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

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ABSTRACT

Objectives Sensory experience is an important determinant of smoking initiation, brand choice and harm perception, but little is known about how cigarette design shapes sensory experience. This study reports which variations in tobacco blend and design characteristics available on the market are likely to be perceived as different by consumers.

Methods Truth Tobacco Industry Documents was reviewed for studies showing noticeable sensory differences resulting from variations in tobacco blend and design characteristics. These differences were compared with tobacco product data as available in the Dutch section of the European Common Entry Gate (EU-CEG) system on 30 April 2020.

Results Industry documents identified discrimination thresholds for ventilation, pressure drop, tobacco weight, filter length, and tar and nicotine levels in smoke while evidence for other design characteristics was less conclusive. In the 103 different cigarette varieties in the EU-CEG database, five main types of cigarettes could be identified by principal component analysis, differing in (combinations of) design characteristics. The most significant differences between brand varieties were tar, nicotine and carbon monoxide emissions and associated parameters filter ventilation, filter length, cigarette length and tobacco weight.

Conclusions While some clusters of brand varieties provided a noticeably different product for consumers, in many cases design differences within these clusters did not exceed the expected discrimination threshold. This indicates that many products on the market are not discernibly different for consumers, and that proliferation of brand varieties has a non-sensory purpose, such as marketing. Policy makers should consider limiting available brand varieties and regulating design characteristics to reduce product appeal.

INTRODUCTION

The sensory experience of smoking plays an important role in smoking initiation, brand choice and harm perception of cigarette brands.[1 2] Therefore, the tobacco industry devotes considerable resources to sensory evaluation of their products.[3] Trained panellists or consumers describe their sensory experience, test whether they can discriminate products or score products on hedonic properties such as liking. Internal tobacco industry documents show that product appeal and inhalation intensity are mainly determined by the harshness-smoothness balance, non-irritant sensory responses such as taste and satisfaction, and resistance to draw (RTD).[4]

The modern cigarette market supplies many brands and types differing in their design characteristics. Variations in tobacco type, additives and physical design characteristics, most notably filter ventilation, determine smoke sensory perception.[2 4 5] It is well known that tobacco additives, especially flavours, increase appeal and inhalation intensity, and therefore flavours or flavourings are regulated in some jurisdictions.[6 7] For example, subjective ratings associated with taste and smell are significantly higher for menthol cigarettes,[8] and perceived 'strength of menthol taste' and 'cooling' effect are dose dependent on the menthol level.[9] Filter ventilation has also been well studied. For consumers, higher degrees of filter ventilation lead to a lighter tasting, and milder and less irritating smoke.[5 10–12] Relatively few peer-reviewed studies have been published on the sensory effects of variations in other cigarette design characteristics. With limited exceptions, it is not known which differences can be discriminated.

While smokers could make distinctions between different types of cigarettes, they were generally not able to choose their own brand among others.[13] Brands with higher nicotine yields could be distinguished from brands with lower yields, and flat-tasting cigarettes from sharp-tasting cigarettes. Although these differences were not explained in terms of design characteristics, two brands in the flat-low nicotine range were 'lights', meaning they were probably high-ventilation cigarettes. Moreover, cigarettes with different nicotine yields could be discriminated, but nicotine was not the only factor determining sensory intensity and taste.[14] Finally, harshness of smoke was higher in the dark tobacco category and generally decreased with the lower smoke yield cigarettes.[15]

Given the large variety of products available on the market, the question arises which variations in cigarette design characteristics can actually be perceived as different by consumers. The current paper addresses this question using commercially available brands on the Dutch market as a case. Industry documents were reviewed for studies showing noticeable sensory differences resulting from variations in tobacco blend and design characteristics. These differences were compared with data on tobacco blend and design characteristics sent to the Dutch authorities via the European Common Entry Gate (EU-CEG).[16] Our findings will inform regulators on the most prominent design characteristics that influence consumer sensory perception of cigarette smoke, and their prevalence on the Dutch market. Regulators can compare the noticeable

sensory differences identified in the industry documents, which apply to all markets, to design characteristic data in their own national markets.

METHODS

Tobacco document review

Iterative keyword-based document searches were conducted online between 1 October and 15 December 2020 in the Truth Tobacco Industry Documents archive hosted at the University of California-San Francisco.[17] Further details can be found in the online supplemental file.

Product data analysis

For analyses of EU-CEG cigarette data, we used tobacco product data as available in the Dutch section of the EU-CEG system[16] on 30 April 2020. Further details can be found in the online supplemental file.

To assess mutual dependencies between product parameters, we determined Spearman correlations. For multivariate comparisons of product data between brands and brand varieties, we visualised data by principal component analysis (PCA) and identified product-type clusters. 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.

Filter ventilation control measurements

To independently evaluate the accuracy of the data in the EU-CEG database, the filter length, filter pressure drop (PD) open and closed and the filter ventilation were measured in 56 different cigarette brand varieties. Filter PD and filter ventilation were measured according to International Organization for Standardization (ISO) 6565 and ISO 9512, respectively.[18 19]

RESULTS

Internal tobacco industry document data

A total of 81 studies describing a discrimination threshold of noticeable sensory differences were identified. A description of the types of studies used by manufacturers to compare differences in perception across products is provided in the online supplemental files 1–3. A summary of these findings, organised by physical design parameters, is provided in table 1. A more detailed description of individual documents, including references, is provided in online supplemental table 1. Table 1 presents a potential threshold range for discrimination for each product characteristic. It should be noted that the evidence indicates linear rather than categorical differences, with no single distinct tipping point with respect to discrimination.[20] Further, measures of discrimination may differ with respect to individuals and between populations of smokers (eg, full flavour vs low tar).[21] Interactions among some physical product characteristics (eg, ventilation and PD) are inherent; however, the studies included were those that attempted to control for interactions and/or limited product differences to support comparisons of specific design characteristics.

Twenty-five studies were identified that evaluated the discrimination of products that differed on the basis of ventilation (ie, per cent of smoke diluted with air due to the addition of holes in the filter). The studies were evenly distributed across expert and consumer panels, and the majority were paired comparisons, although four studies were dependent on factorial analyses applied to a series of separate monadic assessments. Findings were strongly consistent across studies, with ventilation differences of less than 10% generally not identified by smokers, and differences of 12% or greater perceived as significantly different. This pattern held across all levels of ventilation tested, although most tests were between 0% and 50% ventilation. A 1983 British American Tobacco study estimating effect sizes of ventilation changes independent of other product variables indicates a detection threshold between 10% and 12%.[22] An exception, a 2000 RJ Reynolds Tobacco expert panel study, identified significant perceptual differences at ventilation increments below 10% reflecting a perceived change in draw characteristics,[23] underscoring the potential interactions between perceptions of ventilation and draw.

While fewer studies (13) of PD (also called RTD) were identified, most were well designed and made an effort to isolate the potential impact of other design variables. Reported values here are closed PD normalised to millimetres (usually reported as mmWg), similar findings were presented for other PD measures. Threshold for discrimination was around 15–20 mm, where differences less than 15 mm were unidentifiable by smokers, and differences larger than 20 mm were identified in many (but not all) cases. Most products were in the range of 100–140 mm PD, indicating a difference of more than 10%–15%, which was consistent across the range of products tested. Studies indicated that behavioural differences (ie, changes to puff topography)

Table 1 Summary of evidence from industry data for discrimination threshold of noticeable sensory differences

Category	Threshold for discrimination	Evidence	Studies	Type of studies	Test panels
Ventilation	10%–12% difference	Strong, consistent	25	PC, MC	CP, EP
Pressure drop*	15–20 mm difference (10%–15%)	Strong, consistent	13	PC, MC	CP, EP
Tobacco weight	40–60 mg difference (6%–8% of tobacco weight)	Good, consistent	10	FA	CP, EP, AP
Cigarette length	1–2 mm difference (2%)	Limited	3	IM	AP
Filter length	1–3.5 mm difference (10%–15%)	Good, consistent	9	PC, MC, TD, R	CP, EP
Circumference	≤1 mm diameter change (4% difference)	Limited	4	MC, R, FA, IM	CP, EP, MI
Density	13 mg/cm^3	(Very) limited	2	MC, FA	EP
Tobacco blend	≤10% change in blend components	Moderate, not consistent	15	PC, MC, TD, R, FA	CP, EP

*Closed PD, whole cigarette. Evidence descriptor (strong/good/moderate/limited) weights number of studies by strength of study design and reliability; consistency indicates agreement among studies (>5 only).
AP, ad hoc panel; CP, consumer panel; EP, expert panel; FA, factorial analysis; IM, implementation; MC, monadic comparison; MI, mall interview; PC, paired comparison; PD, pressure drop; R, review (multiple studies); TD, triangle discrimination.

were also measurable in response to PD changes and occurred in the same general range as sensory differences.

Studies of tobacco weight differences (10) were primarily conducted among expert panellists and included both monadic and paired comparisons. Tobacco weights generally ranged from 650 to 850 mg, with one study comparing products of 850–1050 mg. While most product discrimination occurred above 50 mg differences, discrimination outcomes were not consistent for differences in the 30–50 mg range. A monadic-based factorial analysis concluded that 6% weight reduction was not discriminable.[24] Other studies indicate a threshold between 4% and 8%.

