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Sensory methods to evaluate perception of flavours in tobacco and other nicotine-containing products: a review

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ABSTRACT

Objectives Sensory methods use human senses to evaluate product attributes. This review provides an overview of the types of sensory methods used to evaluate the perception of flavour in tobacco and other nicotine-containing (ToNic) products and to discuss how sensory data could inform flavoured ToNic product policy.

Data sources PubMed, Embase and Web of Science.

Study selection All peer-reviewed studies evaluating ToNic products using a sensory method published before 23 May 2020.

Data extraction Two independent coders completed title/abstract and full-text screening to choose articles for inclusion (Cohen's kappa=0.85, strong agreement). Each coder completed data extraction on half the articles, recording relevant information (eg, sensory methods used, results). The coders categorised sensory methods and generated overarching themes.

Data synthesis Of 110 articles identified, we included 29 articles containing 35 studies that used sensory methods to investigate ToNic products. The sensory methods included analytic methods such as discrimination and descriptive tests and hedonic methods such as liking tests. Six themes emerged regarding how sensory methods can be used to understand consumer perception and liking of ToNic products and to inform ToNic product policy.

Conclusions The identified studies highlight that sensory data can inform ToNic product policy. Analytic and sensory hedonic ratings can be used to assess a ToNic product's ability to promote addiction in the user (ie, abuse liability). Lastly, hedonic ratings can provide information to assess potential use behaviours.

INTRODUCTION

Data from the 2019 National Youth Tobacco Survey indicate that 69.6% (approximately 4.3 million) middle and high school current tobacco users in the USA report using flavoured (ie, menthol (mint), alcohol (wine or cognac), candy, fruit, chocolate or other sweets) products, such as cigarettes, cigars, electronic cigarettes (e-cigarettes), smokeless tobacco, hookah and pipe tobacco.[1] Available data from other regions also support that flavours other than tobacco are popular among youth. In the European Union (EU), younger respondents are much more likely to prefer fruit-flavoured e-cigarettes (72% compared with 17% of the oldest cohort) and somewhat more likely to prefer candy-flavoured e-cigarettes (22% compared with 11%).[2] Also, the market for flavoured capsule cigarettes has increased globally, with five Latin American countries (Chile, Peru, Guatemala, Mexico and Argentina) having the highest market share for these tobacco products.[3 4] Research shows that younger individuals are more likely to use flavoured capsule cigarettes,[5] and youth rate flavoured capsule cigarettes as more attractive than non-capsule cigarettes and indicate more willingness to try them.[6]

Flavours play a key role in how users and non-users, particularly youth, initiate and continue using tobacco and other nicotine-containing (ToNic) products.[7] Longitudinal data from the US Population Assessment of Tobacco and Health Study (2013–2015) show that initiating with a flavoured product can lead to regular use for youth (ages 12–17), young adults (ages 18–24) and adults (ages 25+).[8] Research also shows that flavours influence product appeal and harm perceptions. Flavours can modulate the sensory (eg, sweetness, cooling, irritation) and reinforcing effects of ToNic products, thereby facilitating product use and potentially increasing product abuse liability.[9–11] Some flavours may alter product use behaviour and nicotine exposure in users, which influences product abuse liability.[12–15] Additionally, data show that youth who currently or had ever used e-cigarettes were more likely than non-users to perceive flavoured e-cigarettes as less harmful than non-flavoured e-cigarettes.[16]

Eleven countries and the EU have some type of flavoured tobacco regulation.[17] In the USA, the Family Smoking Prevention and Tobacco Control Act (FSPTCA) outlines flavour regulations for cigarettes and roll-your-own (RYO) tobacco. The FSPTCA prohibits a cigarette or any of its component parts (ie, tobacco, filter, paper) from containing a characterising flavour other than tobacco or menthol. In February 2020, the US Food and Drug Administration (FDA) finalised a guidance prioritising enforcement against flavoured (other than tobacco or menthol) prefilled pod or cartridge-based e-cigarettes. There are currently no flavour restrictions for other tobacco products; however, FDA has taken action against companies that sell or distribute e-liquids imitating packaging for food products that are often marketed and appeal to youth, such as candy, cereal and/or soda.

In the EU, the Tobacco Product Directive (TPD) also outlines flavour regulations for cigarettes and RYO tobacco and prohibits the marketing of cigarettes and RYO tobacco with a characterising flavour other than tobacco. No overarching flavour

regulation currently exists for cigars, hookah, smokeless tobacco or other tobacco products such as heated tobacco. The TPD gives member states the authority to regulate e-liquid flavours.

Sensory research uses human senses (eg, smell, taste) to investigate perception of product attributes such as flavours. Employing sensory methodologies to understand human perception of flavoured ToNic products could inform ToNic product policies.

The objectives of our research are twofold: to provide an overview of the types of sensory methods used to evaluate the perception of flavour in ToNic products by systematically reviewing peer-reviewed literature and to discuss how sensory methodologies could inform ToNic product policy.

