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“The Importance Of Application Gestures To Enhance Formulation Benefits On Curly Hair”

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1. Introduction

The relentless pursuit of enhanced hair product performance has centered primarily on optimizing formulations by refining ingredient combinations, meticulously adjusting pH levels, and exploring novel chemical structures [1]. While yielding undeniable advancements in hair care, this focus has inadvertently overshadowed another crucial element in the equation: the application process. Understanding how consumers interact with products, their specific gestures, and the impact on efficacy and overall experience remains underdeveloped. This presents a significant opportunity, especially within the curly hair community, where anecdotal evidence suggests application techniques can be as influential as the product itself in achieving desired results.

Curly hair consumers often develop personalized routines and experiment with various application methods shared on online forums. Therefore, this topic and target had shown an increased presence in the social media content, as a result, the Google search for the term “curly hair” had a growth of 232% in 2017 [2]. This wealth of anecdotal evidence underscores the need for rigorous scientific investigation to understand and harness the power of application gestures for the curly target.

This pioneering study delves into the largely unexplored territory of application gestures, seeking to quantify their impact on both the functional performance and the emotional resonance of hair products. Moving beyond anecdotal observations, it establishes a scientific framework for understanding the relationship between application, product performance, and user experience. A deeper understanding of this can unlock a new, more efficient, and sustainable dimension in product development, enabling the enhancement of the benefits and overall experience *without* altering existing formulations and moving away from a solely formula-centric approach to a more holistic perspective. Furthermore, by decoupling performance enhancements from formula modifications, a new layer of flexibility and efficiency is created in the product development process, allowing researchers to respond more rapidly to evolving consumer needs and preferences without the time and resource commitments associated with reformulation. This research has far-reaching implications, potentially transforming product development, marketing, education, and personalized consultations, ultimately enhancing the overall hair care experience.

2. Materials and Methods

To explore the added functional and emotional value, six hair application techniques (HAT) focused on end look were tested versus a standard application (HAT STD) focused only on cleaning and detangling. For all HATs, a quantitative standardized protocol with the same formulation of creamy shampoo, melting conditioner, and detangling leave-on was performed in 30 women in a Central Location Test (CLT) at Rio de Janeiro – RJ Brazil. The participants were aged 19 – 54 years, hair typed from III.5-IV.5 with the curvature illustrated in Figure 1 [3], dark-based hair color, consumers of the used categories of this study, and hair finalization social media content followers and practitioners. Table I shows the distribution of age and hair type.

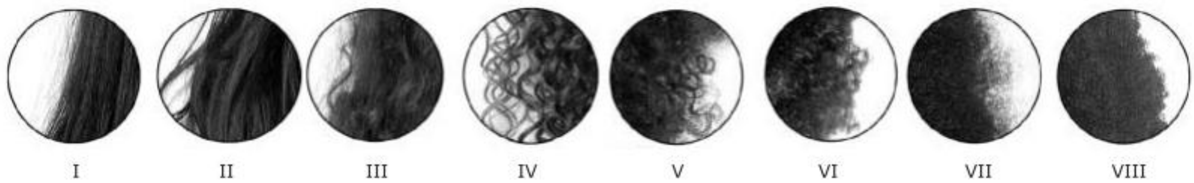

Figure 1. Hair Types Curvature [3].

Table I. Quantitative Study respondents' age and hair type distribution.

Age	Hair type
19 – 30 = 34%	III,5 = 31,25%
31 – 40 = 34%	IV = 34,37%
41 – 54 = 31%	IV,5 = 34,37%

At the CLT, the respondents were submitted to a protocol composed of three phases: Execution of the HAT, Standardized Picture Acquisition, and Functional & Emotion CATA (Check All That Apply) [4], as shown in Figure 2. Phase 1 consisted of the HAT execution and drying time in the HairStation New 2013 from Beauty Star. Then, Phase 2 captured the picture data of the HAT with the Shooting Table Body-HeadScan (ver.4) and FlaShScan by OrionTableTechnolab and Nikon D90 digital camera with an AF-S NIKKOR35mm 1:1.8G macro lens in a dark room. Followed by Phase 3, which comprehended the Check All That Apply (C.A.T.A.) [4] questionnaire answered by the consumers in a standardized bathroom using a digital approach for data collection with Fizz Collect 3.8.0.4 – Nomad, allowing the respondents to access the questionnaire on their cellphones.

