



Smell in Industrial Design: A Systematic Review

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الرائحة في التصميم الصناعي: مراجعة منهجية

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ABSTRACT

A smell in industrial product design is defined as an awareness of the dimensions in design creation. Theoretical development for the role of smells in design has led to a significant increase in industrial design. However, despite numerous studies on smells within industrial design, a holistic overview through systematic reporting remains unavailable. In this paper, the authors conducted a systematic review of studies on smells in academic articles on industrial design. The review method was adopted from the Reporting Standards for Systematic Evidence Syntheses (ROSES). The academic databases involved are Scopus, Science Direct, Web of Science and Google Scholar. This study discovered that studies on smells in industrial design have researched the following aspects: 1) smells as design attributes; 2) users' perceptions based on smells; and 3) appraisals of smells embedded in products. Practitioners, educators and researchers can use this systematic review to examine the needs of smell-related sensorial concerns in the current product design applications.

المخلص

تُعرّف الرائحة في تصميم المنتجات الصناعية بأنها الوعي بالأبعاد المختلفة المتعلقة بها خلال عملية إنتاج التصميم. وقد أدى التطور النظري لدور الرائحة في التصميم إلى زيادة كبيرة في تطبيق ذلك في التصميم الصناعي. ولكن، وعلى الرغم من تعدد الدراسات حول الرائحة في مجال التصميم الصناعي، إلا أنه لا توجد حتى الآن دراسات منهجية شاملة حول ذلك. لذا يتضمن هذا البحث مراجعة منهجية فيما يتعلق بالرائحة كما وردت في المقالات الأكاديمية في مجال التصميم الصناعي، حيث اعتمد البحث في منهجية المراجعة على معايير إعداد التقارير الخاصة بتوليفات الأدلة المنهجية (ROSES). أما قواعد البيانات الأكاديمية التي رجع لها فهي Scopus و Science Direct و Web of Science و Google Scholar. وقد وجد من الدراسة أن دراسات الرائحة في التصميم الصناعي تناولت الموضوع من ثلاثة جوانب هي: (1) الرائحة كسمة من سمات التصميم، (2) إدراك المستخدم للرائحة، (3) تقييمات المنتجات المتضمنة للرائحة. ويمكن للممارسين والأساتذة والباحثين الاستفادة من هذه المراجعة المنهجية للتحقق من الاحتياجات الحسية للرائحة في تصميم المنتجات الحالية.

KEYWORDS الكلمات المفاتيحية

Multisensory design, smell sensory, smell experience, product design, user experience
التصميم متعدد الحواس، حاسة الشم، تجربة الشم، تصميم المنتجات، تجربة المستخدم

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1. Introduction

A smell is a sensory input, along with sight, touch, hearing and taste. A sense of smell enables the interpretation of chemical signals in the environment and supports human functions, such as identifying and recognising substances (Nakamoto, 2013). Smell in product design is defined as the awareness of its dimension in design creation either as an inherent or applied substance (Henshaw *et al.*, 2017). Researchers state that smell can enhance design concepts, assist product usability, change user behaviour, trigger memories, increase aesthetic values and support brand recognition (Feng *et al.*, 2019; Kim, 2015; Ludden *et al.*, 2009; Spence, 2016). Design researchers and designers have realised the value that smell can bring to the design field. Theoretical development for smell in design has led to a significant increase in its application within multiple design fields in recent years (Metatla *et al.*, 2019).

A smell is not typically applied in industrial products, even though technological development allows designers to incorporate smells into design and manufacturing (Bual, 2020). However, products, such as furniture, technological devices, cars and clothes, could benefit from the application of designed smells by evoking positive feelings (Lawson *et al.* 2016). In the future of interactive product design, a

smell is likely to be a new element that provides interactive reminders in addition to ringing, vibration and flickering (Liu and Duan, 2019). The application of smell sensors in automotive design enables air quality assessments and foul detection, stimulates the new car experience and increases product presences (Lawson *et al.*, 2016).

Despite numerous studies on smell within industrial design, a holistic overview through systematic reporting remains unavailable. The closest similar scope of available studies are systematic reviews of smell factors in consumer behaviour and product marketing (Nibbe and Orth, 2017; Rimkute *et al.*, 2016). Therefore, it is necessary to investigate studies on smell within the scope of industrial design. The advantages of conducting a systematic review for this study are that the article-retrieving process is transparent, and the research bias is controlled with more significant objectives. Furthermore, there is a higher motivation to produce quality evidence with more significant results (Xiao and Watson, 2019). It is also highly beneficial to conduct an overview of the applications of smell in current products developed in the industrial design field. This will provide the answer to the following research question: what aspects of smell have been researched in the industrial design field?

