# Conditioned response: Fragrance's cross-modal effect on sensory perception in hair care

**Key words:** fragrances, sensory analysis, cross-modality

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**Abstract**

The cross-modal associations between olfaction and tactile perception are of a particular relevance to cosmetic products whose functions often include the improved sensorial experience of skin and hair. In relation to that, a 'halo' effect, defined as a failure to discriminate between potentially independent attributes (i.e. odour and conditioning effect) is likely to impact on the perception of product efficacy. The aim of this study was to assess the cross-modal and halo effects of two distinct fragrance categories - fruity (F) and green (G) - on the performance of a leave-in hair conditioner, made in two versions: with and without a lubricating polymer. Sensory evaluation, including discrimination, attribute and preference tests were carried out by 21 trained panellists, while instrumental evaluation was performed using a hair combing rig attached to a texture analyser TA XT Plus Texture (Stable Microsystems, UK).

The tresses treated with fragranced leave-in conditioners were perceived as different in terms of their conditioning effect from their non-fragranced equivalent, implying a fragrance-driven halo effect. The tresses treated with the floral fragrance were perceived as smoother and softer than with the green one, whilst the presence of the lubricating active alone did not elicit improved tactile perception. The easiness of combing (sensorial) was not influenced by the presence of fragrances or the silicone-based copolymer, which was in line with the instrumental combing tests of dry hair.

The above findings suggest the existence of cross-modal associations between odour and tactile experience.

## 1. Introduction

Cross-modal associations of olfactory and visual, and olfactory and tactile information processing are of high significance for cosmetic products. Such associations have been demonstrated experimentally and form the foundations of the growing field of sensory science. For example, olfaction and visual association have been studied from several different angles: direct colour/odour associations i.e. cucumber, spearmint and lemon have been associated with green, turquoise and yellow/orange colours respectively (Demattè *et al*, 2006a) and higher odour intensity has been associated with darker colours (Zellner and Kautz, 1990; Kemp and Gilbert, 1997). In another study, the presentation of congruent pairs of visual/odour items was proven to facilitate odour detection (Gottfried and Dolan, 2003).

The cross-modal association of odour and touch were firstly examined in the context of the tactile experience of fabrics. For example, Laird (1932) demonstrated that silk stockings were judged superior when impregnated with a floral scent over those with natural scent, whilst Demattè *et all* (2006b) showed that fabric odorised with lavender odour was perceived as softer than an equivalent odorised with an animal smell. These studies suggest that formulations alone may not give rise to positive tactile perceptions by the consumer. The impact of olfactory context (pleasant/unpleasant) on the perceived pleasantness of touch was studied by Croy *et al* (2016) via functional Magnetic Resonance Imaging and perception ratings, demonstrating that unfavourable olfactory experience modulates the behavioural and neural response to affective touch. Stevenson *et all* (2012) explored the cross-modal associations of odour with texture, colour and others attributes semantically and concluded that smooth texture was associated with almond, aftershave and caramel odours, whilst odours judged as intense and unpleasant raised the perceptions of roughness. In summary, the cross-modal associations are highly relevant not only to the immediate consumer experience of the cosmetic products during their application, but are likely to influence their perceived efficacy for modifying the tactile properties of the hair or skin too.

As hair grooming involves a range of tactile experiences - rubbing, holding and stroking the hair. The consumer tactile perceptions of their own hair whilst using a fragranced haircare product are very important. Correlating instrumental

measurements and panel data, Wartmann and Schwan-Jonczyk (2006) demonstrated that hair fibre diameter and bending stiffness were key to the overall “handling” quality of medium and coarse dry hair, but for finer hair, surface friction was a determiner for perceived softness. The value of this study is that it identifies the desirable single hair fibre properties, thus informing the technical choice of cosmetic ingredients which can deliver those. Furthermore, a strong halo effect of different fragrance families used in shampoos was identified by Chrichill *et al* (2009) who studied the sensory perceptions of foamed and dry hair. The researchers demonstrated that the perceived texture characteristics of hair were affected by the different odours; for example, fruity and floral odours were related to positive attributes such as silky, smooth, sleek and creamy, whilst the herbal scent was related to negative attributes such as sticky, slimy and tangled.

