. However, authors concluded that including more terms can make it more difficult and more tedious for consumers to fill out the survey and can compromise their attention to the task. Long lists of words can lead consumers to select the terms that easily catch their attention without thoroughly analyzing the sample and considering its characteristics. We believe that the number of terms used in this study (i.e., 30) was appropriate and necessary to well describe the emulsions and the similarities/differences between them. We also believe that grouping the synonym terms and listing them together was advantageous for the following reasons: it made it easier for participants to select the appropriate terms for each product, it made characterization of products more consistent, and it made statistical analysis simpler.

In CATA questions/surveys, participants are not told how many terms they should select; they are usually advised to select as many terms as they feel appropriate to describe the given product. This leads to a disadvantage of this technique. We experienced that some consumers only selected 5–6 words from our 30-word list, whereas others selected 10–15 terms. Another limitation of CATA questions/surveys is that technical terms can only be used with careful consideration. Untrained consumers may not know the exact meaning of technical terms and might select them for the wrong reason or not select them at all, which takes away from the value of the results. If technical terms have to be used, definitions for each term should be given to consumers. However, if many terms are used, reading through the definitions and understanding the differences between terms may exhaust participants before even starting the study. Another approach that we used in this study was to provide each consumer with time to review the terms before the study and the opportunity to ask questions.

Previous studies (18,32) suggested that to produce reliable results, the number of untrained consumers used for CATA surveys should be higher than the number of trained panelists used for DSA. We agree with these suggestions and believe that the number of consumers should be at least 50 per survey.

In our study, we did not have a proposed application for our creams (e.g., daily facial cream); we primarily wanted to see how effectively consumers can differentiate between the emulsions based on their sensory characteristics. If there is a target application for the products to be evaluated, term selection should take this application into account, and the CATA survey should have a question about potential applications. In addition, as mentioned previously, most of our participants were regular users of hand and body lotions. We did not exclude people who used products less than two to three times a week. However, we believe that when CATA surveys are used to screen prototypes for a certain target application, participants should be recruited from the target group and should be regular users to provide meaningful results.

Synthesizing previous theories, it was shown that CATA surveys are a reliable and powerful tool to measure consumers' sensory perception and to evaluate cosmetic and personal care products. Our untrained consumers could perceive differences and similarities between products. CATA surveys may serve as a viable complimentary to DSA performed by trained panelists. This technique can be of particular interest to companies that do not have a trained panel or do not have time and/or resources to train a panel for a specific application. In addition, it was also proven that skin feel of the tested cosmetic emulsions was primarily determined by the emulsifiers.

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