This review paper provides a systematic review of current research

works on smell in industrial design. The articles have been retrieved from the following databases: 1) Scopus; 2) Science Direct; 3) Web of Science; and 4) Google Scholar. The reviewed articles were published between June 2010 and June 2020. Practitioners, educators and researchers can use this review paper to better understand smell from academia's perspective and how it can be applied in the design of products.

2. Review Procedure

This study employs the Reporting Standards for Systematic Evidence Syntheses (ROSES) review protocol. ROSES was initially used as a systematic review method for the environmental management field (Gusenbauer and Haddaway, 2018). ROSES aims to guide researchers to report information with an appropriate level of detail. Haddaway (2018) stated that ROSES can be adapted across other fields with similar levels of complexity of topics and methods. Therefore, this review protocol is suitable for adaptation, as no further specific requirements are needed when applying this review protocol in the field of industrial design. When conducting this review protocol, three searching strategies are employed. The first search strategy consists of the following three main sub-processes: identifying, screening and determining the eligibility criteria of exclusion and inclusion of the articles to be reviewed. The next search strategy is assessing the quality of the articles. Finally, the third search strategy is abstracting, analysing and validating the data from the articles.

2.1. Search Strategy:

The first search strategy consists of identifying, screening and assessing articles' eligibility for exclusion and inclusion. Identifying is important to search for synonyms, related terms and variations of a topic's keywords. Screening filters the identified articles in multiple stages using the inclusion and exclusion criteria. Assessing the eligibility of articles refers to the process of manually selecting articles from the previously screened articles to ensure that the articles reviewed in this study fall within the scope of the study. All articles utilised in this systematic review were published between 2010 and June 2020.

In this study, the search for academic articles used the following four (4) databases: Scopus, Web of Science, Science Direct and Google Scholars. The search keywords were used consistently for all four databases. The search process was limited to these four databases after repetitive content was found within the third and fourth databases. The synonyms and spelling possibilities that were considered in the use of search strings and keywords were as follows: product/industrial, design/development and smell/scents/odour/odour/olfaction/olfactory/fragrant/fragrances/perfume/odorants. A total of 256 articles were collected from the identification processes from all databases combined. Thirty-three duplicate articles were removed, and the remaining articles were brought forward to the next stage.

The second stage was to screen the search results. This study's screening process was conducted using the advanced search options available within the academic databases, which are explicitly designed for systematic screening purposes. The advanced search options enriched the searching and screening processes by enabling full search strings using the Boolean operator, phrase search, truncation, wild card and field code functions. These options were available on the three central databases of Scopus, Science Direct and Web of Science. This study's screening inclusion criteria were the English language, along with industrial or product design keywords. The exclusion criteria were carried out by unchecking articles from

journal fields other than design, material, ergonomic, applied science and marketing.

Google Scholar was the fourth additional database used. Google Scholar was selected as a supporting database in the systematic review process, as it produced tremendous results compared to other databases (Gusenbauer and Haddaway, 2018). Therefore, in this study, an additional condition was applied to the Google Scholar database; the publication resources were manually pre-validated through the provided links. The total number of screened articles from all five databases was 185. Table 1 depicts the search strings used for the respective databases.

Table 1: Search strings used for the respective databases

Database	Search String
SCOPUS	TITLE-ABS-KEY(product* OR industrial* AND design* OR development* AND scent* OR odour* OR smell* OR fragrant* OR perfume* OR olfact*)
WEB OF SCIENCE	Ti=(product* OR industrial*) AND Ti=(design* OR development*) AND TS=(scent* OR odour* OR smell* OR fragrant* OR perfume* OR olfactory*)
SCIENCE DIRECT	Title : "product design" AND Abstract: "scents" OR "odour" OR "odor" OR "smell" OR "olfaction" OR "olfactory"
SAGE	for [(Title product*) OR [(Title industrial*) AND [(Title design*)] OR [(Title development*)] AND [(Abstract scent*) OR (Abstract odour*) OR (Abstract smell*) OR (Abstract fragrant*) OR (Abstract perfume*)]
Google Scholar	all abstract all title: design for olfaction smell OR smells OR scents OR scent OR olfaction OR perfume OR perfumes OR fragrance OR fragrant OR odour OR odor OR olfactory "product design" OR "industrial design"

In this study, the eligibility stage was divided into two steps. In the first step, articles were selected after scanning their abstracts, and in the second step, articles were selected after full-text readings. This process involved scanning the titles and abstracts of 185 articles. Articles that were not related to the definition of smell, as in this study, were excluded. Additionally, articles outside the boundary of the design field were excluded. The excluded articles included studies in the field of programming that used the term 'code smell' to define a programming error. Eighty-seven articles remained after the full-text reading of the eligibility stage.