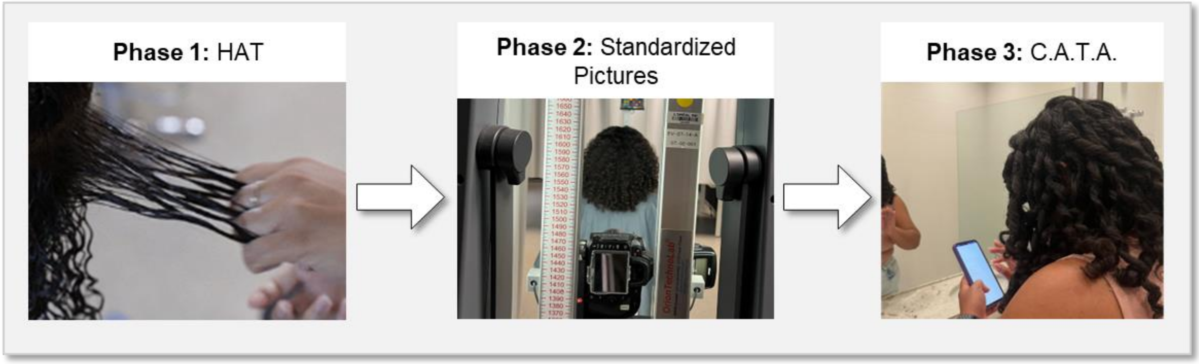

Figure 2: Methodology procedure with phases' illustration.

In Phase 1, HATs were performed by 2 hair experts to guarantee the standardization of gestures between the respondents. HAT 1 to 4 modified just leave-on application by dividing hair into small sections in different ways (HAT 1: pulling and rolling each swatch with fingers; HAT 2: pulling between fingers and shaking in the end; HAT 3: pressing each section with hands and separating swatches; HAT 4: separating into 2 swatches and twisting them together). HAT 5 modified shampoo gesture (on roots with fingertips and move foam to ends) and HAT 6 varied conditioner gesture (dividing into small sections and pressing swatches).

For Phase 2, the setup of the shooting table was done to take standardized pictures from the back of the hair of all the volunteers, but the height of the chair was defined according to the height of each one, as shown in Figure 2. Table II describes the parameters used in the shooting table.

Table II. Description of the parameters of the shooting table.

Parameter	Study set up
Chair angle (°)	0
Camera and flash height (m)	11.50
Camera and flash distance (m)	0.65

Furthermore, the parameters of the camera and the picture collection of Phase 2 were performed in a digital approach using software to configure and control the camera from a computer. Table III describes the parameters used in the Nikon D90.

Table III. Description of the Nikon D90.

Parameter	Study setup
Shutter Speed	1/30
ISO Sensitivity	LO-0.7
Picture Orientation (°)	90
Image Size	L(4288x2848)
Compression Level	JPEG Fine
White Balance	Sunny

After the collection, the pictures from all respondents of each HAT were evaluated regarding 10 visual attributes in a direct comparison versus HAT STD by 4 hair experts in a difference intensity 7-point bivalent scale, as shown in Table IV, using a HP Eye Ease Screen E24m G4 model. To understand the expert evaluation, a statistical analysis was done by calculating the mean between evaluators, which considered the median of all comparisons.

Table IV. Difference Intensity Scale from Expert Evaluation.

Much more	More	Slightly more	Parity	Slightly less	Less	Much less
3	2	1	0	-1	-2	-3

Beyond the expert evaluation, the pictures were also used to analyse the hair volume using HairVolumeAnalysis 2.0. This software quantifies the number of pixels from the hair's area and uses the millimetric measure of each pixel from the ruler positioned in the shooting table to calculate the volume in a 2D approach from the images. With the volume measured from all pictures, the mean hair volume of each HAT was calculated. Then, the mean volume of each HAT was compared to the mean of the HAT STD according to Equation I to calculate the percentual increase or decrease. The statistical analysis was performed using a two-way ANOVA with no repetition, followed by a Dunnett test.

$$Volume\ difference\ (\%) = \frac{mean\ volume\ of\ HAT\ (mm)}{mean\ volume\ of\ HAT\ STD\ (mm)} x100 - 100$$

Equation I. Calculate the percentage difference of volumes.

For Phase 3, the CATA [4] addressed 26 functional terms presented randomly in 6 separate sessions: shine, movement, volume, definition, frizz, and general aspect. After the evaluation of the visual hair benefits, 18 emotional terms were presented randomized order in one session. Each session forced the check of at least one of the terms presented. To analyze the CATA data, a principal component analysis (PCA) [5] was performed using all the terms as active variables, all the HATs as individuals, and standardizing the data to center and reduce the variables and avoid giving more weight to certain variables. Cattell's elbow rule [6] method was used to choose the number of factorial axes to analyse.