Studies of product dimensions including cigarette length and circumference focused on small (ie, visually imperceptible) differences, in the order of 1%–2%, such as differences of 1–2 mm length (in a 100 mm cigarette), and 0.2–0.3 mm differences in a 25 mm circumference. In all cases, these differences were below detection threshold, and more sizeable differences were not assessed. Filter length was considered on a wider scale, primarily as a cost reduction measure.[25 26] Differences from 1 to 3.5 mm were evaluated across consumer studies in products with filter lengths from 13 to 31 mm (ie, in the range of 10%–15% difference). In nearly all cases, differences were not identifiable by smokers. In two exceptions, a 2 mm difference in filter length resulted in a small but measurable difference in taste perception, although preference remained unchanged.[27 28]

While a large number of studies (16) were identified on tobacco blend, product changes tended to include a range of blend characteristics, complicating interpretation of findings. Consistently, however, differences in blend ratios of less than 10% were not discriminable by smokers. This included addition of reconstituted or expanded tobacco to the blend, as well as changes in ratio of flue-cured, burley and oriental tobaccos. Discrimination of larger blend changes was inconsistent. Differences of 15% or more in both flue cured and burley (as percentage of total blend) remained undetectable in two separate studies.[29 30] On the other hand, inclusion of expanded tobacco at levels of greater than 10% was identifiable by smokers.[31 32]

Comprehensive studies were conducted on discrimination of nicotine in tobacco, as well as smoke machine measured tar and nicotine delivery. A difference threshold for tar was identified at 0.7 mg (~10%), although product acceptance and quality control limits were 1 mg or greater.[33 34] A threshold study for smoke nicotine found that a change of 0.2 mg nicotine in smoke (10%–15%) was needed for 10% of the population to identify a difference (called just noticeable difference or JND10).[35] Another summary review comprising multiple studies identified a threshold value for smoke nicotine of 6%, but observed that larger differences would be masked by higher tar levels.[36]

European Common Entry Gate

Using EU-CEG and Dutch market data, we identified 103 cigarette varieties that were available in the Dutch market at the time of the analyses. These belong to 33 brands, with the number of varieties per brand ranging from 1 to 12 (table 2). Eight brands with five varieties or more together contributed to the majority (57) of all brand varieties. Two products that were sold under different brand names but are otherwise identical have been listed under both their brand names in table 2, but used only once for data analyses.

By using analysis of variance to compare within-brand variation to the total variation, we found 14 parameters that had a large role in variation between brand varieties. These mainly concern physical product measures (length, filter length, tobacco weight), filter ventilation (FilterVentilation, FilterDropPressureOpen) and tar, nicotine and carbon monoxide (TNCO) emissions. There were 16 parameters with a small role for variation between brand varieties. These parameters concern tobacco blend (n=6) and the number of additives (n=10). A full overview of product parameter data and summary statistics is shown in Online supplemental table 2.

Table 2 Number of varieties on the Dutch market per brand

Varieties (n)	Brand(s)
12	Marlboro
9	JPS
7	Camel, Gauloises
6	Dunhill, Lucky Strike
5	Pall Mall, Winston
4	Davidoff, Karelia, Peter Stuyvesant
3	Elixyr, L&M
2	American Spirit, Benson & Hedges, Black Devil, Kent, Kornet, Mark Adams, Mohawk, Pueblo, Ruba, Titaan
1	Apache, Bastos, Caballero, Chesterfield, Lambert & Butler, Regal, Silk Cut, Superkings, Texas, Vogue

Nicotine emissions as generated with the ISO smoking protocol strongly depended on filter ventilation. A linear prediction model based on filter ventilation alone predicted nicotine levels with R=0.70. On adding parameters, the best overall model included filter ventilation, tobacco weight and diameter; this model predicted nicotine emissions with R=0.74.

PCA indicated that five types of product could be identified, namely low-TNCO cigarettes (low-TNCO emissions, high filter ventilation), British-style cigarettes (high content of flue-cured tobacco, few flavour additives), American blend cigarettes (more tobacco additives), American blend cigarettes by Philip Morris (more tobacco additives, more expanded tobacco, low PD) and dark tobacco cigarettes (low content of flue-cured tobacco, few flavour additives, low PD, low filter ventilation).

Based on the PCA variable loadings, we found that PC1 related to TNCO and filter ventilation, PC2 to tobacco blend (leaf type and cure method), PC3 to PD closed and expanded tobacco and PC4 to tobacco weight and correlated parameters such as length. Considering our findings from the industry tobacco document review, we selected four parameters for further visualisation, namely: filter ventilation, percentage flue-cured tobacco, filter PD closed and tobacco weight.

Plots for these product characteristics, combined with discrimination thresholds (figure 1, online supplemental figure 1), illustrate that brands, and to a lesser extent brand varieties, can partly be distinguished by their relative position. The six brands with the largest number of brand varieties (Marlboro, JPS, Camel, Gauloises, Dunhill, Lucky Strike) tended to have less within-brand variation compared with the overall market (the median value of their within-brand variation was 21% of the total market variation).

Filter ventilation control measurements

The results of the measurements and EU-CEG data are shown in online supplemental table 3. EU-CEG data agreed reasonably well with the measured data, with some exceptions. In 17 products one or more of the checked parameters were >120% of the EU-CEG data, and in 12 products one or more of the checked parameters were <80% of the EU-CEG data. Exceptional differences were found in 10 cases, where the measured

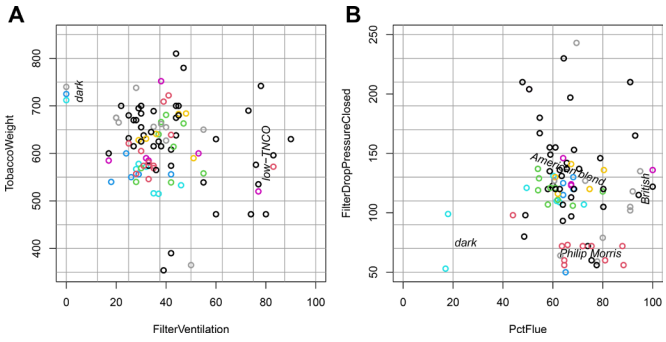

Figure 1 Plots for comparing cigarette types and brand varieties based on product characteristics and their discrimination thresholds. (A) Filter ventilation versus tobacco weight and (B) percentage flue-cured tobacco versus filter PD closed. A full overview of product characteristic plots is shown in online supplemental figure 1. Coloured dots indicate different brands with five or more varieties; black dots indicate brands with two to four varieties; grey dots indicate brands with a single variety. Grey lines are spaced by consumer discrimination thresholds. The approximate region of cigarette types is indicated as italic text. TNCO, tar, nicotine and carbon monoxide.

PD closed was >150% of the EU-CEG data and in one case the filter ventilation was <50% of the EU-CEG data.

DISCUSSION

Contributions of the paper

Our study examines which variations in cigarette design characteristics in the Dutch market are likely to be perceived as different by consumers. We searched the Truth Tobacco Industry Documents to determine which parameters are important for consumer sensory perception of cigarette smoke and which differences can be discriminated by consumers. Additionally, we used EU-CEG data to determine how parameters vary within and between brands. Based on this, we visualised the data to judge which differences are noticeable by consumers.

Tobacco industry discrimination studies as identified in the present review focused on the design parameters of filter ventilation, PD, tobacco weight and tobacco blend, with only limited research found on other physical parameters. Within these main parameters, discrimination thresholds were consistently identified, with absolute parameter differences of 10%–15% generally needed to support consumer perception (or 6%–8% in the case of tobacco weight). Although the documents cited are now decades old, their findings are consistent across multiple time periods and manufacturers; and the design parameters that they describe remain within the same general range as those identified in the current Dutch market. The findings describe the general population of smokers, and further research would be necessary to address specific populations such as naïve users and to assess the influence of factors such as smoking history, gender or level of dependence.

Perceptual interactions among different parameters can be complicated to untangle and some identified discrimination thresholds may vary as a result of parameter interactions. Nonetheless, as indicated by the EU-CEG data (figure 1), many or most cigarette products on the Dutch market are clustered within a limited band of physical parameter measures, with the result that such products will not be perceived as distinguishable by many consumers.

Our results show that in the Netherlands, differences between brand varieties can mainly be found in TNCO emissions and associated parameters cigarette length, filter length, tobacco weight and, especially, filter ventilation. In most cases, differences between brand varieties were smaller than the threshold for discrimination by consumers. This would suggest that most brand varieties, and indeed some brands, will be difficult to discriminate by consumers, with the exceptions of low-TNCO cigarettes. Our plots also indicated different market positionings for brand names with only a single variety, as here too, several types could be distinguished based on product parameters and plot position. Some single-product brands are similar to other products by the same manufacturer (eg, Chesterfield to Marlboro). Others seem to target a market niche, for example, 'dark tobacco' (such as Caballero) or British-style cigarettes (such as Lambert & Butler).

TNCO emissions are not design parameters by themselves. Instead, related physical parameters such as filter ventilation are tuned to give a desired outcome, regarding consumer sensory perception, manufacturing costs and—in the case of filter ventilation—TNCO values as measured under ISO machine smoking regimes for regulatory purposes.[10] We found that filter ventilation determined 70% of the TNCO levels as measured with ISO. More intense smoking methods such as the Canadian Intense better reflect human behaviour in response to filter ventilation, such as more intense puffing and vent blocking, but such data are currently not legally required by the European Tobacco Products Directive (TPD). It should be noted that the Tobacco Products Directive prescribes upper limits of 10 mg tar, 1 mg nicotine and 10 mg CO.[6] In other countries, without such limits, the variation in TNCO levels will probably be higher, with the effect that the observed variety in cigarette characteristics may be higher than in the Netherlands. Given potential market differences, we recommend that researchers in other countries, where similar data are available, conduct comparable studies on the variation of design characteristics in their own markets.