METHODS

Data sources

We worked with an informationist and a panel of sensory research experts to develop the search strings for the literature search. We included general (eg, tobacco) and specific (eg, e-cigarette) tobacco product terms, as well as general (eg, sensory) and specific (eg, chemesthesis) sensory terms. The final search strings for each data source are included in online supplemental file 1. We searched three data sources (PubMed, Embase and Web of Science) with no starting limits on the time period. We completed the search on 22 May 2020. We identified two additional articles from citation tracking.

Study selection

Figure 1 depicts the Preferred Reporting Items for Systematic Reviews and Meta-Analyses diagram for this review. To select studies for this review, the first two authors independently completed title/abstract screening of the citations and excluded studies that were not in English, not about tobacco and/or nicotine-containing products, did not use a sensory method, review articles, animal studies and conference abstracts. The coders had strong agreement for title/abstract screening (Cohen's kappa=0.85).[18] The coders discussed any disagreements and made a joint decision on whether to include or exclude the study. Next, the coders completed full-text screening and had moderate agreement (Cohen's kappa=0.72).[18] Again, the coders discussed any disagreements and made a joint decision on whether to include or exclude the study. Twenty-nine articles containing 35 studies are included in this systematic review.

Data extraction and risk of bias assessment

After full-text screening, each coder completed data extraction on half of the included articles. Specifically, coders recorded

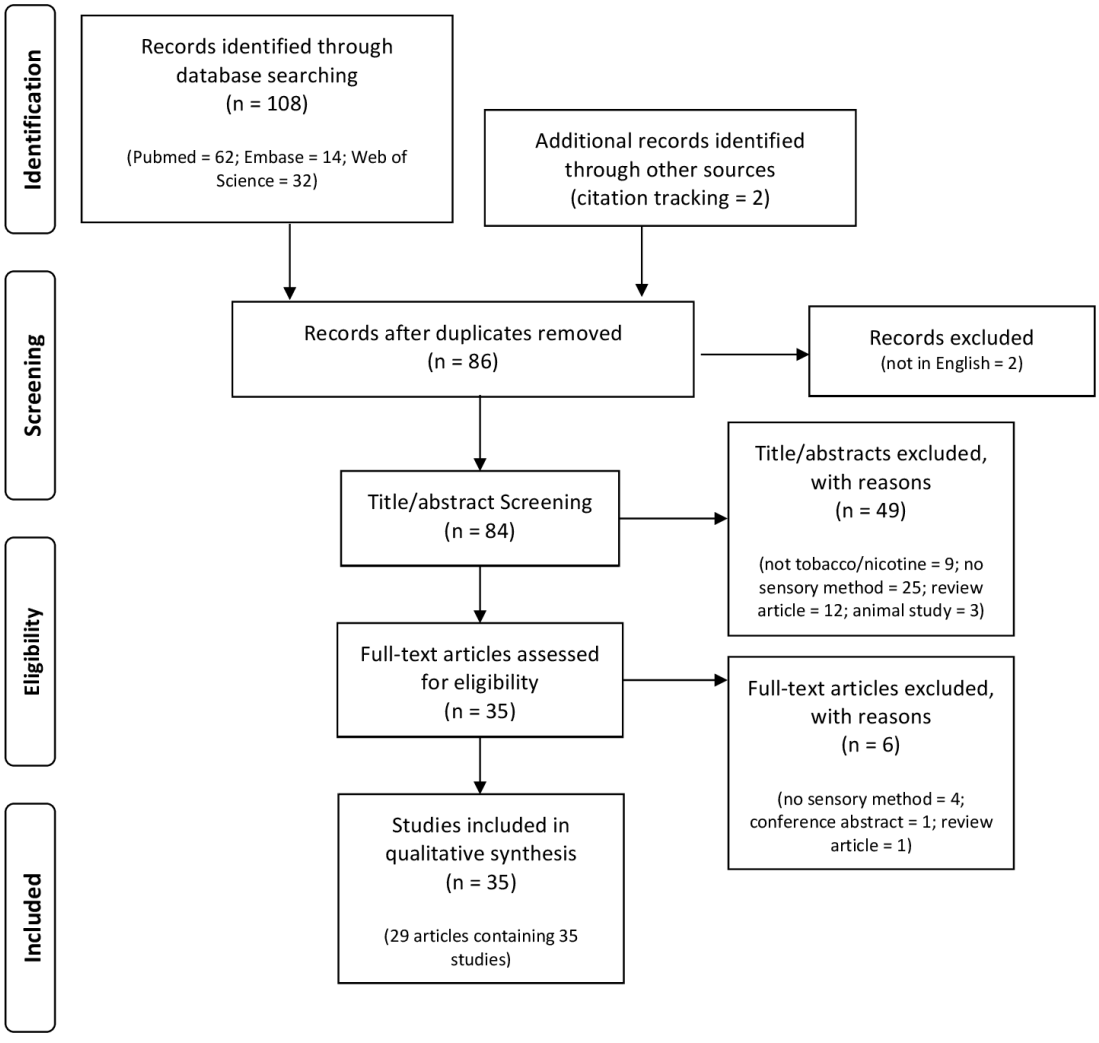

Figure 1 PRISMA flow diagram. From Moher *et al*.[66] For more information, visit www.prisma-statement.org. PRISMA, Preferred Reporting Items for Systematic Reviews and Meta-Analyses.