3. Results

Following the described on-site protocol, each HAT was executed 30 times, resulting in a total of 210 applications for Phase 1. In Phase 2, digital images were captured for all 210 applications, yielding 30 data points per HAT, enabling the analysis via expert evaluation and hair volume quantification. Furthermore, Phase 3 generated 30 completed CATA questionnaires per HAT, culminating in 210 individual consumer evaluations and enabling subsequent PCA.

Expert evaluation

In the expert evaluation results, the overall performance characteristics were observed for each HAT versus the HAT STD, as presented in Table V. Considering this comparison, HAT 1 exhibits the greatest quantities of differences, while HAT 6 demonstrates the greatest similarity to HAT STD, with no discrepancies. Furthermore, HAT 1 presented slightly more Discipline, Individualized, Regularity, Definition, and Shine, while slightly less Volume, Frizz, and Visual Dry Ends. HAT 2 had slightly more Discipline and Best visual, and slightly less Frizz, while HAT 3 delivered slightly more Definition and Shine, suggesting potential for improving product performance through targeted key characteristics for the curly consumer. HAT 4 presented slightly more Volume and Frizz, while slightly less Shine, Discipline, and Best visual, indicating the complexity of achieving more volume and optimal results across multiple key attributes. HAT 5 had only slightly more Best visual.

Table V. Statistical expert results comparing HATs vs HAT STD.

Attributes	*HAT 1*	*HAT 2*	*HAT 3*	*HAT 4*	*HAT 5*	*HAT 6*
Discipline	+	+	=	-	=	=
Volume	-	=	=	+	=	=
Frizz	-	-	=	+	=	=
Individualized	+	=	=	=	=	=
Regularity	+	=	=	=	=	=
Definition	+	=	+	=	=	=
Shine	+	=	+	-	=	=
Visual dry ends	-	=	=	=	=	=
Shrinkage factor	=	=	=	=	=	=
Best visual	=	+	=	-	+	=

HairVolumeAnalysis quantification

Utilizing the described hair volume analysis methodology, the software calibrated each pixel at (15.3×10^{-5}) m, standardized across all 210 digital images. Employing this calibrated value, the volume for each HAT was calculated and, using Equation I, its corresponding comparison to HAT STD, as shown in Table VI.

Table VI. Volume measurement and percentual decrease or increase vs HAT STD.

HATs	Hair Volume ($\times 10^{-2}$ m²)	Volume increase/decrease vs HAT STD (%)
HAT 1	10.14	-16.73%
HAT 2	11.39	-6.46%
HAT 3	12.38	1.64%
HAT 4	13.45	10.44%
HAT 5	12.75	4.70%
HAT 6	12.77	4.85%
HAT STD	12.18	-

Analysis of the results indicates that HAT 1 yielded the lowest volume (-16.7%), while HAT 4 produced the highest volume (+10.4%) compared to HAT STD. Furthermore, the ANOVA analysis resulted in an F-statistic exceeding the critical F-value ($4.28 > 2.15$), as detailed in Table VII. This confirms the hypothesis of statistically significant differences among the mean volumes of the HATs. Subsequent Dunnett's test determined a Difference of the Means Sum (DMS) value of 19319.77. Only the difference between the mean volume of HAT 1 and the mean volume of HAT STD surpassed the DMS value, Table VIII presents the calculated differences. Therefore, it can be concluded that HAT 1 was the only HAT exhibiting a statistically significant difference for volume when compared to HAT STD, considering the HairVolumeAnalysis measurements.

Table VII. ANOVA results from the mean volume of each HAT.

Variation source	SQ	gl	MQ	F	p-value	critical F
HAT's volume	21279856405	6	3546642734	4.28	0.000472	2.15

Table VIII. Absolute mean volume difference of each HAT vs HAT STD.

	HAT 1	HAT 2	HAT 3	HAT 4	HAT 5	HAT 6
|HAT's mean volume - HAT STD's mean volume|	20373.16	7859.03	2001.61	12706.46	5720.67	5901.54

PCA mapping from CATA assessment

The PCA [5] generated a mapping that divided HATs into 2 factorial axes and 3 clusters, Figure 3 represents the graphic visualization with the picture of all HATs from one respondent as an example. The discriminative terms used to describe each cluster had a p-value lower than 5% and a high difference comparing the average of the variable for the individuals in the class (Mean in Category) vs the average of the variable from all clusters combined (Overall Mean).

