

Supplementary file: Variations in cigarette brand characteristics: can consumers tell the difference?

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1.1 Tobacco document review

Initial searches were conducted pairing terms identifying sensory testing (sensory panel, sensory evaluation, consumer panel, expert panel, monadic, sequential, paired comparison, triangle test) and/or measures of discrimination (difference, detection, discrimination, threshold, noticeable, discernable, recognizable/recognition, JND (just noticeable difference)) with physical product characteristics (filter ventilation, air dilution, pressure drop, draw resistance, RTD, tobacco weight, density, filter length, cigarette length, circumference, blend, reconstituted tobacco, expanded tobacco). For example, a search conducted on ("paired comparison" AND discrimination AND "filter ventilation") yielded 104 document results. In cases where the number of identified documents exceeded 300, only the first 300 results of the search were reviewed. After identification and preliminary review of the initial set of documents, follow-up searches were conducted based on projects, researchers, and terms considered relevant to the study aims. For example, POL (Product Opinion Lab) and HTI (Home Testing Institute) were identified as primarily responsible for consumer sensory discrimination testing for Philip Morris.

More than 6,000 documents were reviewed by at least one reviewer (GFW), from which a collection of 195 documents were identified as directly relevant to the research aims. Relevance was judged against the following criteria: 1) identification of discrimination thresholds for specific physical product characteristics, 2) sensory/discrimination comparisons of products with differences in one or more physical characteristics, or 3) internal discussion of recognizable differences among products. Two reviewers (GFW, CP) independently assessed relevant documents and extracted information on recognizable product differences and discrimination thresholds (Supplementary Table 1). Category thresholds were identified by weight of evidence across studies, defined the measure or range of measures above which most studies reported significant difference, and below which they reported no significant difference. Discrepancies were resolved through discussion and/or application to other team members. Evaluation included consistency of evidence across

documents, manufacturers and time periods, strength and transparency of study design, reliability of evidence, and potential limitations.

1.2 Product data analysis

Products were filtered in a stepwise fashion to 1) cigarettes, 2) the most recent submission per product ID, 3) excluding products listed as no longer active in the Dutch market. The resulting list was checked manually to remove 4) redundant products, for example due to different batches; in such cases only the most recent submission was used. Finally, 5) products that were not, or no longer, available on the Dutch market (including web shops) were excluded. Because the European ban on cigarettes with a menthol characterizing flavor¹ had not yet taken effect at the time the analyses were conducted, such products were not excluded.

For the remaining products, we analyzed data for 59 parameters regarding physical measures (size, weight), filter ventilation, and the closely related tar, nicotine and carbon monoxide (TNCO) emissions as measured with the ISO smoking protocol,² tobacco blend, and the number of additives per product part (e.g., tobacco, filter, paper) and per function (e.g., humectant, flavor). A list of all parameters can be found in Supplementary Table 2. Statistical analyses were performed in R versions 4.0.0 or later, or in Microsoft Excel.

For each parameter, we determined summary statistics such as minimum, maximum and average. Using analysis of variance (ANOVA), we determined for each parameter the total variation and extent to which this could be attributed to within-brand variation. If this was more than 45% and at least three brands showed within-brand variation, we considered that *within*-brand variations played a large role in explaining total market variation with regard to manufacturers and/or consumers. On the other hand, if it was less than 20%, we considered the role of brand variations as small because product varieties were mainly attributable to variation *between* brands.

For determining the influence of product parameters on nicotine emissions, we used linear regression to model nicotine as a function of one or more parameters. Model predictions were compared using five-fold cross validation. The most parsimonious model, based on the Akaike information criterion, was chosen.

To assess mutual dependencies between product parameters, we determined Spearman correlations. For multivariate comparisons of product data between brands and brand varieties, we visualized data by Principal Component Analysis (PCA) and identified product type clusters. Next, we set out to reduce the number of parameters for a visualization that captured the results of the industry document and EU-CEG analyses, while allowing for a more intuitive interpretation of the data, similar to the visualization approach by Jaffe.³ This was done by prioritizing parameters with high PCA variable loadings and selecting from sets of well-correlated parameters the parameter with the most evidence based on the industry data analysis. As part of this approach, a percentage flue-cured parameter was calculated as $100 * \text{Flue-} / (\text{Flue-} + \text{Air-} + \text{Fire-} + \text{Sun-cured})$. Discrimination threshold values based on industry documents were used to draw grids. For tobacco blend, no clear threshold emerged from the industry documents and therefore the largest non-detectable difference was used.

1.3 Internal tobacco industry documents data

Perceptual/sensory comparisons of tobacco products range from informal expert panels to large-scale consumer studies and may include a single scaled preference (thermometer, or “liking” measure) and/or more specific and sensitive sensory attributes such as strength, harshness, and taste.⁴ Common study designs include monadic tests, in which a single product is evaluated; paired comparisons, in which a control and test product are assessed together; and triangle tests, in which the smoker evaluates three products, of which two are the same.⁵ Products which are rated equally in terms of preference, even across a wide range of sensory measures, may nonetheless be perceived as substantially different by smokers. The focus of the present study was on measures of discrimination, such as whether a reduction in tobacco weight could be implemented without detection by product users⁶ or to define quality control limits in product manufacture.^{4,7} Relevant studies relied on factorial analysis of data collected across multiple product tests, as well as direct product comparisons.

References

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