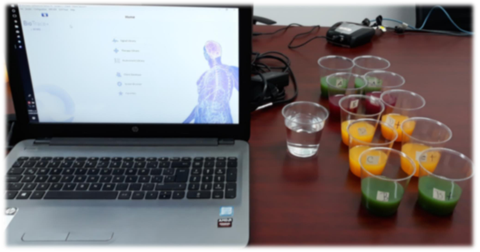

Neurophysiological KPIs for flavor and fragrance appraisal

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ABSTRACT

TITLE:
Neurophysiological KPIs for flavor and fragrance appraisal

BACKGROUND:
The most critical part in the flavor and fragrance development pipeline is the evaluation of formula candidates by actual untrained subjects. This procedure face the challenge of collecting data accurate enough to decide which formula must undergo production. The accuracy and sometimes reliability of this untrained subjects represent a constant doubt to the current procedure due to the subjectivity and inconsistencies inherent to the data collection instruments, based in self-report and declarative scales.

OBJECTIVE:
Offer a methodology sound enough to establish quantitative, numerical, and comprehensive key performance indicators (KPIs) to appraise flavor and fragrance formulas based on the actual interaction of subject's neurophysiology in a controlled exposition protocol.

METHODS:
We integrated three already accepted and highly replicable methodologies to compare neurophysiological states triggered by sensorial stimuli in order to isolate activity attributable to said stimulation away from idiosyncratic activity. The standardization of the method offer a novel and reliable tool to reduce product development pipeline and support with quantitative data the selection of the most feasible formula candidate for production.

RESULTS:
After several repeated studies we found that the combination of the following variables represent a reliable source of information to support the validation of formula candidates: attentional response, active-executive response, and emotional valence. Candidates that outperform competing formulas in each of this neurophysiological KPI's are better in –respectively- sensorial distinction, volitional approach, and overall liking.

CONCLUSIONS:
The use of neurophysiological KPIs offer a reliable, cost-effective and scientifically valid approach to collect and compare the response of untrained subjects to new flavor and fragrances, with the chance of not only avoiding the bias inherent of declarative instruments, but also to quantify this biases when comparing neurophysiological data with declarative responses. This last aspect, offer a whole new opportunity to demonstrate the effect that blinding, open label, branding and priming has (or not) in the sensorial appraisal of formulas.

BACKGROUND

The development pipeline of a new flavor and fragrance (F&F) formula is a systematic endeavor involving a series of steps characterized by a cumulation of dexterous chemistry, sensitive judge and visionary planning. In the processes encompassed, one of the most critical is the evaluation of formula candidates by actual untrained subjects. While preliminary steps involve the participation of lengthily trained and experienced judges to select candidates, the final decision prior to production usually involves the phase known as "customer test", which comprises the presentation of the formulas to untrained research participants representing the actual final consumer. To date, the most common tools for collecting data from these participants are based in self-report evaluation and hedonistic scales. This data collection tools face at least two inherent weakness that contrast with the rest of the F&F development meticulousness: vague reporting and biased grading. While efforts exists to correct this problem, there is no consensus of the best practices to nullify or at least reducing vagueness of results, as well as response bias.

OBJECTIVE

Offer a methodology sound enough to establish quantitative, numerical, and comprehensive key performance indicators (KPIs) to appraise flavor and fragrance formulas based on the actual interaction of subject's neurophysiology in a controlled exposition protocol.

METHODS

Our approach comprise the use of three different methods which operational convenience as well as their sensibility and specificity are well studied by the scientific community and which supportive fundamentals are available elsewhere:

- Electroencephalographic global field power (EEG GFP)

  A way to analyze electrical brain activity in order to compare two different states[1] at the sequence absence-presence-absence (ABA) of a sensorial stimulus, in order to statistically compare the changes in conscience micro-states[2,3]. It is much more suitable for dynamic scenarios where experimental subjects perform executional tasks than methods based on bandwidth frequency analysis, as the later is highly sensible to muscular artifacts and circadian rhythms[4]. Results are coded in a change or no-change state for the attentional and premotor microstates.

- Blood volume pulse (BVP) heart rate variability and vascular tone

  The peripherical vascular system offers a direct correlate of affective states in healthy subjects[5], thus, with a classificatory analysis of vascular tone[6] and hear rate variability[7], it is possible to compute emotional valence and arousal from the dimensional theory of emotion.