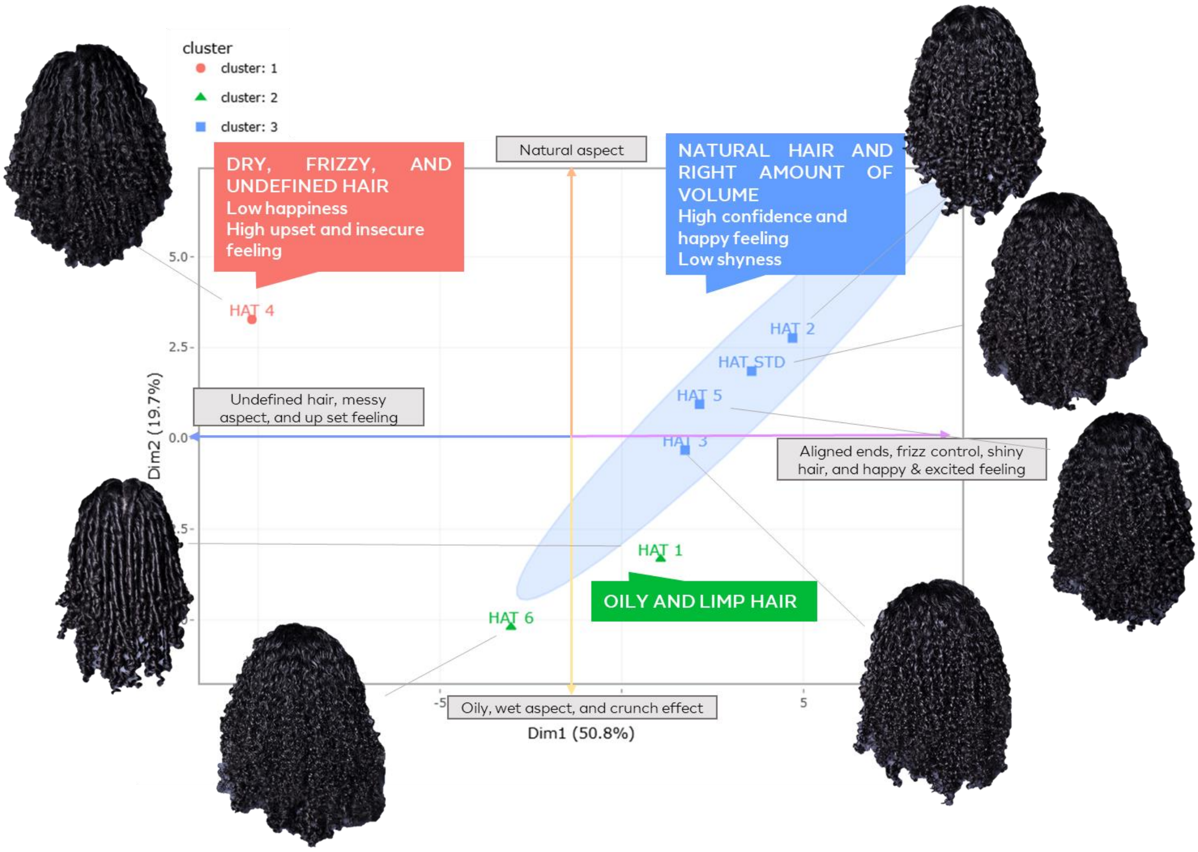

Figura 3. HATs mapping with axis and clusters description, and 1 respondent's pictures representation.

The PCA mapping of consumer CATA data elucidated the relationship between perceived hair attributes and emotional responses. Considering the statistics, the clusters were described as: 1st DRY, FRIZZY AND UNDEFINED HAIR; 2nd OILY AND LIMP HAIR; 3rd NATURAL HAIR AND RIGHT AMOUNT OF VOLUME. The first cluster was characterized by a visual performance with low definition, discipline, healthy and moisty hair, high frizz, dry hair, and messy aspect, which evoked high upset and insecure feelings, while low happiness. The second cluster presented high oily and limp hair and low natural aspect for visual performance, which did not translate into any discriminating emotion. The last cluster had a high right