We found that some brand varieties provide a noticeably different product for consumers, such as a low-TNCO version, but in most cases the differences are relatively small and typically did not exceed the threshold for consumers.

Limitations

While our EU-CEG analysis included the number of additives per function, we did not look at which specific additives were used or whether additive differences may be distinguished by consumers, as the complexity of additives and additive properties exceeded the scope of this paper. Further, characterising flavours have been banned in the European Union since 2016, and menthol since 2020,[6] limiting the potential for flavours to serve as recognisable differentiators among products. Brand varieties show relatively little variation in tobacco composition and the number of additives. A limited analysis of additives suggests some aspects that appear more related to presentation (inks used on cigarette paper, filter overwrap, tipping paper and tipping paper inks) and as such are less likely to lead to sensory differences. Other parameters such as sizing agents and viscosity modifiers may lead to sensory differences by acting on parameters such as PD, although we did not see a clear correlation. Overall, tobacco composition and additives show some differences between brands, although it is not clear to what extent they can be discriminated by consumers.

The data used for this study were submitted to EU-CEG by manufacturers as part of their mandatory reporting to national authorities. Because it is not always feasible or practical to validate that the data are correct (or entered correctly), this could be

seen as a limitation of our data set. However, filter ventilation emerges as an important parameter from our analyses. Control measurements showed that EU-CEG data agreed well with the measured data, with some exceptions. Although we cannot extrapolate this agreement to all other parameters, there is at least some evidence that the data overall are valid.

Regulatory implications

The results of this paper show that within the Dutch market, many of the variations within and between brands may be imperceptible by consumers. Five clusters of cigarettes could be identified with different combinations of design characteristics: low-TNCO cigarettes, British-style cigarettes, American blend cigarettes, American blend cigarettes by Philip Morris and dark tobacco cigarettes. The striking similarities in design characteristics across multiple products may suggest that certain combinations of cigarette parameters appeal to different types of smokers. Cases in which a brand places several products within the same cluster indicate that brand variety is not always motivated by sensory differences but may also serve as a means to provide choice options and target specific subgroups as, for example, through brand image.

By comparing data presented in this study with data from their own market, regulators can evaluate differences in brand characteristics and determine which products are likely to be perceived by smokers as different. Such an evaluation can be used as a basis to limit brand diversification, particularly in cases where no clear sensory differences are identified. For example, regulations could set limits on introduction of new brand variants that fall within the range of characteristics of products already on the market. Alternately, differences in product characteristics as identified in the present study could be used to inform evaluation of proposed product changes, as under the US Food and Drug Administration substantial equivalence pathway, and trigger more thorough review. Regulators may also wish to consider whether product clusters such as those identified in the present study represent ideal constructions to support tobacco use and may be a target for efforts to reduce cigarette appeal.

What this paper adds

⇒ The modern cigarette market supplies many brands and types differing in their design characteristics such as filter ventilation and tobacco blend.
⇒ Little is known about how design characteristics affect users' sensory experience.
⇒ Our study is the first to examine which variations in design characteristics available on the market are likely to be perceived as different by consumers using a combination of Truth Tobacco Industry Documents and European Common Entry Gate industry data of the Dutch market.
⇒ We found five clusters of cigarettes with different combinations of design characteristics. Within these clusters, differences between cigarettes will most likely not be noticeable by consumers.
⇒ This may suggest that these five combinations of design characteristics appeal to different types of smokers. Proliferation of brand varieties within these clusters may instead play a marketing role.
⇒ Based on our findings, regulators should consider limiting available brand varieties and regulating design characteristics to reduce product appeal.

CONCLUSIONS

Among the cigarettes on the Dutch market, there are few noticeable differences between brands and brand variations, with the exception of the five clusters that correspond to different types of cigarettes. While some brand varieties provide a noticeably different product for consumers, such as a low-TNCO version, in most cases the differences are relatively small. Thus, proliferation of brand varieties within these clusters may play a marketing role rather than representing discernibly different products to consumers.

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REFERENCES

1 Henningfield JE, Hatsukami DK, Zeller M, *et al*. Conference on abuse liability and appeal of tobacco products: conclusions and recommendations. *Drug Alcohol Depend* 2011;116:1–7.
2 Agaku IT, Omaduvie UT, Filippidis FT, *et al*. Cigarette design and marketing features are associated with increased smoking susceptibility and perception of reduced harm among smokers in 27 EU countries. *Tob Control* 2015;24:e233–40.
3 Talhout R, van de Nobelen S, Kienhuis AS. An inventory of methods suitable to assess additive-induced characterising flavours of tobacco products. *Drug Alcohol Depend* 2016;161:9–14.
4 Rees VW, Kreslake JM, Wayne GF, *et al*. Role of cigarette sensory cues in modifying puffing topography. *Drug Alcohol Depend* 2012;124:1–10.
5 Talhout R, Richter PA, Stepanov I, *et al*. Cigarette design features: effects on emission levels, user perception, and behavior. *Tob Regul Sci* 2018;4:592–604.
6 European Commission. Tobacco products directive (2014/40/EU), 2014. Available: https://ec.europa.eu/health/sites/health/files/tobacco/docs/dir_201440_en.pdf
7 US Food and Drug Administration. Family Smoking Prevention and Tobacco Control Act (section 907(a)(1)(A)), 2009. Available: https://www.govinfo.gov/content/pkg/PLAW-111publ31/pdf/PLAW-111publ31.pdf
8 Strasser AA, Ashare RL, Kaufman M, *et al*. The effect of menthol on cigarette smoking behaviors, biomarkers and subjective responses. *Cancer Epidemiol Biomarkers Prev* 2013;22:382–9.
9 Ashley M, Dixon M, Sisodiya A, *et al*. Lack of effect of menthol level and type on smokers' estimated mouth level exposures to tar and nicotine and perceived sensory characteristics of cigarette smoke. *Regul Toxicol Pharmacol* 2012;63:381–90.
10 Kozlowski LT, O'Connor RJ. Cigarette filter ventilation is a defective design because of misleading taste, bigger puffs, and blocked vents. *Tob Control* 2002;11 Suppl 1:i40–50.
11 Cutler TJ, Nye DA. Anything but 'empowerment'? Smokers, tar and nicotine data and cigarette design. *Health Risk Soc* 2000;2:69–81.
12 O'Connor RJ, Caruso RV, Borland R, *et al*. Relationship of cigarette-related perceptions to cigarette design features: findings from the 2009 ITC U.S. survey. *Nicotine Tob Res* 2013;15:1943–7.
13 Jaffe AJ, Glaros AG. Taste dimensions in cigarette discrimination: a multidimensional scaling approach. *Addict Behav* 1986;11:407–13.