More recently, a novel device generating hair friction data from the direct contact with hair and converting it to sound, and consequently to music, has been presented (Nomura *et al*, 2017). Although the tactile and auditory stimuli in this project are connected by an algorithm, the experience is one of cross-modal association.

This aim of this study was to compare the impact of two fragrance types on the tactile perceptions of dry bleached hair treated with a leave-on conditioner. This vehicle was selected as the most suitable for imparting lasting odourising on the hair, as well as tactile benefits such as smoothness and softness. In technical terms, the deposition of conditioning agents lubricates the hair fiber and diminishes the surface friction and combing forces (Scott and Robbins, 1980). However, further enhancement of this effect was achieved via the addition of a specialty polymer, in accordance with the supplier’s literature (Schaefer, 2012). A range of sensory panel tests were used to evaluate the tactile properties of hair after the application of a control conditioning base and the enhanced conditioner in its fragranced and non-fragranced variations. In addition, the ease of combing of hair odourised via the leave-on conditioner and with alcoholic spray of the tested fragrances were tested instrumentally.

## 2. Materials and methods

### 2.1. Materials

**2.1.1. Fragrances**. Two fragrances were developed for this experiment: fruity and green, based on the fragrance family descriptors given by Chrichill *et al* (2009).

**2.1.2. Treatments.** A leave-in conditioner base (CB) was formulated, to which Bis-Diisopropanolamino-PG-propyl Dimethicone/Bis-Isobutyl PEG-14 Copolymer (amino-glycol-silicone block copolymer - AGSC) was added for enhanced slipperiness, smoothness and fragrance release. Alcoholic solutions of the fragrances were prepared, containing 15%w/w fragrance and 85%w/w denatured alcohol. The conditioning formulations and all treatment variables are listed in Tables 1&2.

**2.1.3. Test substrate.** Caucasian hair tresses with the length of 30cm and the weight of 3.5g were used in all tests (Banbury Postiche, UK). To amplify the effect of the leave-in conditioner, all tresses were pre-bleached using a commercial powder bleach and developer containing $H_2O_2$, 30vol. (Salon Services, UK).

**Table 1**. Leave-in conditioner formulations: conditioning base (Cond Base), conditioning base with 2% amino glycol silicone copolymer (AGSP Cond), conditioning base with 2% amino glycol silicone copolymer and floral and green fragrance, respectively (AGSP Cond + F and AGSP Cond + G)

| | ***INCI Name*** | ***Cond Base*** | ***AGSP Cond*** | ***AGSP Cond + F*** | ***AGSP Cond+ G*** |
|---|---|---|---|---|---|
| | | % w/w(g) | | | |
| A | Sodium Polyacrylate (and) Dimethicone (and) Cyclosiloxane (and) Trideceth-6 (and) PEG/PPG-18/18 Dimethicone | 2 | 2 | 2 | 2 |
| | Dimethicone | 7 | 7 | 7 | 7 |
| | Dimethicone (and) Dimethiconol | 3 | 3 | 3 | 3 |
| B | Deionized water | 82.5 | 80.5 | 78.5 | 78.5 |
| | 1,3-Butylene Glycol | 5 | 5 | 5 | 5 |
| C | **Bis-Diisopropanolamino-PG-propyl Dimethicone/Bis-Isobutyl PEG-14 Copolymer (AGSP)** | **-** | **2** | **2** | **2** |
| | Phenoxyethanol (and) Ethylhexylglycerin | 0.5 | 0.5 | 0.5 | 0.5 |
| | Fruity fragrance | - | - | 2.0 | - |
| | Green fragrance | - | - | - | 2.0 |

### 2.2. Methods

**2.2.1Treatment application (leave-in conditioners*).*** Each dry hair tress was placed on aluminium foil. 1g of conditioning treatment per 5g of hair was used. The products were dosed using hypodermic sterile syringes and applied evenly along the length of a tress. The tress was then combed 5 times using a wide-tooth comb and massaged through both sides for 30 seconds manually using gloved fingers. The tress was rested on the foil for 3 minutes and then gently blow-dried for 3 minutes, using cold air setting, in order to acquire assembly reflecting that of a moving head of hair.