amount of volume and natural aspect, while low artificial aspect and limp hair, which evoked high confidence and happy feelings, as well as low shyness.
In addition to the clusters' characterization, the axes were also interpreted. The terms used to describe them had a high correlation with cos2 higher than 0,5 and the largest ones for the respective dimension. The abscissa positioning with positive increasing enhances intensity in aligned ends, frizz control, shiny hair, happiness, and excitement, while with negative increasing enhances intensity of undefined hair, messy aspect, and upsetness. The ordinary axis with positive increasing enhances intensity in natural aspect while the negative increasing enhances intensity in oily, wet aspect, and crunch effect.
Considering this mapping, HATs 2, 3, and 5 were positioned in the NATURAL HAIR AND RIGHT AMOUNT OF VOLUME cluster as the Routine STD. Therefore, from the consumers' view, the application techniques 2, 3, and 5 delivered the right amount of volume and natural aspect, which is also perceived in the application focused only on cleaning and detangling (HAT STD), and this visual result evoked positive emotions as confidence and happiness. HATs 1 and 6 were positioned in the OILY AND LIMP HAIR cluster. HAT 4 was clusterized as DRY, FRIZZY, AND UNDEFINED HAIR, and this perceived visual result evoked negative emotions as upsetness and insecurity.
The axes revealed a progression of aligned ends, shine, and happiness/excitement across the different HATs in the following order: 1 < 3 < 5 < STD < 2. Natural appearance increased in the order: 5 < STD < 2 < 4. Oily, wet aspect, and crunch effect followed the order of HATs 3 < 1 < 6, with a high increase from 3 to 1. Finally, undefined hair, a messy appearance, and upset feelings intensified from HAT 6 to 4, with a significant difference between these two HATs.

4. Discussion

These findings reveal a complex interplay between application method, visual hair characteristics, and emotional impact, offering valuable insights for formulators seeking to optimize product performance and consumer experience, without altering hair care formulas.
The clustering of HATs 2, 3, and 5 with HAT STD in the "Natural Hair and Right Amount of Volume" group, mirros the expert evaluation where these HATs shared a high number of parity attributes (7, 8 and 9 respectively) with HAT STD, including volume – a defining characteristic of this cluster. In addition to the HairVolumeAnalysis, which showed that these HATs had a percentual difference in volume lower than 6.4% and did not have statistical differences compared to HAT STD. The functional performance perceived in the three analysis methods from HATs 2, 3, 5, and STD shows that these techniques effectively deliver a desirable end look, evoking positive emotions, as confidence and happiness, while reducing shyness, a negative emotion.
Conversely, HATs 1 and 6 were grouped in the "Oily and Limp Hair" cluster, aligned with the expert evaluation and the HairVolumeAnalysis that showed HAT 1 with less volume than HAT STD, which was considered as limp hair appearance by the respondents. Furthermore, despite having all matching attributes with HAT STD in the expert evaluation, HAT 6's different clustering reinforces the weight of an oily look for curly-haired consumers, a characteristic that

was not evaluated in the expert assessment of this study. In addition, even presenting an increase in definition for HAT 1 from the expert panel, its clustering highlights the potential for certain application techniques to inadvertently contribute to undesirable oily appearance for consumers. This observation warrants further investigation into the mechanisms by which application techniques influence sebum distribution and perceived oiliness.

HAT 4 was positioned in the "Dry, Frizzy, and Undefined Hair" cluster, aligned with the expert assessment of increased frizz and decreased shine. The expert-noted reduction in discipline translated to the consumer perception of undefined hair, resulting in lower happiness and increased insecurity and upset feelings. The corresponding negative emotional responses emphasizes the importance of addressing frizz control, shine, and definition for this target. In addition, HAT 4 was the only technique that delivered more volume from the expert evaluation and demonstrated the highest increase in volume from the HairVolumeAnalysis. This shows a need for future research for a HAT that increases volume but does not impact other visual attributes as frizz, definition, and shine.

5. Conclusion

These findings have significant implications for cosmetic formulators. By understanding the nuanced impact of application techniques on perceived hair attributes and emotional responses, formulators can develop products and usage instructions tailored to specific consumer needs and desired outcomes. For instance, formulations designed for curl definition could be paired with application techniques similar to HAT 1, while volumizing products might benefit from techniques like HAT 4. Furthermore, it is possible to use different HATs at the same time to achieve a look that favors more than one attribute. In addition, clear and concise instructions on optimal application methods are crucial for consumers to achieve desired results, which impacts the emotional response and, therefore, the product acceptance and loyalty.

Future research should explore the interaction between product formulation and application technique in greater detail. This includes investigating the impact of different product viscosities, textures, and ingredient compositions on the effectiveness of various application techniques. Going beyond the evaluated HATs, there is the opportunity to research new applications, mainly to optimize attributes as volume and oily look without compromising frizz, definition, and shine, and increase consumer global acceptance. Additionally, studying the influence of individual hair types and other curl patterns will allow more personalized product recommendations and usage instructions. In addition, the evaluation of physiological data would increase the understanding of the subconscious acceptance of the different performances delivered. Therefore, by continuing to investigate the intricate relationship between application, product, and consumer perception, it would be possible to develop innovative solutions that deliver optimal hair care experiences and optimize product development beyond formulation.

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