14 Kochhar N, Warburton DM. Puff-by-puff sensory evaluation of a low to middle tar medium nicotine cigarette designed to maintain nicotine delivery to the smoker. *Psychopharmacology* 1990;102:343–9.
15 Nil R, Bättig K. Separate effects of cigarette smoke yield and smoke taste on smoking behavior. *Psychopharmacology* 1989;99:54–9.
16 European Commission. European common entry gate system. Available: https://ec.europa.eu/health/euceg/
17 Truth Initiative. Truth tobacco industry documents. Available: https://www.industrydocuments.ucsf.edu/tobacco
18 International Standardisation Organisation (ISO). ISO 6565: tobacco and tobacco products — draw resistance of cigarettes and pressure drop of filter rods — standard conditions and measurement, 2015. Available: https://www.iso.org/standard/64265.html
19 International Standardisation Organisation (ISO). ISO 9512: cigarettes — determination of ventilation — definitions and measurement principles, 2019. Available: https://www.iso.org/standard/73027.html
20 Hayes C, Keene C. Brica weight series: summary of subjective investigations. 1995 Sept 13. Philip Morris records; master settlement agreement. Available: https://www.industrydocuments.ucsf.edu/tobacco/docs/#id=mqnp0217 [Accessed 10 Feb 2021].
21 Ennis DM, Mendell S, Rowe CH. The relationship between Dilution/RTD ratios and consumer perception. 1983 June 17. product design MSA collection. Available: https://www.industrydocuments.ucsf.edu/tobacco/docs/#id=mgvj0037 [Accessed 10 Feb 2021].
22 British-American Tobacco Company Limited. Group Research and Development Centre (Harding, BC). Effects of Ventilation and Pressure Drop Variability on the Sensory Properties of a Low Delivery Cigarette - Report Number RD 1912 Restricted. 1983 April 08. British American Tobacco Records. Available: https://www.industrydocuments.ucsf.edu/tobacco/docs/#id=msxx0203 [Accessed 10 Feb 2021].
23 Gordin HH. Sensory evaluation study. SPU physical variable study. Effect of total dilution on product perception. 2000 nov 27. RJ Reynolds records; master settlement agreement.. Available: https://www.industrydocuments.ucsf.edu/tobacco/docs/#id=lglw0186 [Accessed 10 Feb 2021].
24 Summary of 1993 (19930000) cost reduction initiatives. 1994 nov 29. RJ Reynolds records; master settlement agreement.. Available: https://www.industrydocuments.ucsf.edu/tobacco/docs/#id=fxvc0089 [Accessed 10 Feb 2021].
25 Stanford BC. Product research report. final report 1mm filter length discrimination test. 1982 AUG 17. RJ Reynolds records; master settlement agreement.. Available: https://www.industrydocuments.ucsf.edu/tobacco/docs/#id=kspl0184 [Accessed 10 Feb 2021].
26 Snyder SL. 1980 (800000) product changes. 1980 April 30. RJ Reynolds records; master settlement agreement., 1980. Available: https://www.industrydocuments.ucsf.edu/tobacco/docs/#id=nrpm0095 [Accessed 10 Feb 2021].
27 Geiszler WA. Filter length changes for 85 MM merit. 1981 March 05. Philip Morris records; master settlement agreement.. Available: https://www.industrydocuments.ucsf.edu/tobacco/docs/#id=hlyj0119 [Accessed 10 Feb 2021].
28 Gordin HH. Filter length increase review of previous research. 1997 July 24. RJ Reynolds records; master settlement agreement.. Available: https://www.industrydocuments.ucsf.edu/tobacco/docs/#id=lqmd0230 [Accessed 10 Feb 2021].
29 Gignac J. Sensory evaluation of burley and flue-cured sub-blend variation (type and level) - winston lights 85vf. 1990 March 20. RJ Reynolds Records; Master Settlement Agreement.. Available: https://www.industrydocuments.ucsf.edu/tobacco/docs/#id=sjwd0152 [Accessed 10 Feb 2021].
30 Beatley VE, Cantile AF, Daniel HG. 4010 brand development Virginia panel test 9509 production merit menthol 100mm, merit AC and casing (DOAEI) vs. Merit menthol 100mm with DBC bright and burley percentages reversed, merit AC and casing (DOAEJ). 1980 OCT 15. Philip Morris records; master settlement agreement. Available: https://www.industrydocuments.ucsf.edu/tobacco/docs/#id=znjd0122 [Accessed 10 Feb 2021].
31 0 percent G-13. 1989 nov 21. RJ Reynolds records; master settlement agreement. Available: https://www.industrydocuments.ucsf.edu/tobacco/docs/#id=jhwm0230 [Accessed 10 Feb 2021].
32 Cantile A, Collins J, Daniel HG. Virginia panel test 5540 85mm alpine menthol y76-4 (D9BBH) vs. 85mm alpine menthol y80-1 with 12 percent ET (D9BBI). 1979 Oct 01. Philip Morris records; master settlement agreement.. Available: https://www.industrydocuments.ucsf.edu/tobacco/docs/#id=gtml0038 [Accessed 10 Feb 2021].
33 Air dilution control training presentation module #1: Tar and consumer acceptance. 1983 March 15. RJ Reynolds Records; Master Settlement Agreement. Available: https://www.industrydocuments.ucsf.edu/tobacco/docs/#id=qjgg0003 [Accessed 10 Feb 2021].
34 ULT 'tar' and air dilution variability-acceptance study. 1982 Oct 12. RJ Reynolds Records; Master Settlement Agreement:500898550-500898568.. Available: https://www.industrydocuments.ucsf.edu/tobacco/docs/#id=fgkc0094 [Accessed 10 Feb 2021].
35 Janjigian K, Perfetti TA, Green CR. Nicotine just noticeable difference study of full flavor non-menthol 85mm products. 1985 Sept 05. RJ Reynolds records; master settlement agreement. Available: https://www.industrydocuments.ucsf.edu/tobacco/docs/#id=ysdg0100 [Accessed 10 Feb 2021].
36 RJR. nicotine and smoker satisfaction. 1987 Jan 03. Ness Motley law firm documents. Available: https://www.industrydocuments.ucsf.edu/tobacco/docs/#id=jtpd0040 [Accessed 10 Feb 2021].

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 flavor [1] 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*Flue-/(Flue- + Air- + Fire- + 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 users[6] 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

1. European Commission. Tobacco Products Directive (2014/40/EU). 2014. https://ec.europa.eu/health/sites/health/files/tobacco/docs/dir_201440_en.pdf.
2. International Standardisation Organisation (ISO). ISO 4387: Cigarettes - Determination of total and nicotine-free dry particulate matter using a routine analytical smoking machine. 2019. https://www.iso.org/standard/76549.html.
3. Jaffe AJ, Glaros AG. Taste dimensions in cigarette discrimination: a multidimensional scaling approach. *Addict Behav* 1986;11(4):407-413.
4. ULT 'tar' and air dilution variability-acceptance study. 1982 Oct 12. RJ Reynolds Records; Master Settlement Agreement:500898550-500898568. https://www.industrydocuments.ucsf.edu/tobacco/docs/#id=fgkc0094 (accessed 2021 Feb 10).
5. Wood AJ. Introductory comment. 1970 Oct. Philip Morris Records; Master Settlement Agreement. https://www.industrydocuments.ucsf.edu/tobacco/docs/#id=xslv0145 (accessed 2021 Feb 10).
6. Stanford BC. Product research report. Final report 1mm filter length discrimination test. 1982 Aug 17. RJ Reynolds Records; Master Settlement Agreement. https://www.industrydocuments.ucsf.edu/tobacco/docs/#id=kspl0184 (accessed 2021 Feb 10).
7. Strategic product development. Project GTC specification study: Cigarette weight test. 1995 April 06. RJ Reynolds Records; Master Settlement Agreement. https://www.industrydocuments.ucsf.edu/tobacco/docs/#id=rmfb0227 (accessed 2021 Feb 10).

Supplementary Table 1: Truth Tobacco Industry Document studies describing a discrimination threshold of noticeable sensory differences