data on the ToNic product studied, research objective, research subjects, study design, sensory methods used, results and the main discussion points from each study. The coders noted any risk of biases, such as type of research (eg, academic), funding source, relevance, strength of evidence (ie, low, medium or high quality) and validity issues. After data extraction, the coders discussed any risk of bias findings and made a final determination to include or exclude the article. The coders did not exclude any articles after the risk of bias assessment; however, they identified industry-funded research as a potential risk of bias. For transparency, industry-funded research is flagged with an asterisk in the review.

Coded variables

To categorise the sensory methods used in each study, both coders categorised all sensory methods as analytic or hedonic and then specified the test (eg, descriptive, liking). Analytic methods quantify the chemical and physical properties of products. Examples of analytic methods include discrimination tests, which provide scientific evidence that two products are or are not perceptually different, and descriptive tests, which usually use trained panellists to obtain complete sensory descriptions of products on various attributes, making it possible to identify underlying (ingredient or process) variables.[19] Hedonic methods describe the degree of consumer acceptance and preference for products. An example of a hedonic method includes liking tests, which measure how much a participant likes a product.[19] When the coders disagreed, they discussed the coding decision until they came to an agreement.

The first coder reviewed the extracted data and generated themes using a conventional content analysis method, focusing on the contextual meaning of the text.[20] This approach is informed by grounded theory where the goal is to broadly describe the phenomenon with no preconceived ideas of categories or themes that might emerge from the data.[21] The second coder reviewed the extracted data as well as the suggested themes from the first coder. Both coders discussed and came to an agreement on the final themes that emerged from the studies, as well as the final categorisation of studies by theme.

RESULTS

The ToNic products included were cigarettes and RYO tobacco (n=13),[22–34] e-cigarettes and e-liquids (n=10),[11 35–43] nicotine replacement therapy (NRT; eg, nicotine gum; n=5),[44–48] and other products (eg, 'novel hybrid tobacco vapor product'; n=3).[27 30 49]

The sensory methods used included analytic methods such as discrimination and descriptive tests and hedonic methods such as liking tests. While the search identified articles using focus groups, where participants rated or described their perceptions of different ToNic products, we did not include these studies because the researchers did not use sensory methods to collect information on human senses.

Six themes emerged related to how sensory methods and data can be used to understand consumer perception and liking of ToNic products and to inform ToNic product policy. Table 1 summarises the extracted themes by citation, product tested, sensory method and type of sensory test used.

Theme 1: sensory methods can inform ToNic product development and acceptance

Similar to food and consumer science research, expert sensory panels (ie, individuals trained to assess attributes) are used in research and development of new ToNic products. In one study, Poynton and colleagues[49]* used two expert panels and both descriptive and discrimination methods to inform the research and development of a 'novel hybrid tobacco vapor product': an electronic vapour device using non-flavoured propylene glycol (PG), vegetable glycerin (VG), water, nicotine and a 130 mg blended tobacco plug. An expert panel (23 panellists) compared the hybrid product with a closed system device using 'blended tobacco' e-liquid and confirmed significant sensory differences between them. Another expert panel (eight panellists) used descriptive methods to assess the sensory attributes of the hybrid product, including mechanics (ease of draw), strength, flavour and taste, mouthfeel, and consistency of flavour. Additionally, Lin and colleagues[23] conducted a study to inform the research and development of cigarettes with lower toxicant yields. An expert panel (11 men, 2 women) used descriptive methods to assess the sensory attributes (impact, irritation, off-taste, aroma and softness) of tobacco treated to reduce alkaloids. Overall, researchers found relationships between the presence of tobacco alkaloids and sensory attributes. Specifically, they found positive correlations between off-taste, irritation and impact attributes, and negative correlations between alkaloid levels and aroma and softness attributes.

Sensory panels have also been used to conduct research on making current ToNic products more acceptable to consumers. Yin and colleagues[24] characterised the sensory attributes of Chinese faint-scent cigarettes to understand which chemical compounds were responsible for specific sensory attributes in the cigarettes; the knowledge would be helpful for improving the characteristic aroma of Chinese faint-scent cigarettes. The study combined a sensory panel with chemical analyses to show that various attributes are correlated with specific compounds. An expert panel (eight men, four women) used descriptive methods to assess 12 sensory attributes (freshness, scorched, baked, spicy, acidic, sweet, fruity, creamy, flowery, balsamic, fresh-green and herbaceous) of eight different brands of Chinese cigarettes. The researchers then used gas chromatography-mass spectrometry to detect volatile compounds in the mainstream smoke. Using partial least squares regression, the researchers identified 67 volatile compounds correlating to freshness, acidic and flowery aroma attributes. Researchers have also used untrained consumers to complete hedonic and descriptive sensory assessments of product acceptability after using ToNic products. Five clinical laboratory studies researched the acceptability of oral or inhaled NRT products or cigarettes.[27 30 46–48] These studies provided sensory information such as liking, satisfaction, mouthfeel and perceived strength of flavour.