- Implicit association test (IAT)

  While the classic IAT is based in sole time-response paradigms[8], the combination of the test with time-locked neural correlates such as electrical coherence[9] offer a better way to classify the responses with an association index. Comparing said index with declarative rational responses, it is possible to calculate a numerical value of the actual conscious bias through linear regression.

For the F&F industry we have developed two data collection settings. **Picture to the left**, the implementation of a BVP system for ten simultaneous subjects at a traditional taste test group session. This allows the systematic comparison of declarative scales with the physiological emotional score. **Picture to the right**, a full montage for simultaneous EEG GFP and BVP collection in an ABA paradigm, followed by an IAT trial to associate the immediate sensorial experience to standardized claims, pictures or concepts. In this document we will share results of a study following this later setting.

Standardized protocol for collecting neurophysiological data to obtain metrics for the sensorial experience of an individual subject. The sequence is repeated for every target stimulus of interest.

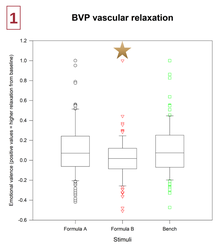
1. Baseline
   - Exposition to neutral stimulus in standardized task and timeframe
   - Collection of EEG and BVP activity
2. Stimulus exposition
   - Presentation of target stimulus in standardized task and timeframe
   - Collection of EEG and BVP activity
3. Post-exposition residual state
   - Exposition to neutral stimulus in standardized task and timeframe
   - Collection of EEG and BVP activity
4. Experience evaluation
   - Presentation of IAT training items followed by target items in standardized task and timeframe sequence
   - Collection of EEG activity and manual trigger button
5. Desaturation phase
   - A period for desaturation from stimulation is placed in-between repeated measurements.

RESULTS

This study design delivers six KPIs (number identifies graphs):

1. Emotional valence.- variation ratio of BVP vascular tone
2. Emotional arousal.- variation ratio of BVP heart rate variability
3. Emotional response and characterization.- horizontal axis represents valence and vertical axis represents arousal from indicators 1 and 2
4. Attentional response.- proportion of subjects that present a GFP attentional change
5. Ejective action response.- proportion of subjects that present a GFP premotor change
6. Spontaneous association.- proportion of subjects that consider true the claim after correcting bias detected from IAT linear regression

1



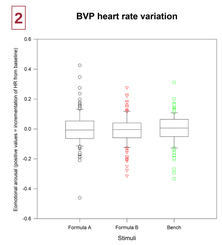
Friedman Repeated Measures Analysis of Variance on Ranks
Dependent Variable: Valence

Group	N	Missing	Median	25%	75%
Formula A	126	0	0.0714	-0.0619	0.243
Formula B	126	0	0.0182	-0.0856	0.121
Bench	126	0	0.0746	-0.0700	0.252

Chi-square= 19.811 with 2 degrees of freedom. (P = <0.001)
Multiple Comparisons versus Control Group (Dunn's Method) :

Comparison	Diff of Ranks	Q	P<0.05	
Formula B vs Bench	0.468	3.717	Yes	
Formula A vs Bench	0.0278	0.220	No	

2

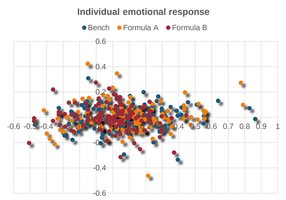


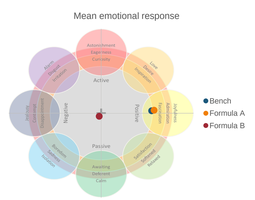
Friedman Repeated Measures Analysis of Variance on Ranks
Dependent Variable: Arousal

Group	N	Missing	Median	25%	75%
Formula A	126	0	-0.00710	-0.0645	0.0536
Formula B	126	0	-0.00413	-0.0591	0.0402
Bench	126	0	0.00631	-0.0513	0.0643

Chi-square= 1.190 with 2 degrees of freedom. (P = 0.551)

3





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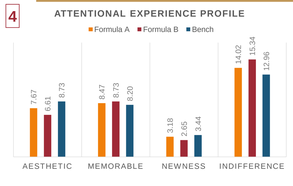


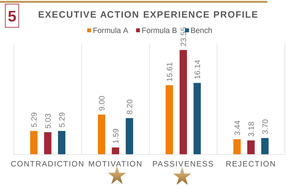
Chi-square

Subjects	Formula A	Formula B	Bench	
Aesthetic	29.000	25.000	33.000	Counts
	7.672	6.614	8.730	Total %
Memorable	32.000	33.000	31.000	Counts
	8.466	8.730	8.201	Total %
Newness	12.000	10.000	13.000	Counts
	3.175	2.646	3.439	Total %
Indifference	53.000	58.000	49.000	Counts
	14.021	15.344	12.963	Total %