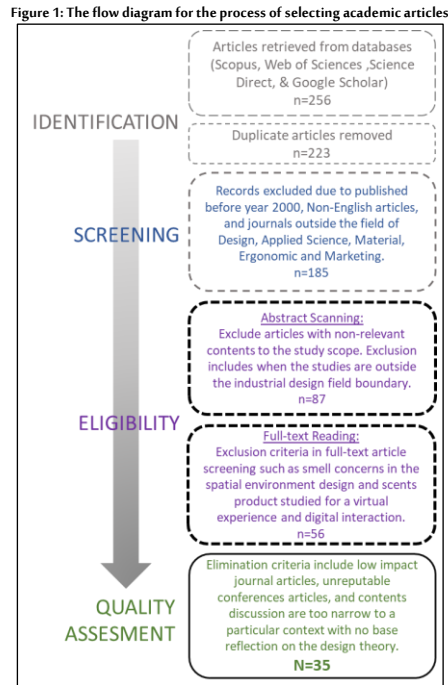
Throughout the full-text reading process, notes on the relevant content of smell related to this study's aims and scope were highlighted. In the full-text article screening, the studies where the primary concern of smell was focused on the spatial environment design, products for virtual experience and digital interaction were excluded. Through the eligibility process, 56 articles were left for the following quality appraisals.

2.2. Quality Assessment:

The appropriate articles' quality was ensured because the appointed research professionals and topic experts validated these articles during the quality assessment stage. First, academic articles were scanned using SClmago, which is a portal used to rank journals that provides indicators to measure the scientific influence of scholarly journals. This step was conducted to ensure that all articles were published in indexed journals. In addition, all eligible articles were presented to two independent researchers in the industrial design field for quality appraisals. Experts ranked the articles into the following three (3) categories; high, moderate, and low. According to Rodgers *et al.* (2009), only high- and moderately-ranked articles should be reviewed to ensure the quality of analysis and discussion outcomes.

Both appraisers mutually agreed on all the final articles chosen for the review in this study. Disagreements were discussed before deciding on the inclusion or exclusion of the articles. During this process, 21 academic articles were excluded. Academic articles were excluded because they were published in non-indexed journal articles or unrepeatable conferences articles. The final number of academic

articles was 35. Figure 1 illustrates the process or flow of selecting the final 35 academic articles for the review.



The remaining articles were then used in the next stage of the abstraction and analysis process.

2.3. Data Abstraction and Analysis:

The integrative review method was employed as it enables the reviewing of diverse research designs. In this stage of article abstraction, all 35 academic articles were read and analysed. Particular attention was given to the articles' study objectives, results and discussions. The data abstraction process was conducted according to the research questions of this study. Any data from the reviewed academic articles that could answer the research questions was noted. The notes were then abstracted and placed into a table.

Next, the themes that emerged from the articles were identified through a thematic analysis. Notes that were collected from the abstraction process of both data sets guided the themes. This process involved noting patterns, clustering words, counting repeated terms and noting the similarities and relationships within the abstracted data (Yin, 2017).

The first step of the thematic analysis for the data set was to detect potential clusters to build themes. During this process, the patterns that emerged among the abstracted data were identified. Similar or related data was organised into groups and possible subgroups. Next, the accuracy of the themes was reviewed. The possible codes under each theme were examined to ensure their usefulness and relevance to the research questions. Next, the themes were analysed for the theme group naming process. Throughout the development of the themes, codes under each theme were discussed among the authors to detect any inconsistencies. The plausible concepts associated with the research topic and industrial design field were also discussed.

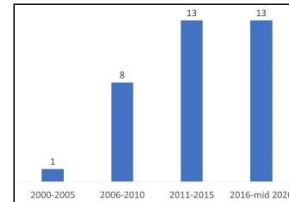
After the themes were developed, the similarities and differences of each developed theme were compared. Codes and terminologies under each theme were analysed, and any associations with the theoretical framework were synthesised. The themes were then aligned, and the use of its information was examined. Finally, the themes were finalised through a mutual agreement among the

authors on the built themes and their alignment within the theoretical framework. The themes and data were then visualised in a table. These findings are discussed in the next section.