Theme 2: smelling can detect flavour and evaluate liking of ToNic products

Four manuscripts described methods where participants smelled (instead of used) a ToNic product and completed sensory measures.[22 29*33 39] Krüsemann and colleagues[29] conducted a study where 20 non-smoking women detected menthol odour in cigarettes using discrimination methods. Two studies described training expert panels to smell tobacco products and identify sensory attributes using descriptive methods,[22 *33] both for European regulatory purposes. In another study, Krüsemann and colleagues[39] compared participants' hedonic ratings of various flavoured e-liquids while smelling and vaping. The group found that smelling and vaping hedonic measures correlated strongly; therefore, smelling could be used in future studies where recruiting participants to use nicotine-containing

Table 1 Extracted themes

Theme	Authors	Products	Sensory methods	Types of sensory test
Sensory methods can inform ToNic product development and acceptance.	Rose *et al*[27]	Cigarettes, nicotine inhaler	Analytic	Descriptive
	Levin *et al*[30]	Cigarettes	Hedonic	Liking
	Lin *et al*[23]	Cigarettes	Analytic	Descriptive
	Yin *et al*[24]	Cigarettes	Analytic	Descriptive
	Arendt Nielsen *et al*[46]	Nicotine gum	Analytic	Descriptive
	Jensen *et al*[47]	Nicotine gum	Analytic	Descriptive
	Muramoto *et al*[48]	Nicotine lozenge	Hedonic	Liking
	Poynton *et al*[49]*	Novel tobacco vapour product	Analytic	Discrimination, descriptive
Smelling can detect flavour and evaluate liking of ToNic products.	Chambers and Paschke[33]*	Cigarettes, RYO	Analytic	Descriptive
	Krüsemann *et al*[22]	Cigarettes, RYO	Analytic	Descriptive
	Krüsemann *et al*[29]	Cigarettes	Analytic	Discrimination
	Krüsemann *et al*[39]	E-liquids	Analytic, hedonic	Descriptive, liking
Individual human factors can influence sensory perception.	Ashley *et al*[28]*	Cigarettes	Analytic, hedonic	Descriptive, liking
	Skaczkowski *et al*[32]	Cigarettes	Analytic, hedonic	Descriptive, liking
	Skaczkowski *et al*[31]	Cigarettes	Analytic, hedonic	Descriptive, liking
	Krishnan-Sarin *et al*[11]	E-cigarettes	Hedonic	Liking
	Leventhal *et al*[42]	E-cigarettes	Analytic, hedonic	Descriptive, liking
	Mead *et al*[35]	E-cigarettes	Analytic, hedonic	Descriptive, liking
	Krüsemann *et al*[39]	E-liquids	Analytic, hedonic	Descriptive, liking
	Pang *et al*[40]	E-cigarettes	Hedonic	Liking
	Ahijevych *et al*[45]	Nicotine lozenges, nicotine inhaler	Analytic, hedonic	Descriptive, liking
Flavours can enhance sensory attributes and liking of ToNic products.	Kim *et al*[43]	E-cigarettes	Analytic, hedonic	Descriptive, liking
	Krishnan-Sarin *et al*[11]	E-cigarettes	Hedonic	Liking
	Leventhal *et al*[42]	E-cigarettes	Analytic, hedonic	Descriptive, liking
	Mead *et al*[35]	E-cigarettes	Analytic, hedonic	Descriptive, liking
	Muramoto *et al*[48]	Nicotine lozenge	Analytic, hedonic	Descriptive, liking
Sensory methods can identify perceptions of non-flavoured ToNic product attributes.	Jaffe and Glaros[34]	Cigarettes	Analytic	Discrimination, descriptive
	Kochhar and Warburton[25]	Cigarettes	Analytic, hedonic	Descriptive, liking
	Pritchard *et al*[26]*	Cigarettes	Analytic, hedonic	Descriptive, liking
	Goldenson *et al*[36]	E-cigarettes	Analytic, hedonic	Descriptive, liking
	Leventhal *et al*[42]	E-cigarettes	Analytic, hedonic	Descriptive, liking
	Mead *et al*[35]	E-cigarettes	Analytic, hedonic	Descriptive, liking
	Pullicin *et al*[41]	E-cigarettes	Analytic, hedonic	Descriptive, liking
	Leischow *et al*[44]	Nicotine gum	Analytic	Descriptive
	Arendt Nielsen *et al*[46]	Nicotine gum	Analytic	Descriptive
	Harvanko *et al*[38]	E-cigarettes	Analytic, hedonic	Descriptive, liking
Flavours can interact with nicotine-specific sensory attributes to influence product acceptability, palatability and liking.	Pritchard *et al*[26]*	Cigarettes	Analytic, hedonic	Descriptive, liking
	Rose *et al*[27]	Cigarettes, nicotine inhaler	Analytic	Descriptive
	Goldenson *et al*[36]	E-cigarettes	Analytic, hedonic	Descriptive, liking
	Rosbrook and Green[37]	E-cigarettes	Analytic, hedonic	Descriptive, liking
	Leventhal *et al*[42]	E-cigarettes	Analytic, hedonic	Descriptive, liking
	Pullicin *et al*[41]	E-cigarettes	Analytic, hedonic	Descriptive, liking
	Arendt Nielsen *et al*[46]	Nicotine gum	Analytic	Descriptive
	Jensen *et al*[47]	Nicotine gum	Analytic	Descriptive