#	Category	Noticeable difference/ Discrimination data	Study type	Participants	Cigarette/market	Characteristics	Notes	Year and company	Source (#id)
1	ventilation	SD 55 vs 69, 69 vs 74 % (see PD)	PC	CP	ULT smokers	vent 55, PD 5.0; vent 69, PD 3.9; vent 74, PD 2.8	ventilation and PD moved in parallel; "it appears it is possible to optimize a product by making various diluted/PD ratios available on the same blend"	1983/PM	mgvj0037
2	ventilation	SD 26 vs 39, 39 vs 56 % (see PD)	PC	CP	ULT smokers	vent 26, PD 7.9; vent 39, PD 5.3; vent 56, PD 3.5	ventilation and PD moved in parallel; "it appears it is possible to optimize a product by making various diluted/PD ratios available on the same blend"	1983/PM	mgvj0037
3	ventilation	SD 0 vs 12, 12 vs 21 % (FF only) NSD 12 vs 21 (LT only), 0 vs 12 %	PC	CP	10-15 mg smokers; 15+	vent 0, PD 4.3; vent 12, PD 3.4; vent 21, PD 3.1	(further analysis of prior study); PD more important for LT smokers	1983/PM	mgvj0037
4	ventilation	NSD across all pairs 18 vs 30, 30 vs 35, 18 vs 35 %	PC	CP	LT smokers	vent 18, PD 4.1; vent 30, PD 3.5; vent 35, PD 2.9	ventilation and PD moved in parallel	1982/PM	gsxd0122, mgvj0037
5	ventilation	SD 0 vs 12, 12 vs 21 % (Winston smokers only, NSD Marlb smokers)	PC	CP	FF smokers	vent 0, PD 4.3; vent 12, PD 3.4; vent 21, PD 3.1	ventilation and PD moved in parallel	1982/PM	trxd0122, mgvj0037
6	ventilation	SD 0 vs 25, 0 vs 35 % NSD 30 vs 40, 25 vs 30 %	PC	EP	FF smokers; LT smokers	vent 0, 25, 30, 35, 40		1994/RJR	ksld0224
7	ventilation	SD acceptance at 12, discrim at between 6-12 %	MC, FA	CP	5-7 mg tar (ULT) smokers	vent 36, 39, 44, 46, 49, 55, 59 (tar reduced from 7.3-4.5)	12% difference equivalent to 1.5 mg tar; recommend expanding control limits to at least 6%	1982/RJR	fgkc0094
8	ventilation	SD 35 vs 55 % NSD 40 vs 50 % (imputed)	MC, FA	CP	5-7 mg tar (ULT) smokers	vent 36, 39, 44, 46, 49, 55, 59 (tar reduced from 7.3-4.5)	new control limits set based on findings	1984/RJR	ktcp0018
9	ventilation	SD (small) 15 vs 30, 0 vs 15; SD (strong) 0 vs 30 %	MC, FA	EP	Winston FF prototypes	vent 0, 15, 30 (and fines 0-30)		1987/RJR	xjmw0011
10	ventilation	SD 29 vs 36, 36 vs 41, 31 vs 41 % NSD 31 vs 34, 34 vs 36 %	PC	EP	LT prototypes	vent 30, 32, 34, 36, 41; PD 110, 118	10% ventilation change = change perception PD	2000/RJR	lglw0186
11	ventilation	SD 12 vs 29, 11 vs 25 %	PC	EP	FF, LT prototypes	vent 0, 10, 30 (PD constant)	[other variables effect perception of ventilation]	1988/BW	fzgh0045
12	ventilation	NSD 0 vs 10 %	PC	CP	Marlb FF smokers, FF smokers	vent 0, 10		1977/PM	fxvx0124
13	ventilation	SD 0 vs 22 %	PC	CP	Marlb FF smokers, FF smokers	vent 0, 22; additional flavor (top dressing)	SD despite offset with increased flavor	1979/PM	fqwh0045
14	ventilation	SD 0 vs 12 % (reduces impact and irritation)	PC	EP	vent, PD, permeability paired high/low configs	vent 0, 12	"minimal change in impact and irritation... is best achieved by slight modifications in 2 or 3 design parameters as opposed to an extreme change in a single design feature"; ventilation and PD offset each other in perception	1980/BAT	hfnx0203
15	ventilation	SD perception 45 vs 75 and 30 vs 58 % control	PC	EP	Ares prototype, so no filtration	vent 30, 45, 58, 75	changes in perception include impact, body, irritation	1983/BW	mhjy0136
16	ventilation	SD in strength, impact, and harshness 16 and 35 % NSD acceptance 16, 23, 35 %	MC, FA	CP	LT smokers	vent 16, 23 35; filter PD 84, 97, 114	also paired effects of ventilation and filter PD	1991/RJR	yygp0097
17	ventilation	NSD 30 vs 40 %	PC	EP	LT prototypes	vent 30, 40, "benchmark" (unidentified)		1994/RJR	msld0224
18	ventilation	NSD 15 vs 20 % (isolated from other variables)	MC, FA	CP	FF Marlb smokers	vent 15, 20; filter PD 100, 115; Camel/Dakota blends	dilution paired with PD, blend	1990/RJR	fxyg0100
19	ventilation	SD in strength and impact 0 vs 15 % NSD 0 vs 10 %	PC	EP	LT prototypes	vent 0, 10, 15	other parameters apear to be constant	1995/RJR	qpby0231, mfvy0231
20	ventilation	SD 50 % ventilation/high PD (lowest preference) NSD 25 and 0 %	MC	EP	LT prototypes	vent 0, 25, 51; PD 4.7, 4.4, 1.6; tar ~10.5 mg	if tar is held constant, PD becomes important. NSD - minor differences… "very equal in taste and preference"	1974/PM	fyjy0042
21	ventilation	SD 0 vs 25 % in taste and acceptability (when PD held constant)	PC	EP	LT prototypes	vent 10, 25; PD 145 mm; tar ~12 mg		1990/BAT	zkdh0135, ygvj0037
22	ventilation	1% increase = 0.01 decrease acceptance and up to 0.05 decrease in sensory measures; noticeable around 0.5-0.7 (~10-12%)	MC, PC, FA	EP	Virg LT prototypes	vent <37.5 to >49.6%; PD 100 to 131 mm	estimates effect sizes of vent changes independent of other variables [implies around 10% threshold]	1983/BAT	msxx0203
23	ventilation	SD in impact emerge around 10 % (38 vs 48); strong differences above 12 % (>50 vs 38) NSD < 10 %	MC, PC, FA	EP	Virg LT prototypes	vent <37.5 to >49.6%; PD 100 to 131 mm	measured (paired) sensory effect differences	1983/BAT	msxx0203
24	ventilation	limited SD 35 vs 45, 0 vs 10 % NSD 15% vs 30%	MC, FA	CP	FF/ LT/ ULT prototypes	filter PD 83, 103, 123; vent 0, 15, 35, 50, 65; resulting in set of products with PD, tar, nic, and t/n at various levels	resulting in products with cigarette filter pd, tar, nicotine, and t/n at various levels; acceptance was mainly a function of air dilution	1985/RJR	hlky0097
1	pressure drop	SD discrimination dependent on behavioral differences	PC	EP	LT prototypes	vent 39, 51, 67, 73, 78; also varied filter efficiency (38-65); tar 4.9-7.7 mg	NSD for products with = tar when puff behaviors held constant; Smoker perception of a cigarette influenced by PD more than by difference in delivery	1981/RJR	mjvf0098
2	pressure drop	NSD 100 vs 115 mm (isolated from other variables)	MC, FA	CP	FF Marlb smokers	vent 15, 20; filter PD 100, 115; Camel/Dakota blends	dilution paired with PD, blend	1990/RJR	fxyg0100
3	pressure drop	NSD perception 7.8 vs 12.6 mm (but increased effort)	MC	CP	FF smokers	PD 7.8, 8.8, 10.6, 12.6	(also evidence for compensation)	1987/BAT	pnlj0213, ygvj0037
4	pressure drop	SD draw perception at 113 mm NSD 73 vs 53 mm	MC	CP	random recruitment	PD 113, 73, 53 (closed filter PD 86, 54, 29); tar constant ~10 mg		1984/BAT	ygvj0037
5	pressure drop	NSD perception 135 vs 95 mm irritation/impact	MC	CP	random recruitment	PD 135, 95; vent 43, 66; tar constant ~9 mg		1990/BAT	ygvj0037
6	pressure drop	1mm increase= 0.01 decrease acceptance and up to 0.02 decrease in other sensory; noticeable is around 0.5-0.7 (~25-35 mm)	MC, PC, FA	EP	Virg LT prototypes	vent <37.5 to >49.6%; PD 100 to 131	estimates effect sizes of PD changes independent of other variables [implies around 25mm threshold]	1983/BAT	msxx0203
7	pressure drop	SD 25 mm (95-120) flavor and mouthfeel; 30 mm (125-95)mouthfeel and impact; SD 20 mm (110-130) mouthfeel and effort NSD 15 mm (100-115)	MC, PC, FA	EP	Virg LT prototypes	vent <37.5 to >49.6%; PD 100 to 131	measured (paired) sensory effect differences	1983/BAT	msxx0203
8	pressure drop	SD perception 3.9-4.6 mm NSD 4.6-4.8 mm	R	EP	Viceroy and Marlb prototypes	PD 3.9, 4.6, 4.8	findings from 1977 BW study; pressure drop main source of discrimination	1981/BAT	rglj0199
9	pressure drop	SD perception and behavior 16-23 mm change (from 123 control) NSD for 11 mm change	PC	EP	FF prototypes	PD 100, 113, 123, 140 (modified by tobacco tob wt/dens); tar 15-17 mg	sensory changes in impact and not flavor	1991/BAT	khpy0194
10	pressure drop	SD 124 to 141 perceived draw but no other sensory; SD perceived draw 124 to 101 mm NSD PD 124 to 113 mm	PC	EP	FF prototypes	PD 114, 124, 125, 138 (modified by tobacco tob wt/dens); tar 15-17 mg	PD changes influenced smoking mechanics but had little effect on sensory intensities	1994/BAT	grdb0172
11	pressure drop	SD with increase of 16 or decrease of 23 mm from control NSD perception when PD reduced 11 mm	PC, FA	EP	FF prototypes	PD 101, 113, 124, 141 (modified by tobacco tob wt/dens); tar 15-17 mg	PD changes influenced smoking mechanics but had little effect on sensory intensities	1992/BAT	gncp0213, grdb0172
12	pressure drop	-	R	-			sensory effects of PD are variable; lower PD reduces acceptance in LT but increases acceptance in ULT products	1992/BAT	ygvj0037
13	pressure drop	-	TA	CP	Marlb FF/ Marlb LT smokers	PD 4.3, vent 68; PD 6.3, vent 50	PD changes smoking behavior, altering perceptions; 0.5 in reduction in PD = volume increase of 6-8%; ET necessary to offset dilution	1975/PM	txkj0191
1	cigarette length	No outcomes measured (99.5, 99, 98.5 all standardized to 98; 84 standardized to 83 mm)	IM		all products	circ 99.5, 99, 98.5, 98; circ 84, 83; modeling indicates tob wt from 0.859 to 0.846; from 0.751 to 0.739	cost control measure (allows weight reduction)	2000/PM	nldx0219, xmwn0152
2	cigarette length	production control limits 1 mm for both 99.5, 98.5	IM		all products	circ 99.5, 99, 98.5, 98	[no concerns re: perception]; cost control measure (allows weight reduction)	1999/PM	jqxl0162
3	cigarette length	100 to 99 mm considered	IM		all products	circ 100, 99	[no concerns re: perception]; cost control measure	1992/Ame	fgpn0145
1	filter length	NSD 1-3 mm filter length increase	R	EP	FF and LTS	Flength (only change identified: 1 mm (for King), 3 mm (for 100s, paired to tipping increases))	Flength increase instituted across all brands (cost reduction); "will not have a significant impact on taste/smoking qualities as long as the relative draft remains the same"	1980/RJR	nrpm0095
2	filter length	SD sensory 2 mm increase NSD perception 25 vs 26, 27.5 to 31, acceptance 23 to 27 mm	R, MC, TD	CP	FF, LT, ULT products	Flength 31, 27.5; Flength 26, 25; Flength 27, 23	Flength "minimal effect on overall acceptability"	1997/RJR	lqmd0230
3	filter length	NSD increase 27.5 vs 31 mm (some sensory (taste) difference in LT in specific subsets of smokers)	PC, TD	CP	4 LT/ULT 100 products	Flength 31, 27.5	Flengths can be increased without affecting consumer acceptance	1984/RJR	ntpy0093, fyvj0149
4	filter length	NSD acceptance 25 vs 27 mm, but SD in perception (taste/ satisfaction)	PC	CP	Merit M and FF	Flength 25, 27; (wt/other changes not specified)	recommend increase in length	1981/PM	hlyj0119
5	filter length	NSD 13 vs 15, 13 vs 17, 15 vs 17 mm	PC	CP	Viceroy	Flength 13, 15, 17	very early study; smokers could not discriminate across lengths	1957/BW	mhgg0138
6	filter length	NSD 25 vs 26 mm	TD	CP	LT/ UL	Flength 25, 26	cost savings measure; "the consumer is not able to discriminate"	1982/RJR	kspl0184
7	filter length	NSD 25 vs 27 mm	PC	CP	Bright (LT)	Flength 25, 27		1983/RJR	lxkk0096, fxdb0019
8	filter length	NSD 25 vs 27.5 mm (LT smokers)	PC	CP	Merit/ LT smokers	Flength 25 and 27.5; tob wt 0.713, 0.678 g	no preference differences; possible sensory differences (spicy, sweet) among Merit smokers	1979/PM	jkkd0122
9	filter length	NSD 25 vs 27 mm (FF and LT smokers)	PC	CP	Marlb LT/ FF/ LT smokers	Flength 25 and 27; tob wt and dens differences	no preference or sensory differences, FF or LT smokers	1979/PM	njyv0119
1	circumference	SD 23 vs 25 mm (visual and touch + sensory) NSD 24 vs 25, 25 vs 26 mm	PC	MI	85 mm, white tipped, 9 mg,	circ 22, 23, 24, 25, 26	circ study	1983/PM	sknj0045
2	circumference	NSD perception circ reduced 25 to 24.75/24.8 mm	R	CP, EP	FF and LTS	circ 25, 24.75, 24.8	circ reduction instituted across all brands (cost reduction); "change will not have a significant impact on the taste of smoking qualities of RJR products"	1980/RJR	nrpm0095
3	circumference	NSD perception 24.8 vs 24.5 mm	MC, FA	EP	Salem FF 100	circ 24.8 vs 24.5	"minor perceptual difference", recommends implementation	1997/RJR	kldv0186
4	circumference	no outcomes measured (24.8 to either 24.7 or 24.6 mm considered)	IM		all products	circ 24.8, 24.7, 24.6	[implementation and outcomes?]; cost control measure (allows weight reduction)	2000/PM	nldx0219
1	tobacco weight	SD (enhanced smoothness) at 0.1 g (16% increase) NSD at 0.05 g (8%);	-	FP	Camel Light prototypes	tob wt 0.64, 0.69, 0.74, 0.81 g (modified by RT)	[limited details]	1992/RJR	qrpd0095
2	tobacco weight	SD 8% increase for firmness, burn rate NSD 4% reduction (30 mg)	PC	EP	LT prototypes	tob wt 0.73 g control, 0.70, 0.67, 0.62	Tob wt decreases of 8% (or more)= perceptual rod firmness and lit resistance decrease, and perceptual smoke concentration and burn rate increase	1992/RJR	kkmx0084
3	tobacco weight	SD control-50, control-30 mg in harshness/impact NSD control+50 mg	MC, FA	AP	Marlb, FF, LT smokers	tob wt 750 control, 850, 800, 720, 700, 650	"results suggest that panelists are able to discriminate subjective differences beginning at a Tob wt reduction of 30 mg"	1995/PM	jmgy0082
4	tobacco weight	SD at 50 mg 6 of 10 sensory attributes NSD at 25 mg	PC	EP	FF prototypes	tob wt 720, 745, 770, 795, 820 mg; tar ~15-16	linear difference, not tipping point; also find sequence effects; "hesitant to recommend 25 mg weight reduction in single step"	1995/PM	mqnp0217
5	tobacco weight	strong SD by puff 6 NSD in earlier puffs for -30 or +50 mg	MC, FA	EP	Marlb prototypes	tob wt 750 control, 850, 800, 720, 700, 650	assess individual puffs rather than whole cigarette	1995/PM	shml0055
6	tobacco weight	SD sensory at 30 mg and above including harshness, character, liking	MC, PC, FA	EP	Marlb prototypes	tob wt 750 control, 850, 800, 720, 700, 650	"A weight reduction of 30 mg was sufficient to produce statistically significant differences ($p < 0.05$) relative to the control weight cigarette for ratings of hot, harsh, peppery and liking."	1995/PM	msmp0043
7	tobacco weight	SD across various other weights NSD 0.95 vs 0.976, 0.882 vs 0.848	MC, FA	EP	FF M prototypes	tob wt 0.848, 0.882, 0.926, 0.976, 1.031 g (control 0.95 g)	more perceptual differences in NM study; possible that menthol masked perceptual differences	1992/RJR	xtlw0011
8	tobacco weight	NSD 1.33 vs all other configurations = NSD +-0.04 g or 3% wt	MC, PC, FA	EP	FF prototypes	cig wt 1.29, 1.31, 1.33, 1.35, 1.37 g	"what difference from target weight elicits perceptual difference"	1995/RJR	rmfb0227
9	tobacco weight	NSD perception tob weight 0.734 to 0.715 g	PC	CP	Marlb FF	tob wt 0.715, 0.734 (through changes in RT)	reduced weight achieved through changes in blend	1986/PM	gnck0022
10	tobacco weight	SD weight reduction 12% NSD weight reduction 6%	MC	CP	all products	exp tob for weight reduction	cost reduction initiatives	1994/RJR	fxvc0089
1	density	SD perception at 7% difference/0.02 g/cc (smallest unit measured); (strong difference at 0.04)	MC, FA	EP	Camel Light, 8 mg tar	dens 0.23, 0.25, 0.27, 0.29, 0.31; tob wt 0.64, 0.7, 0.75, 0.81, 0.87; vent 29, 31, 33, 36, 39; tar ~8	air dilution rose from 29-39%	1985/RJR	qjlc0087, qlyx0095
2	density	SD ~15 mg (in most cases) NSD sensory measures 230 vs 243 mg	MC, FA	EP	FF prototypes	dens 217, 232, 247, 262, 277 mg; variable tob wt	shared draw, differences in taste, impact, irritation	1985/BW	jjlg0135
1	tobacco blend	SD perception	MC, PC	CP	LT/ ULT	leaf quality changes (e.g. lugs vs tips) up to 10%	inconsistent effects of moderate blend changes; in blind studies "smoker do recognize their own brand and tend to rate that product more favorably"	1995/IMP	hsjk0138
2	tobacco blend	SD interactions NSD perception ammoniated vs non-ammoniated RT, denicotinized vs regular tobacco	MC, FA	EP	FF prototypes	regular and denic flue-cured, burley; ammoniated and non-ammoniated RT	Perceptual differences are not found between G-7 and G-7A. Perceptual differences are not found between regular and denicotinized tobaccos	1984/RJR	mjdj0095