3. Background of the Reviewed Articles

This study obtained 35 selected academic articles for review from the methodology section's procedures. Figure 2 shows the year ranges of the published academic articles that were selected for this review. The chart shows one published design between 2000 and 2005, eight articles published between 2006 and 2010, 13 articles published between 2011 and 2015 and 13 articles published in the last five years.

Figure 2: Selected articles published by the range of years



Based on the thematic analysis and academic articles, the following three themes were developed: 1) attributes; 2) perceptions; and 3) appraisals. Table 2 shows the developed themes and codes based on these articles.

Table 2: Theme codes developed from the articles

#	Themes	Theme Codes
1	Attributes	Solution Properties, Information Transmitter, Dominant Function, Added Value, Influence, Cross-Modalities, Meaningful Association, Textile Properties, Sign, Meanings, Metaphor, Consumer Attributes, Cultural Elements, Purification
2	Perception	Aesthetic Pleasures, Emotional Domain, Memory Trigger, Evoke Surprise, Quality Impression, Memory Recall, Nostalgia, Behaviour Encouragement, Behaviour Motivation, Cognitive Interpretation, Proximity
3	Appraisals	Positive Evaluation, High Evaluation, Determine Product Liking, Product Preferences, Application Evaluation, Product Perception

4. The Articles' Reviews

'Attributes', 'perception' and 'appraisals' were the themes that emerged from the smell sensory-related articles in the industrial design field. 'Attributes' refers to smells as design attributes in these articles. In contrast, 'perception' refers to the cognitive responses of smells from products, and 'appraisals' is derived from studies investigating consumers' evaluations of smells embodied in products.

4.1. Smells as Design Attributes:

Academic articles within this theme highlighted a smell as follows; 1) an element of a design solution; 2) an information transmitter; 3) a dominant function; 4) an added value; 5) an influencer's perception; 6) a component of the cross-modalities design approach; 7) a medium for a meaningful association, sign or metaphor; 8) an attribute of consumer personalities; 9) a cultural element; and 10) an element of purification. Attributes of smell that have been highlighted in these studies suggest that a smell needs to be the following: (1) applied congruently within a context; (2) a supplementary design element association; (3) aligned as a cultural appropriation; and (4) applied to a suitable product category.

A smell is one of the sensory attributes that receives product information. Therefore, the experiences heavily depend on the targeted product users. A smell can be a solution to problems that are usually activated by other sensory attributes (Crilly *et al.*, 2004). Additionally, attributes of a smell can powerfully convey particular meanings in a product, namely cultural meaning, colour and taste prediction (Kauppinen-Räsänen *et al.*, 2018). Moreover, removing an unwanted smell is an essential attribute in selected product design categories, such as in the design of air purifiers and cleaning products

(Cho *et al.*, 2019).

A smell can be employed as a product design metaphor either on its own or combined with other congruent properties (Hekkert and Cila, 2015). According to Fenko *et al.* (2010), the different modalities' roles during use are product-dependent. During use, the dominant sensory modality mainly depends on the primary product function; a smell is primary for a particular product category, such as food and cleaning products. From the perspective of purchasing behaviour, Kivioja (2017) suggests that a scent for single products and product categories should only represent the main product's attribute. One relevant smell is applicable for all similar accessories, such as wallets, bags, shoes and belts, where consumers perceive all these accessories as one category. A smell offers meaningful product interactions when placed within a relevant product category (Hekkert and Cila, 2015).

Multiple studies highlight that a smell provides added value to textile products and their accessories. Material with a smell can affect users' perceptions and influence designers in their material selection process. Therefore, scents provide the possibility of being an essential factor in material development either as the main functional element or an added value (Koncar, 2016).

4.2. Smell Perception:

Within the theme 'perception', studies indicate that a smell does the following: 1) provides aesthetic pleasures; 2) arouses an emotional realm; 3) evokes surprise; 4) gives a quality impression to products; 5) recalls memories and brings back nostalgia; 6) encourages and motivates a particular behaviour; 7) stimulates cognitive interpretation; and 8) gives product proximity.

When sensorial roles are determined separately, olfactory takes the leading role within the emotional domain, the association of memories, and intensity of experiences (Schifferstein and Desmet, 2007). According to Kim (2015), the following five emotional responses arise from applying a smell to a product: refreshment, eco-friendly, romantic, intensity and aesthetic. These emotional responses emerged from her study on smell responses from scented clothing materials. In addition, smell intensity gives an impression of product quality (Schifferstein *et al.*, 2013). A smell provides aesthetic pleasures and increases users' proximity to a product, as well as the appeal of products through scented product advertising (Ruzeviciute *et al.*, 2020).