*Industry-funded research.
E-cigarettes, electronic cigarettes; RYO, roll-your-own; ToNic, tobacco and other nicotine-containing products.

products could be unethical (eg, nicotine-naïve individuals, youth).

Theme 3: individual human factors can influence sensory perception

Studies found that sensory perceptions of ToNic products are influenced by a variety of individual human factors including tobacco user status, age, sex, taste phenotype and brand preference. Researchers have used hedonic methods to show that liking for some flavours differed across different groups of ToNic product users. For example, adult cigarette smokers reported no difference in liking between fruit-flavoured and sweet-flavoured (ie, cherry, chocolate) versus unflavoured e-cigarettes,[35] while young adult current e-cigarette users reported increased appeal with fruit-flavoured e-cigarettes compared with tobacco flavour.[42] Other studies have found that menthol flavour (compared with all other flavours) had higher e-cigarette liking scores and improved taste across youth, young adult and adult product users.[11 35 42] Additionally, among cigarette smokers, Ashley and colleagues*[28] analysed the effect of menthol concentration and noted differences in regular and occasional menthol smokers in Japan and Poland using the following attributes: irritation, throat catch, strength of menthol taste, cooling effect and overall liking. They found

that occasional menthol smokers in Japan perceived menthol cigarettes as irritating, and throat catch intensity increased with menthol concentration. Regular menthol smokers from both countries found no difference in perceived irritation between menthol concentrations, reported significant reductions in perceived throat catch intensity at higher menthol concentrations, and indicated increased overall product liking compared with occasional menthol smokers. Krüsemann and colleagues[39] recruited both smokers and non-smokers to compare hedonic ratings of smelling and vaping e-liquids. They found that non-smokers' mean liking ratings were highest for sweet flavours like strawberry, watermelon and caramel, and smokers' mean liking ratings were highest for mint and peppermint. Despite these suggestive differences, the overall differences in flavour liking between non-smokers and smokers for the individual e-liquid flavours were not statistically significant.

A smaller body of literature evaluated the influence of sex and genetic differences on sensory perception. Using hedonic measures in a laboratory vaping study, Pang and colleagues[40] investigated sex differences in ratings of e-cigarette flavour liking and willingness to use. The results indicated slight preference differences between men and women: men preferred fruit-flavoured e-cigarettes, while women preferred both fruit-flavoured and menthol-flavoured e-cigarettes. Ahijevych and colleagues[45] assessed the relationship between individuals' bitterness perception from their ability to taste n-6-propylthiouracil and sensory experience following use of NRT (ie, nicotine lozenges and inhaler). The n-6-propylthiouracil taste phenotype was not associated with strength of sensation, liking or satisfaction of NRT.

Research also suggests that brand name preference can alter sensory perception of ToNic products. Two studies assessed the impact of brand names on participants' sensory evaluation of cigarettes in Australia.[31 32] In one study, participants smoked two identical cigarettes: one depicting a premium brand name and one depicting a value (ie, less expensive) brand name. Participants rated the cigarettes using hedonic and descriptive measures.[32] Cigarettes smoked from packs displaying premium brand names were rated as having better taste, being less harsh and being less dry than identical cigarettes smoked from packs displaying value brand names. In the second study, participants smoked two identical cigarettes: one depicting a premium brand name and one with the brand name masked.[31] Using hedonic and descriptive measures, participants rated the branded cigarette as having more favourable and less stale taste and reported higher purchase intent compared with the masked cigarette.