Chi-square= 2.328 with 6 degrees of freedom. (P = 0.887)
The proportions of observations in different columns of the contingency table do not vary from row to row. The two characteristics that define the contingency table are not significantly related. (P = 0.887)

Power of performed test with alpha = 0.050: 0.162

5



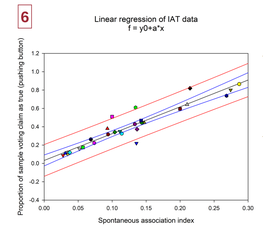
Chi-square

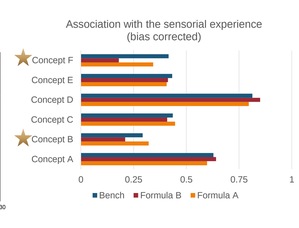
Subjects	Formula A	Formula B	Bench	
Contradiction				
	20.000	19.000	20.000	Counts
	5.291	5.026	5.291	Total %
Motivation	34.000	6.000	31.000	Counts
	8.995	1.587	8.201	Total %
Passiveness	59.000	89.000	61.000	Counts
	15.608	23.545	16.138	Total %
Rejection	13.000	12.000	14.000	Counts
	3.439	3.175	3.704	Total %

Chi-square= 28.236 with 6 degrees of freedom. (P = <0.001)
The proportions of observations in different columns of the contingency table vary from row to row. The two characteristics that define the contingency table are significantly related. (P = <0.001)

Power of performed test with alpha = 0.050: 0.993

6





Linear Regression
Declared = 0.0324 + (2.924 * Association)
N = 28
R = 0.943 Rsqr = 0.889 Adj Rsqr = 0.885
Standard Error of Estimate = 0.079

	Coefficient	Std. Error	t	P
Constant	0.0324	0.0292	1.110	0.277
Association	2.924	0.203	14.439	<0.001

Analysis of Variance:

	DF	SS	MS	F	P
Regression	1	1.306	1.306	208.477	<0.001
Residual	26	0.163	0.00626		
Total	27	1.469	0.0544		

Normality Test (Shapiro-Wilk) Failed (P = <0.001)
Constant Variance Test: Passed (P = 0.986)
Power of performed test with alpha = 0.050: 1.000

Friedman Repeated Measures Analysis of Variance on Ranks
Dependent Variable: Concept B

Group	N	Missing	Median	25%	75%
Formula A	126	0	0.0214	0.0214	0.585
Formula B	126	0	0.0214	0.0214	0.0214
Bench	126	0	0.0214	0.0214	0.563

Chi-square= 9.598 with 2 degrees of freedom. (P = 0.008)
Multiple Comparisons versus Control Group (Dunn's Method) :

Comparison	Diff of Ranks	Q	P<0.05	
Formula B vs Bench	0.210	1.669	No	
Formula A vs Bench	0.0317	0.252	Do Not Test	

NOTE: Only test for Concept B is shown. Request annex for Repeated Measurements Analysis of variance for each concept evaluated, and Two Way ANOVA for comparing repeated measurements Formula x Concept.

This results are from a study where we tested three different liquid food formulas in 126 female participants in a factorized sequence. After breaking the blind, formulas were recoded as Bench (an actual leader product in market), and the two candidates as Formula A and Formula B. The goal of the study was to meet parity with bench. Candidate formulas were previously tested in a quantitative study (n=1200) where both met a draw, without significant differences. The study was requested to determine a winner between both. Star (★) identifies significant differences.

CONCLUSIONS

The use of neurophysiological KPIs offer a novel, reliable and trustworthy method to isolate the sensorial experience in components impossible to appraise subjectively, especially those linked to the very primary sensation elicited by stimuli. The possibility to combine declarative responses with IAT provide a further advantage as the neurophysiological data can be cross-referenced with declared perception, so further analysis such as logistical regression become of interest. The herein data used as sample study can be used to determine the following conclusions, solely based on the statistical tests, without further subjective or interpretative intervention:

- Formula A is the most suitable candidate as it meets parity with Bench in emotional valence, attentional experience, executive action experience as well as meeting the six experience claims in similar levels.
- Formula B performs under the Bench in the following indicators: emotional valance, motivation (within ejective action), Concept B ad Concept F (within spontaneous association).

Key methodology references:

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