**Table 2**. List of all hair treatments used for sensory evaluation

| Type of Treatments | Description |
|---|---|
| Treatment 1 | Cond Base |
| Treatment 2 | AGSP Cond |
| Treatment 3 | AGSP Cond + F (fruity fragrance) |
| Treatment 4 | AGSP Cond + G (green fragrance) |
| Treatment 5 | F (fruity fragrance) + 85% ethanol |
| Treatment 6 | G (green fragrance) + 85% ethanol |

**2.2.2. Design of the discrimination test.** The discrimination test was deemed most appropriate as a start, since it is simple and minimises sensory fatigue and carry-over effect throughout the sensory evaluation process. The aim was to assess the cross-modal association between odour and what was technically identical tactile conditioning effect delivered by the selected active copolymer. Each fragrance was tested via a separate test, following the same protocol. Each participant was presented with one of the four possible pairs of treated hair at the time: a pair of hair tresses treated with the identical unfragranced AGSC conditioner; a pair of hair tresses treated with identical fragranced AGSC conditioner; a pair of hair tresses of which one treated with fragranced and one treated with unfragranced conditioner; all pairs were presented in alternating order to different participants. For each fragrance, the total number of matched pairs (10) was almost equal to the total number of different pairs (11). After touching the presented pair of tresses, each participant had to report if they were the same or different in terms of their degree of conditioning.

**2.2.3. Design of the attribute test.** An attribute test was also performed but on a different day. The aim was to investigate the cross-modal effect between olfaction and tactile characteristics **smoothness, softness and ease of combing** of hair. A ten-point scale was used, with the following anchors: 0 = *drags, coarse and difficult to comb* and 10 = *smooth, soft and easy to comb.* The test followed the within-participants repeated design, with two factors: fragrance (fruity/green) and presence of AGSP. The test consisted of four blocks of 36 trials (three trials per condition) and lasted for

approximately 40 minutes per person. To avoid the same fragrance or the same hair tress being presented on consecutive trials, the presentation of the four treatments were randomised (Demattè *et al*, 2006b), 2006). Randomisation also minimised the systemic carry-over and order effects. Each hair tress was presented 30 seconds after the previous one to minimise possible carryover effect and to prevent testing fatigue (Kemp, Hollowood and Hort, 2009).

**Figure 1(a**): Participant evaluating the tactile properties (Smoothness, Softness and Ease of Combing) of hair tresses

**Figure 1(b**): Participant evaluating the scent of hair tresses treated with fragranced conditioners

**2.2.4. Data analysis.** SPSS (IBM, USA) was used to process all data obtained from the instrumental and sensory tests and results with 95% confidence level, ($\alpha$= 0.05) have been reported.

Instrumental combing data. The instrumental combing data per tress/treatment was expressed as the mean force of the five combing strokes ±SD. Paired t-test was performed to compare the means of the combing force and the work of combing for each tress, before and after a treatment.

Discrimination test. Chi-square tests was performed to determine the association between the types of treatment pairs presented to the participants and the responses given.

Attribute test. The data obtained from the attribute test on a rating scale of 0 to 10 was expressed as means ±SD. One-way between-groups ANOVA and Tukey HSD test were employed (as appropriate).