3	tobacco blend	NSD 0 vs 10 RT (various pairs), up to 35% RT inclusion (expert panel)	PC	CP, EP	filter cig	recon ("blended leaf") 5,7.5, 10; and 10-60%	Marlb vs experimental Marlb with the BL in the blend constituting 25, 35, 55 and 75% of the total blend. One out of 7 smokers could detect differnces between the Marlb and the experimental Marlb with 75% of its blend consisting of BL	1964/PM	kzbg0189
4	tobacco blend	SD perception across most other pairs NSD 14-17, but SD perception across most other pairs	MC, FA	EP	Winston Light	stem content 11, 14, 17, 19, 21, 25	Perceptual differences (27 characteristics) but no linear relationship established	1999/RJR	gfwx0186
5	tobacco blend	shorts SD sensory 0 vs 8%; stems SD sensory 0 vs 2% NSD sensory 0 vs 5, 5 vs 8 %	PC	EP	Winston FF/ FF prototypes	shorts 0, 5, 8; stem 0, 2	remove stems from products; shorts control limit plus/minus 1%	1985/RJR	llpd0098
6	tobacco blend	SD perception 0 vs 11, 0 vs 15, 0 vs 30, 30 vs 50 NSD 0 vs 6 (duo-trio);	R	CP, EP	FF/ LT/ ULT prototypes	expanded tobacco 0-50% across range of studies	SD sensory identified in most studies	1989/RJR	jhwm0230
7	tobacco blend	NSD burley 13 vs 21, bright 16 vs 48 %	MC, FA	EP	Winston LT prototypes	burley/bright 17/32% (control), 21/16%, 13/48%	50% decrease or increase in the Burley or Flue-cured sub-blend did not change the perception of the current product	1990/RJR	sjwd0152
8	tobacco blend	NSD blend changes (increased ET/stem)	TD	CP	FF and LTS	blend changes for cost reduction	increased expanded tobacco, rolled stem, lower grade tobacco, other changes for cost reduction	1982/RJR	kgfb0085
9	tobacco blend	NSD blend changes ET 10 vs 20 + oriental 15 vs 5 %, new RT	PC	CP	Marlb FF	blend changes: increase ET 10 to 20%, oriental 15% to 5%, RL/RCB shift	multiple simultaneous blend changes considered	1983/PM	tlpd0013
10	tobacco blend	NSD RT 0 vs 5%	PC	CP	Marlb FF	recon "BL" 0, 5	early study; some sensory differences but not consistent	1957/PM	lydh0106
11	tobacco blend	NSD change in RT type (cooked flavor RLTC vs 150B)	PC	CP	Marlb FF	recon type	NSD changes in processing and ingredients of reconstituted tobacco even when used at levels of ~20%	1984/PM	lgwh0106
12	tobacco blend	NSD consolidation of sub-blends	TD	CP	Camel other major brands	20 subgrades burly reduced to 4, 20 subgrades bright reduced to 4	common group blending = consolidation of products blends and sub-grades used	1983/RJR	klym0184, fghk0088
13	tobacco blend	NSD RT "dust sheet" used in place of G7-1(inclusion level and supplier held constant)	MC, FA	EP	Doral FF	RT "dust sheet" 22, 32%; RT g7-1 22, 32%	[some differences when inclusion or supplier changed]	1990/RJR	njwd0152
14	tobacco blend	SD 12% expanded tobacco	PC, TD	CP	Alpine/ FF M smokers	12% ET	sensory/ taste differences identified; discrimination in duo-trio	1979/PM	gtml0038
15	tobacco blend	NSD burley and bright ratio reversed (35/15 vs 15/35 %)	PC	CP	Merit M/ FF M/ LT M smokers	bur/bri 35/15		1980/PM	znjd0122, pxnc0035, rhhl0033
16	tobacco blend	NSD expanded tobacco 12%/ recon tob 24% vs ET 6%/RT 20%/ expanded stems 5%	PC	CP	Marlb FF	ET 12/6; RT 24/20	no sensory or preference differences	1980/PM	khvw0107
1	nicotine	SD high (2.95, 3.28) vs low (1.74, 2.15 mg) NSD 2.95 vs 2.15 mg	PC	EP	Camel 70 prototypes	tobacco nic 1.74, 2.15, 2.31, 2.95, 3.28, 4.07%	even the NSD group shows some evidence of discrimination	1986/RJR	lkyw0095
2	nicotine	NSD perception 1.72 vs 2.06 mg	PC	EP	unfiltered prototypes	tobacco nic 1.72, 2.06	nicotine range not great enough to be detected perceptually	1986/RJR	xlfc0087
3	nicotine	JND tobacco nicotine (>10% of pop) ~0.4 mg/cig; smoke nicotine ~0.2 mg/cig	PC, FA	EP	FF/ LT/ ULT prototypes	tob nic 1.7-2.6 mg; smoke nic levels 0.3-.75 mg	[published]	1988/RJR	jmkk0114
4	nicotine	JND tobacco nicotine (>10% pop) ~0.2-.3 mg/cig; smoke nicotine ~0.2 mg/cig	PC, FA	EP	FF NM prototypes	tob nic 1.3-2.4 mg; smoke nic levels ~1-2 mg	applies to FF prototypes only	1985/RJR	ysdg0100
5	nicotine	NSD nicotine 1.06 vs 1.28 mg (t/n from 14 to 12)	MC, FA	CP	Winston and Camel FF	tob nic 1.06, 1.28; casing as well as blend differences	NSD Camel vs composite (Winston SD, too many factors to isolate)	1992/RJR	qnvf0055, tjxp0013
6	nicotine	threshold value for detection of smoke nicotine 6%	R		all products	tobacco nic, other blend changes	masking effect of tar: smokers can distinguish a cigarette with 11.1 mg "tar" and 1.4 mg nicotine (T/N = 7.9) from a control cigarette with the same blend without nicotine, but surprisingly cannot distinguish a cigarette with higher tar (26.5 mg) and nicotine (1.76 mg) (T/N = 15 .1) from a control cigarette without nicotine, due to an apparent masking effect	1978/RJR	jtpd0040
7	nicotine	NSD 1.59 vs. 1.98 mg	PC	CP	Marlb FF	tob nic 1.59, 1.98 (PD 5.0, 4.6 in)		1984/PM	kpfb0040, tqwk0113
1	tar	SD acceptance at 1.5 mg tar; JND (harshness 0.7 mg)	MC, FA	CP	5-7 mg tar (ULT) smokers	tar 7.3, 7.1, 6.4, 6.0, 5.6, 4.9, 4.5 mg (vent 36-59)	recommend expanding control limits to at least 1.5 mg tar	1982/RJR	fgkc0094
2	tar	-	-	CP	low tar smokers	tar levels 1 - 7 mg	1 mg change in tar = 7% change in acceptance; "Changes in tar level change consumers' perception of taste and acceptance of our products."	1983/RJR	qjgg0003
3	tar	tar control limit plus/minus 1.5 mg	MC, FA	CP	FF/ LT/ ULT prototypes	PD 83, 103, 123 mm and ven 0, 15, 35, 50, 65) resulting in different PD, tar, nic, and t/n at various levels	tar control limit "well within range of consumer acceptability"	1985/RJR	hlky0097