Theme 4: flavours can enhance sensory attributes and liking of ToNic products

Sensory research using both analytic and hedonic measures shows that flavours affect consumer perception of ToNic products. Kim and colleagues[43] assessed the relationship between consumer perception of sweetness, coolness, bitterness, harshness and flavour and participants' liking of e-cigarettes. They found that sweetness and coolness were positively correlated with liking, while harshness and bitterness were negatively correlated with liking. Two studies used descriptive methods to determine that fruit (eg, cherry) flavoured e-cigarettes were perceived as sweeter, smoother and less bitter than unflavoured and tobacco-flavoured e-cigarettes among adult ToNic product users.[35 42] In another study of youth e-cigarette users, researchers observed that cooling sensations increased with increased menthol e-liquid concentration relative to no menthol.[11] Participants in a study using hedonic methods to assess the efficacy of NRT products rated peppermint and cinnamon flavours as more appealing than plain flavour (ie, unflavoured).[48]

Theme 5: sensory methods can identify perceptions of non-flavoured ToNic product attributes

Our search identified articles that used sensory methods to evaluate perceptions of non-flavoured ToNic product attributes. Nicotine is the primary addictive constituent found in ToNic products[50] and is described as bitter tasting.[51 52] Nicotine also activates multiple sensory systems[53] and produces measurable sensory effects in consumers. Studies using descriptive methods have found that nicotine in e-cigarettes increased perceived throat hit, bitterness, irritation and harshness in users[35 36 41 42]; these effects of nicotine increased with increasing nicotine concentration. Three studies assessed smokers' sensory perception of nicotine in cigarettes.[25 *26 34] The studies used analytic methods to provide descriptive measures of sensory attributes (eg, impact to the nose, mouth, chest and throat, smoothness, harshness, strength, and tobacco taste)[25 *26 34] and hedonic measures of satisfaction (ie, liking) following product use.[25 *26] While the results for some sensory attributes did not provide interpretable patterns for determining sensory differences by nicotine yield, product acceptance and liking were significant. The results yielded similar patterns, with the higher nicotine/tar cigarettes having greater acceptance/liking than the low nicotine/tar cigarettes. Jaffe and Glaros[34] also used analytic discrimination methods and found that smokers could detect differences between commercial cigarettes of varying levels of nicotine, carbon monoxide and tar.

Pritchard and colleagues[*26] noted that sensory factors may be as important as nicotine pharmacology in affecting smokers' ratings of liking and product acceptance. Another study evaluated the effects of nicotine and interactions with menthol inside the mouth. Healthy non-smokers provided descriptive ratings after chewing varying doses of nicotine gum.[46] Compared with placebo (ie, 0 mg nicotine gum), gums containing nicotine were associated with greater perceptions of bitterness, warming sensation, burning sensation and strength. The results revealed that nicotine-containing gums (compared with placebo) elevated pain and irritation intensity. Similarly, Leischow and colleagues[44] conducted a dose–response study to compare the short-term sensory effects of five nicotine gum formulations (three placebo and two treatment). The results revealed sensory differences between the nicotine formulations.

Sensory methods have also been used to evaluate the effect of PG and VG content in e-cigarettes on nicotine, overall product liking and other sensory attributes (eg, throat hit, strength of the puffs).[38] Using descriptive sensory methods, e-cigarette users detected inhalation sensation differences among different mixtures of PG and VG.

Theme 6: flavours can interact with nicotine-specific sensory attributes to influence product acceptability, palatability and liking

Studies support that sensory methods can evaluate how flavours interact with nicotine-specific sensory attributes to impact product acceptability and liking, including reducing nicotine's harshness and masking its bitter taste.[*26 27 36 37 41 42 46 47] For example, Rosbrook and Green[37] used descriptive and hedonic measures to evaluate the interaction of menthol and nicotine in e-cigarettes in current menthol cigarette smokers. Researchers instructed subjects to inhale colour-coded only (ie, no flavour or nicotine concentration information) e-cigarettes and to

complete ratings of overall sensation, coolness/cold, harshness/irritancy and liking/disliking. The results showed that a high concentration of menthol increased the overall sensation of e-cigarettes containing a low concentration of nicotine. In addition, participants' ratings of menthol coolness/cold were higher among higher nicotine concentrations, and menthol reduced the perceived harshness of high nicotine concentrations. Researchers have identified similar findings among young adult current e-cigarette users, where descriptive and hedonic measures identified that nicotine increased bitterness and harshness and reduced appeal and smoothness in e-cigarettes; these effects of nicotine were attenuated by fruit and menthol e-liquid flavours to a greater extent than by tobacco e-liquid flavour.[42]

DISCUSSION

We identified a growing body of literature describing sensory methods used in ToNic product research. Overall, we found 29 peer-reviewed articles containing 35 studies that investigated cigarettes and RYO tobacco, e-cigarettes and e-liquids, NRT, and other products using various sensory methods. The studies used analytic methods to measure descriptive sensory attributes (eg, harshness) and to detect differences, and hedonic methods to measure liking. Extracted themes show that sensory methods can inform both product development and product acceptance, as well as identify individual and product differences in sensory perception. Also, smelling can be used as a proxy for using ToNic products. The results show that (1) flavours can enhance liking of ToNic products, (2) sensory methods can identify perceptions of non-flavoured ToNic product attributes, and (3) flavours can interact with nicotine's sensory attributes to influence the product's acceptability, palatability and liking.