## 3. Results

### 3.1. Mean combing force (N) of bleached hair vs respective treatments

There were no significant difference in the mean combing force between a bleached hair tress before and after the respective leave-in conditioner treatments (base conditioner, and the AGSP Cond with and without respective fragrances), as evident from Table 3. The exception was the treatment including green fragrance (treatment 4), which was borderline significant (p=0.047). Therefore, a separate investigation into the effect of fragrance ingredients could be carried out to identify the source of such effect. Both alcoholic solutions (treatments 5 and 6) significantly increased the mean combing force.

**Table 3.** Mean combing force (N) of bleached hair vs respective treatments using multiple paired samples t-tests.

| | **Cond Base** | **AGSP Cond** | **AGSP Cond + fruity fragrance** | **AGSP Cond + green fragrance** | **fruity fragrance + 85% ethanol** | **green fragrance+ 85% ethanol** |
|---|---|---|---|---|---|---|
| **Combing force (N)** | 0.08 ±0.02 | 0.11 ±0,04 | 0.14±0.08 | 0.014±0.04 | 0.015±0.06 | 0.15±0.06 |
| **Combing force (N) after conditioning** | 0.09 ±0.01 | 0.08±0.002 | 0.08±0.002 | 0.09±0.005 | 0.23±0.01 | 0.23±0.01 |
| **p value (two-tailed0** | 0.53 | 0.59 | 0.16 | 0.047* | 0.02* | 0.04* |

* indicates significant difference at 5% level

### 3.2. Discrimination test results

The Chi-Square test confirmed the presence of significant difference between the types of the presented treatment pairs and the responses of the participants. Therefore, for each type of fragrance, the tresses treated with a fragranced conditioner were perceived as being different from the ones treated with non-fragranced conditioner.

**Table 4**. Number of responses given to the presentation of the respective matched and unmatched pairs.

| | **Matched pair: The same** | **Matched pair: Different** | **Unmatched pairs The same** | **Unmatched pairs Different** |
|---|---|---|---|---|
| **AGSP Cond+ fruity** | 8 | 2 | 2 | 9 |
| **AGSP Cond + green** | 8 | 2 | 1 | 10 |

### 3.3 Attribute Test Results

There was a statistically significant difference in the rating of smoothness between the hair treated with a fragranced conditioner and the hair treated with the conditioner base alone (Fig. 2a). For softness, only the fruity fragrance led to statistically significant result. The conditioner containing the AGSP alone, was not rated higher than the base (Fig. 2b). The differences between the products in terms of the combing ease were not statistically significant.

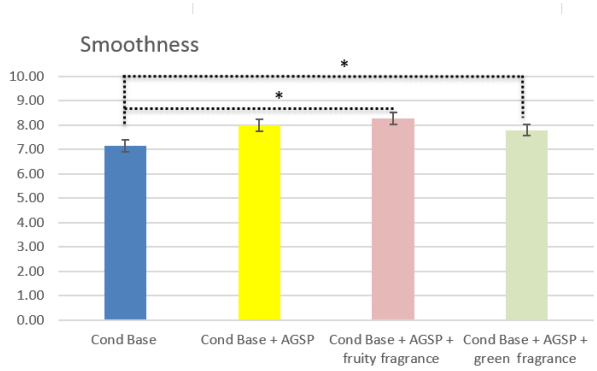


**Figure 2a**: Smoothness rating results

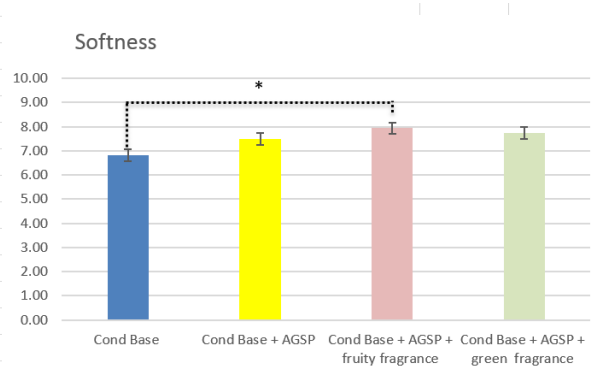


**Figure 2b**: Softness rating results

## 4. Discussion

The instrumental combing test suggests that the application of the leave-in conditioning treatment did not improve substantially the mean dry combing force for lightly bleached hair. The result can be explained by the moderate damage to the cuticle after one bleaching procedure, which is mostly manifested in wet state, but is undetectable after the water swelling is removed following blow drying. This hypothesis is supported by Evans (2013) who concluded that dry combing force, normally lower than wet combing, is less sensitive to the differences in the efficacy of treatments. However, the sprayed-on alcoholic solutions elicited higher combing force which suggests that they caused some cuticle swelling.