Abbreviations: SD; significant difference. NSD; no significant difference. JND; just noticeable difference. PC; paired comparison. MC; monadic comparison. FA; factorial analysis. R; review (multiple studies). TD; triangle discrimination. IM; implementation, TA; topagraphy analysis. CP; consumer panel. EP; expert panel. FG; focus group. AP; ad hoc panel. MI; mall interview. Marlb; Marlboro. Virg; Virginia. ULT; ultralight. FF; full flavor. FFLT; full flavor light. LT; light. Vent, ventilation. PD; pressure drop. Circ; circumference in mm. FL; Flength; filter length. Tob wt; tobacco weight. Cig wt; cigarette weight. Dens; density. Rec tob; reconstituted tobacco. Exp tob; expanded tobacco. Tobnic; tobacco nicotine level. Smoke nic; smoke nicotine level. PM; Philip Morris International. RJR; R.J. Reynolds Tobacco Company. BW; Brown & Williamson Tobacco Corporation. BAT; British American Tobacco. IMP; Imperial Tobacco.

Supplementary materials

Supplementary Table 2. Overview parameters and statistical results

Parameter group	Parameter	Min	Max	Average	CV (%)	%Var in/tot	Role
Measures	Length (mm)	69	99	85	8	56	large
	Diameter (mm)	5.4	8.3	7.7	7	28	.
	Weight (mg)	513	1078	859	11	33	.
	TobaccoWeight (mg)	354	810	615	13	47	large
	FilterLength (mm)	0	30	24	22	61	large
Filter ventilation	FilterVentilation (%)	0	90	39	44	56	large
	FilterDropPressureClosed	50	243	122	34	27	.
	FilterDropPressureOpen (mmH2O)	40	286	91	28	78	large
TNCO	Tar (mg)	1.0	10.0	7.8	31	66	large
	Nicotine (mg)	0.1	1.0	0.6	30	63	large
	CO (mg)	1.0	10.0	8.2	29	58	large
Tobacco composition	part type: Tobacco leaf	8	100	58	35	17	small
	part type: Cut stems	0	73	20	66	42	.
	part type: Reconstituted tobacco	0	31	6	101	23	.
	part type: Expanded tobacco	0	63	16	92	23	.
	part type: Other/Unspecified	0	7	0	714	0	small
	leaf type: Virginia	11	95	59	31	25	.
	leaf type: Burley	0	42	19	50	30	.
	leaf type: Oriental	0	18	7	61	33	.
	leaf type: Kentucky	0	4	0	1015	84	.
	leaf type: Dark	0	43	1	713	81	.
	leaf type: Other	0	75	10	183	4	small
	leaf type: Unspecified	0	31	4	154	8	small
	cure method: Air	0	77	22	60	41	.
	cure method: Fire	0	4	0	1015	84	.
	cure method: Sun	0	18	6	79	17	small
	cure method: Flue	11	95	59	30	26	.
	cure method: Other	0	75	13	139	6	small
Number of additives	Grand Total	14	115	61.9	40	27	.
by category	tobacco (burnt)	0	72	21.7	86	25	.
	paper (burnt)	4	13	6.3	36	16	small
	side seam adhesive (burnt)	0	5	2.4	50	33	.
	inks used on cigarette paper (burnt)	0	12	2.0	150	46	large
	filtration material (unburnt)	0	9	3.9	48	10	small
	filter overwrap (unburnt)	0	10	4.9	40	48	large
	filter adhesive (unburnt)	0	14	5.5	56	22	.
	tipping paper and tipping paper inks	0	30	15.0	36	57	large
	adhesive (unburnt)	0	3	0.3	279	0	small
	adhesive (burnt)	0	1	0.0	714	0	small
by function	Adhesive	0	11	3.6	70	32	.
	Binder	2	19	8.1	44	32	.
	Carrier	0	6	1.2	129	9	small
	Colour	0	16	5.1	98	23	.
	Combustion Modifier	0	3	1.2	69	36	.
	Casing	0	5	0.7	246	15	small
	Fibre	0	5	2.7	54	17	small
	Filler	2	30	7.2	76	34	.
	Filter Component	0	1	0.1	325	0	small
	Filtration Material	0	2	0.8	67	20	.
	Flavour and/or Taste Enhancer	0	67	13.7	118	25	.
	Humectant	0	5	2.2	57	37	.
	Plasticiser	0	5	2.1	62	21	.
	Preservative	0	11	0.8	251	69	large
	Solvent - Processing Aid	0	19	3.9	123	2	small
	Reduced Ignition Propensity Agent	0	1	0.1	291	34	.
	Sizing Agent	0	5	1.6	77	49	large
	Water-Wetting Agents	0	1	0.0	500	0	small
	Viscosity Modifier	0	2	0.1	368	71	large
	Other	0	52	6.6	222	23	.