Implications

Results from studies using sensory methods to evaluate ToNic products can inform policymakers' knowledge of use behaviours. Analytic data may inform whether ingredient changes (eg, flavours, sweeteners) or changes in nicotine content are perceived by consumers and how those sensory perceptions differ between products. This information can inform regulation, given that sensory perceptions during product use can influence product acceptance and use behaviours.[54] Hedonic ratings in conjunction with nicotine pharmacokinetic or exposure assessments can be used to assess a ToNic product's abuse liability, which informs the likelihood of addiction in current users and non-users who might initiate use. Drug liking is associated with self-administration and has been shown to be the most sensitive and reliable subjective effects measure of abuse liability.[55] Generally, drugs with greater positive ratings of liking have greater abuse liability.[55]

Sensory findings may also provide insight into potential ToNic product use behaviours, which, from a regulatory perspective, is important for understanding population impact. To understand participants' perception and use intentions of flavoured ToNic products, studies have combined hedonic ratings (ie, liking) with self-reported measures of appeal (ie, willingness to use again).[36 40 42] Sensory data also support that flavours improve the taste and mask the harshness and bitterness of nicotine in ToNic products, which makes it easier to initiate and regularly use them.[56 57] Furthermore, studies have combined descriptive and hedonic sensory methods with mouth level exposure[*28] and topography measures,[38] which allows for an assessment of how sensory perceptions may influence individual product use behaviours. Hedonic ratings of products may reflect their ability to serve as suitable substitutes when evaluating product switching among current product users (eg, the likelihood of cigarette smokers completely switching to e-cigarette use).

Data from sensory panels assessing flavours can also be used for ToNic regulatory purposes. For example, sensory methods could assess whether an additive imparts a characterising flavour other than tobacco for regulatory and compliance purposes.[58] The EU uses sensory methods to evaluate flavours in two consumer products, olive oil[59] and butter.[60] Expert panels trained to assess several attributes are used to classify the quality grade of oil and to determine butter quality.[61 62] Talhout and colleagues[58] also discuss key decisions to consider when developing and validating sensory methods to assess flavours for regulatory and compliance purposes. First, one must determine a set of reference products for assessing against. Second, one must define the cut-offs for characterising flavour (eg, is it based on the percentage of the panel that can discern the flavour?). Third, one must decide when the test should occur (ie, before, during or after consumption). Fourth, one must determine the specificity of the characterising flavour description (eg, non-tobacco vs fruit-flavoured tobacco). Fifth, one must decide whether an expert or consumer panel can be used. Sixth, one must decide whether it is necessary to prove the tobacco additives impart the characterising flavour.

The EU also uses an expert panel complemented by a chemical assessment to assess via smelling whether characterising flavours are present in cigarettes and RYO tobacco. The methodology for sensory analysis is based on a comparison of aroma attributes of the test product with those of reference products.[63] The Health Effects Tobacco Composition consortium developed a proof of principle and recommended this concept to the European Commission.[64]

As training and maintaining sensory panels are costly, and thus a potential barrier for policymakers, a supranational sensory panel supporting several jurisdictions with sensory data could be considered. This panel could either be based in one location or in several locations worldwide. The latter would allow for intercultural comparisons and could be facilitated by holding testing sessions online. The classic sensory panel testing paradigm would need to be adapted with respect to factors such as the need for a common language, simultaneous testing by all panellists, distribution of samples and the role of the panel leader.

In addition to evaluating flavours, sensory methods can be included in regulatory policies. In June 2021, Health Canada proposed measures to restrict flavours in vaping products.[65] Their proposal included a measure to prescribe sensory attributes standards to prevent a sensory perception (smell, taste or chemesthesis) other than one that is typical of tobacco or of mint/menthol. This sensory standards measure in combination with the other measures (ie, restrictions on promotion/labelling and flavour ingredients including all sugars/sweeteners) would limit consumers' perceptual experience to tobacco or mint/menthol. Additionally, limiting the promotion/labelling to tobacco or mint/menthol would align the promoted flavour, the ingredients and the user experience.

Limitations

We limited our literature search to published literature in peer-reviewed journals; thus, we excluded tobacco industry documents from the Truth Tobacco Industry Documents archive and other non-peer-reviewed sources. Although we identified and included four articles written by industry-funded researchers,[*26 *28 *33 *49] we recognise that the industry may have conducted

What this paper adds

⇒ Sensory research uses human senses (eg, smell, taste) to investigate perception of product attributes such as flavours.
⇒ This study provides the first review of sensory methods used to evaluate perception of flavours in tobacco and other nicotine-containing (ToNic) products.
⇒ Sensory methods can inform knowledge of actual and potential ToNic product use behaviours.
⇒ Sensory methods can assess whether an additive imparts a characterising flavour other than tobacco.
⇒ Sensory methods can be included in ToNic product regulatory policies.

sensory research that is not represented in this review. Additionally, our search strategy did not include an exhaustive list of potential sensory terms. Consequently, there may be additional sensory research that is not represented in this review. Since our goal was to broadly identify ToNic product research using general sensory methods, future reviews can expand the search to include more specific sensory terms.