Previous studies have demonstrated that the choice of odours can indirectly elicit a more favourable perception of product quality, also known as a halo effect (Milotic 2004; Li *et al*. 2007). The discrimination tests confirmed this phenomena as the participants perceived the tresses conditioned with fragranced leave-on conditioner as different from those treated with the non-fragranced conditioner, although the conditioning effect and fragrance type used constitute independent technical product

attributes. Furthermore, in the attribute tests, the AGSP-fruity leave-on conditioner obtained statistically significant higher ratings than the conditioning base for both smoothness and softness, whist the un-fragranced AGSP product did not. This result infers an association of fruity fragrances with positive tactile characteristics of hair. AGSP-green leave-on conditioner also received statistically higher scores in comparison with the conditioner base for smoothness, but not for softness, although the base formulation was the same as that with fruity fragrance.

The combined results for smoothness and softness infer a stronger cross-modal association effect for the odours and the tactile attribute of smoothness. The inclusion of silicone-containing copolymer as a technical differentiator between the conditioner base and the fragranced treatments has an amplifying effect on the cross-modal associations of the fragranced products, as it imparts low inter-fibre friction and slipperiness. On the other hand, the attribute “softness” corresponds to properties such as fibre stiffness, hence it is less influenced by the presence of silicone active in the product. Thus, it is suggested that the cross-modal effect between odour and the attribute of softness was weaker and, effectively, insignificant for the green fragrance.

The cross-modal effects demonstrated in this study could be attributed to the associative memory of cosmetic and hair care products, and particularly to the exposure to fruity odours. Interestingly, hedonic preference is unlikely to be a contributing factor, as in a short separate test 71% of 21 volunteers preferred the green fragrance over the fruity.

The subjective evaluation for combing ease did not distinguish between different treatments, which is in agreement with the instrumental combing results (Table 3). One explanation for the lack of cross-modal effect is the overall lack of hair tangling due to the presence of silicone active, which influenced most powerfully the subjective assessment. However, learnt associations between odours and combing are perhaps less common than those of fruity odours and tactile experiences in general.

A study conducted by Mitchell *et al*. (1995) reported that when the consumers were exposed to a scent perceived to be congruent with the product class (in this case hair leave-in conditioner), they tended to spend more time processing the information and developing inferences that turn into decisions on the efficacy of the products or purchase decisions. Meanwhile, incongruent scents led to cognitive interference that

evoked irrelevant information in the consumer's memory, which impeded their decisions. In this study the fruity fragrance represented the highest level of congruency, thus higher attribute ratings were given in comparison with the green fragrance, regardless of the otherwise identical formulation.

## 5. Conclusion

This project aimed to assess the cross-modal effect of two distinct categories of fragrance, fruity (fruity/floral) and green (fresh/green) on the sensory perception of hair leave-in conditioner, in addition to the effect of the amino glycol silicone copolymer (AGSP) known for its conditioning performance.

Cross-modal associations were found between the fruity odour and the sensory properties softness and smoothness. The halo effect of fragrance was also demonstrated, which supported the cross-modal data. Furthermore, the results imply that the inclusion of an active ingredient for hair tactile enhancement (in this case amino glycol silicone copolymer) may not lead to enhanced differentiation of the product, unless the fragrance congruent with the desired sensory association is present. Indeed, such an ingredient in combination with a suitable odour would achieve a stronger cross-modal association and product differentiation.

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