For each parameter, we determined summary statistics such as minimum, maximum, average and coefficient of variation (CV) over the set of 103 cigarettes. Using analysis of variance (ANOVA), we determined for each parameter the total variation and extent to which this could

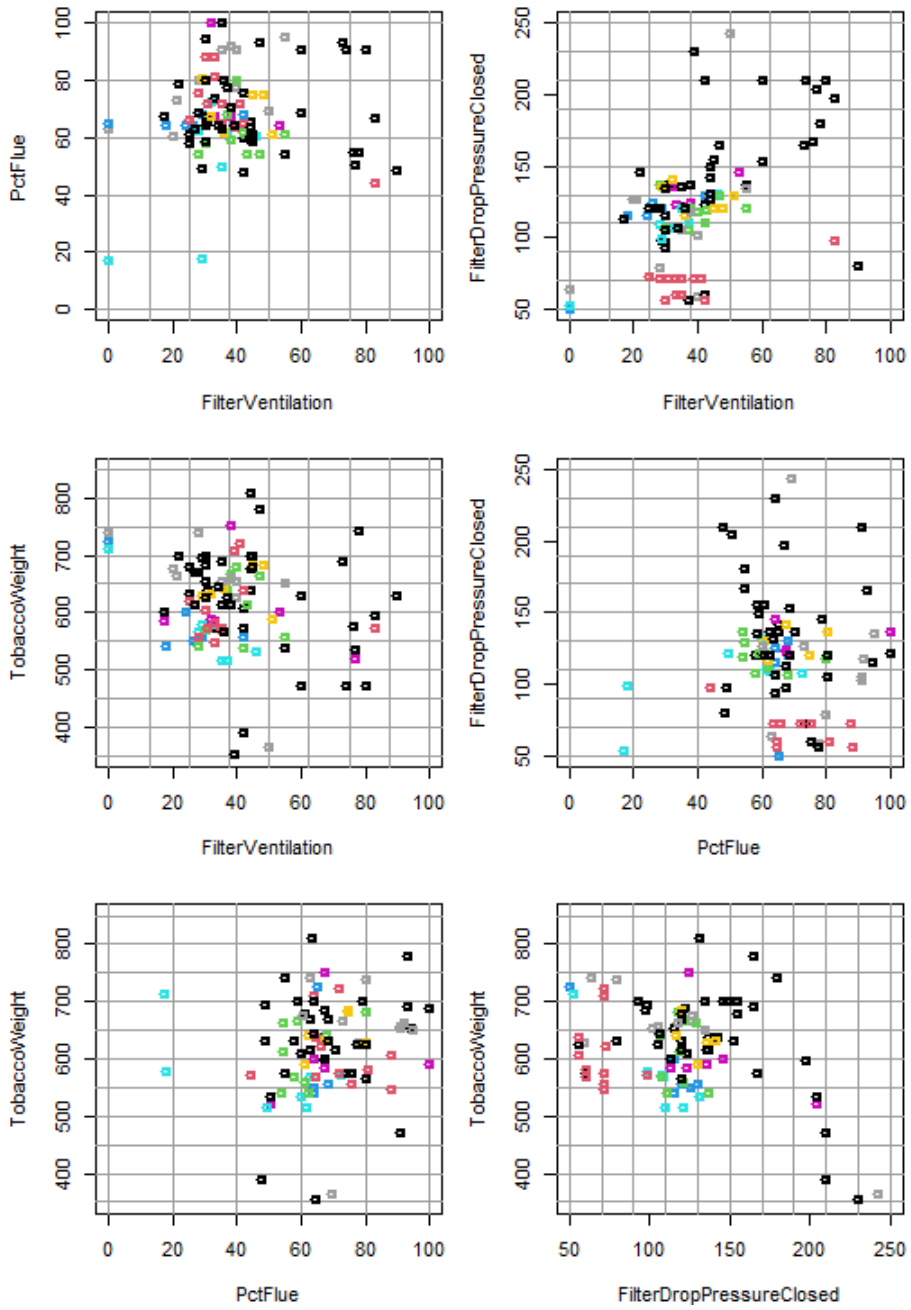
be attributed to within-brand variation. If this value (%Var in/tot) was more than 45% and at least three brands showed within-brand variation, we considered that *within*-brand variations played a large role in explaining total market variation with regard to manufacturers and/or consumers. On the other 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.

Supplementary Table 3: Laboratory results compared to EU-CEG data (in this table the results lower than the EU-CEG data are presented in different shades of blue, the higher results in red, with increasing intensities related to larger differences)

Product ID	EU-CEG data					Measured results				
	Nicotine (mm/cig)	Filter length (mm)	Filter Drop Pressure Closed (mmWg)	Filter Drop Pressure Open (mmWg)	Filter Ventilation (%)	Filter wrapper length (mm)	Filter length (mm)	Filter Drop Pressure Closed (mmWg)	Filter Drop Pressure Open (mmWg)	Filter Ventilation (%)
TP-2020-01	0.9	27	124	85	38	32	26	108	77	37
TP-2020-02	0.6	30	243	137	50	35	30	241	143	56
TP-2020-03	0.6	27	137	107	28	31	27	131	99	28
TP-2020-04	0.8	22	120	97	27	27	22	117	95	27
TP-2020-05	0.6	27	72	89	31	33	26	118	92	25
TP-2020-06	0.8	27	131	87	44	26	21	129	103	28
TP-2020-07	0.8	27	113	93	17	32	27	108	92	18
TP-2020-08	0.6	30	210	130	42	35	30	170	139	41
TP-2020-09	0.7	21	73	100	25	26	21	94	69	37
TP-2020-10	0.6	27	136	96	35	33	27	131	98	35
TP-2020-11	0.7	21	56	74	42	25	21	119	96	26
TP-2020-12	0.7	27	120	91	27	33	27	137	99	37
TP-2020-13	0.7	27	72	90	39	33	27	120	83	40
TP-2020-14	0.5	27	131	92	46	25	21	102	85	24
TP-2020-15	0.1	27	204	83	77	32	28	203	82	79
TP-2020-16	0.6	27	110	77	37	32	27	125	89	37
TP-2020-17	0.7	27	60	75	35	32	28	105	82	27
TP-2020-18	0.3	27	210	105	74	31	27	214	97	76
TP-2020-19	0.6	27	60	80	42	32	28	122	93	28
TP-2020-20	0.8	21	105	85	30	25	21	109	86	29
TP-2020-21	0.6	27	137	89	38	32	28	138	94	38
TP-2020-22	0.8	22	97	85	30	33	28	116	70	43
TP-2020-23	0.8	21	109	86	28	25	21	100	80	27
TP-2020-24	0.4	27	167	45	76	32	27	160	43	78
TP-2020-26	0.7	27	119	85	43	25	21	111	90	26
TP-2020-27	0.6	27	80	80	90	33	27	124	93	34
TP-2020-28	0.3	27	165	85	73	32	27	165	87	69
TP-2020-30	0.6	27	136	103	32	33	27	133	96	33
TP-2020-31	0.7	21	56	77	37	25	21	125	93	30
TP-2020-32	0.6	27	210	120	60	32	27	212	128	56
TP-2020-33	0.8	21	105	85	30	25	21	109	87	28
TP-2020-34	0.5	27	180	43	78	32	27	168	58	74
TP-2020-37	0.7	21	106	76	37	33	27	134	102	28
TP-2020-38	0.6	27	72	91	33	32	28	115	86	30
TP-2020-39	0.1	27	210	80	80	32	27	218	69	83
TP-2020-40	0.6	30	230	150	39	36	30	165	157	39
TP-2020-41	0.4	27	146	88	53	33	27	143	85	54
TP-2020-42	0.1	27	197	59	83	32	27	150	77	69
TP-2020-43	0.7	27	125	100	26	33	27	128	103	25
TP-2020-44	0.7	27	60	83	33	33	26	134	96	35
TP-2020-45	0.7	27	136	104	29	33	27	131	98	31
TP-2020-46	0.8	21	107	83	30	25	21	131	96	34
TP-2020-47	0.6	27	136	103	32	32	27	125	95	30
TP-2020-48	0.5	27	130	79	51	32	27	130	81	52
TP-2020-49	0.8	22	98	85	29	27	22	105	79	34
TP-2020-50	0.9	21	115	95	24	25	22	123	101	25
TP-2020-51	0.6	27	123	81	42	31	27	127	84	44
TP-2020-52	0.5	27	130	95	42	33	27	140	98	41
TP-2020-53	0.7	27	118	79	40	32	27	131	93	37
TP-2020-54	0.8	27	120	91	25	31	26	122	98	25
TP-2020-55	0.3	27	210	105	74	32	27	213	102	74
TP-2020-56	0.9	21	165	110	47	25	21	161	119	39
TP-2020-57	0.4	27	137	107	55	33	27	151	83	53
TP-2020-58	0.1	27	98	63	83	33	27	178	70	84
TP-2020-59	0.7	27	120	95	29	33	27	130	101	29
TP-2020-60	0.8	22	116	85	36	26	22	128	93	37

Measured result < 95% EU-CEG data
Measured result < 90% EU-CEG data
Measured result < 85% EU-CEG data
Measured result < 80% EU-CEG data
Measured result < 50% EU-CEG data

Measured result > 105% EU-CEG data
Measured result > 110% EU-CEG data
Measured result > 115% EU-CEG data
Measured result > 120% EU-CEG data
Measured result > 150% EU-CEG data



Supplementary Figure 1: Product characteristics plots. Colored dots indicate different brands with five or more varieties, black dots brands with two to four varieties, grey dots brands with a single variety. Grey lines are spaced by consumer discrimination thresholds.