CONCLUSIONS

The studies in this review highlight that sensory methods can inform ToNic product policy. Sensory methods provide information on the ability of flavours and other product attributes to enhance liking of ToNic products and the ability to mask the harshness, irritation and bitterness associated with high nicotine concentrations in products. As ToNic products continue to be used throughout the world and new ToNic products are developed, future research can further inform sensory science's role in policy.

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Systematic review of sensory methods to evaluate perception of flavors in tobacco and other nicotine-containing products

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Supplemental Material : Database Search Strings

Completed searches 5/13/2019 and 5/22/2020

PUBMED

((((((((("tobacco"[MeSH Terms]) OR "tobacco products"[MeSH Terms]) OR "electronic nicotine delivery systems"[MeSH Terms]) OR "tobacco industry"[MeSH Terms])) OR ((((((((((((((((("cigarette"[Title/Abstract]) OR "e cigarette"[Title/Abstract]) OR "electronic cigarette"[Title/Abstract]) OR "electronic nicotine delivery"[Title/Abstract]) OR "e liquid"[Title/Abstract]) OR "cigar") OR "cigarillo"[Title/Abstract]) OR "little cigar"[Title/Abstract]) OR "hookah"[Title/Abstract]) OR "smokeless tobacco"[Title/Abstract]) OR "chew tobacco"[Title/Abstract]) OR "oral tobacco"[Title/Abstract]) OR "snuff tobacco"[Title/Abstract]) OR "pipe tobacco"[Title/Abstract]) OR "dissolvable tobacco"[Title/Abstract]) OR "nicotine"[Title/Abstract]))) OR "snus"[Title/Abstract])) AND ((((((((((((("flavoring agents"[MeSH Terms]) OR "sweetening agents"[MeSH Terms]) OR "flavor"[Title/Abstract]) OR "flavor/aroma"[Title/Abstract]) OR "flavor/odor"[Title/Abstract]) OR "flavour"[Title/Abstract]) OR "flavour/aroma"[Title/Abstract]) OR "flavour/odour"[Title/Abstract]) OR (("flavourant"[Title/Abstract] OR "flavourants"[Title/Abstract]))) OR "odorant"[Title/Abstract]) OR "odourant"[Title/Abstract]) OR "taste"[Title/Abstract]) OR (("taste/aroma"[Title/Abstract] OR "taste/flavor"[Title/Abstract] OR "taste/flavor/smell"[Title/Abstract] OR "taste/flavors"[Title/Abstract] OR "taste/flavour"[Title/Abstract] OR "taste/odor"[Title/Abstract] OR "taste/odour"[Title/Abstract])) OR "chemesthesis"[Title/Abstract])) AND ((("sensory"[Title/Abstract]) OR "chemosensory"[Title/Abstract]) AND ((evaluat* OR test OR tests OR panel OR detection OR method OR methods OR methodology)))) NOT ((((("rat"[Title/Abstract]) OR "rats"[Title/Abstract]) OR "mouse"[Title/Abstract]) OR "mice"[Title/Abstract])

EMBASE

'tobacco'/exp OR 'tobacco industry'/exp OR cigarette:ab,ti OR 'electronic cigarette':ab,ti OR 'e liquid':ab,ti OR cigar:ab,ti OR cigarillo:ab,ti OR 'little cigar':ab,ti OR hookah:ab,ti OR 'waterpipe tobacco':ab,ti OR 'smokeless tobacco':ab,ti OR 'chewing tobacco':ab,ti OR snus:ab,ti OR 'tobacco snuff':ab,ti OR 'pipe tobacco':ab,ti OR 'dissolvable tobacco':ab,ti OR nicotine:ab,ti

AND

flavor:ab,ti OR 'flavoring agent':ab,ti OR 'sweetening agent':ab,ti OR 'aromatic compound':ab,ti OR

odor:ab,ti OR chemesthesis:ab,ti

AND

(sensory:ab,ti OR chemosensory:ab,ti) AND ('evaluation study':ab,ti OR 'panel study':ab,ti OR detection:ab,ti OR procedures:ab,ti OR test*:ab,ti)

NOT

(rat:ab,ti OR rats:ab,ti OR mice:ab,ti OR mouse:ab,ti)

WEB OF SCIENCE

(TS=(("Cigarette*" OR "Electronic Cigarette*" OR "electronic nicotine delivery systems" OR "E-cigarette*" OR "e-cigs" OR "E-liquid" OR "e-juice" OR "tobacco heating system" OR "waterpipe" OR "hookah" OR "cigar*" OR "smokeless tobacco" OR "snuff" OR "snus" OR "chew* tobacco" OR "oral tobacco" OR "pipe*" OR "dissolvable*") AND ("tobacco" OR "nicotine")) NOT TS=("rat*" OR "mice" OR "mouse"))

AND

(TS=("Flavoring Agents" OR "Sweetening Agents" OR "taste" OR "flavor*" OR "aroma" OR "odor*" OR "chemesthesis"))

AND

(TS = (("Sensory" OR "chemosensory") AND ("evaluat*" OR "panel*" OR "detect*" OR "analysis" OR "method*")))