A particular smell to a person is positively associated with memory recall. A smell created by an object or an image is referred to as melancholia connected to the nostalgic memory recall that triggers episodic data. The episodic data can influence products' usability concepts (Chamorro-Koc *et al.*, 2009). The way that a smell can trigger memories can be incorporated into the design to encourage meaningful associations with a product (Nibbe and Orth, 2017).

Although scents are usually applied as a design attribute congruently with a product's context and its design element, incongruent scents may create surprise responses. According to Ramirez (2014), olfactory incongruity is a strategy to elicit surprise. However, Ramirez also underlined that appropriation is crucial to receive a complimentary evaluation. Ludden *et al.* (2012) stated that surprises evoked by olfactory incongruities are less direct in comparison to other sensorial mismatches. Ludden adds that olfactory congruities can be thought of as 'discovery surprises', as users have to hold products closer to sniff before they can feel the 'surprise' (Ludden *et al.*, 2012).

Scents can be priming stimuli in everyday products that motivate behaviour changes (Cash *et al.*, 2017). Zuo (2016) stated that scents applied to a wearable design enhance wellness by stimulating behavioural responses. Smell properties are cognitive information

interpreted through design intention in wearable and fashionable products (Wang *et al.*, 2018; Zuo *et al.*, 2016). Other than wearable products, the olfactory properties are also known to enhance one's dining experience. Spence (2017) noted that an olfactory experience in future dining products should encourage healthier eating behaviour.

4.3. Appraisals of Smell-Embedded Products:

Within the theme 'appraisals', studies have indicated that scented products do the following: 1) consistently receive a positive evaluation; 2) receive a high evaluation if applied to a suitable product category; 3) are a factor that determines product liking; 4) boost product preferences; and 5) provide a positive design perception.

An iterative process of applying and evaluating the application of odours during the design process is essential. Within studies that assess scented textile, the consistent positive evaluation was received from potential customers. However, despite the positive evaluation for scent-infused products, technology needs to deliver a pleasing fragrance for at least multiple cycles of product use. Products that received a high positive evaluation and showed potential in enhancing pleasures were products that were scent-infused, and this application matched with their colours (Lin and Sun, 2018; West and Carroll, 2014).

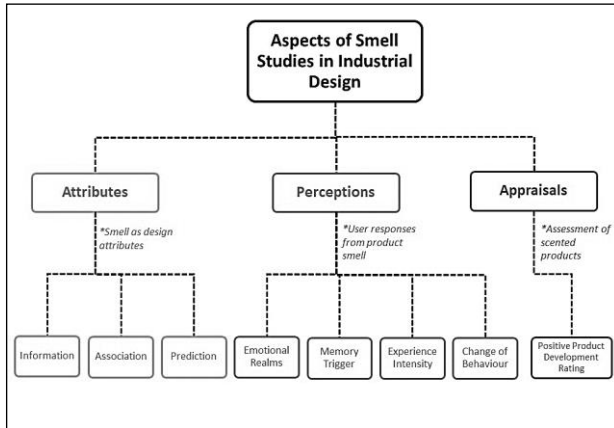
Designers should consider the evaluation of olfactory factors within product applications. This is because scents are related to the product category and the context of its application, and in product assessment, these factors determine product liking (Ludden and Schifferstein, 2009). For instance, a study on how children assessed food found that the smell and colour of a food product positively influenced their perception of preferences (Gollety and Guichard, 2011).

Moreover, smell factors are evaluated in studies for their purchasing potential. For instance, the packaging's scent can enhance the likelihood of purchase (Spence, 2016). Zuo *et al.*'s (2016) findings agree with this because in their study, it was noted that the initial perception of a product was based on sensory properties, such as colours, textures, sounds, smells and tastes (Zuo *et al.*, 2016).

5. Discussion

The scholarly articles show an increase of smell related studies in industrial design products from 2011 until recent years. Studies related to smell sensory attributes focus on smells as attributes in design. Additionally, they focus on users' perceptions of the smells of products and appraisals of smells embedded in products (see Figure 3). These three aspects were identified from thematic categorisations that were partially lead by deductive coding from previous frameworks within research areas, such as the affective responses model, consumer responses to product design and the human-product interaction model (Diego-Mas *et al.*, 2016; Yoon *et al.*, 2018).

Figure 3: Aspects of smell studies in industrial design



Within the perspective of smells as attributes in design, studies show that a smell is regarded as an element in the design of products that transmits information and acts as an element of association and component of prediction. As an element in the design of a product, a smell acts as an informant for the level of hygiene, the origin of the material used and the signal of the deterioration of food products. Additionally, a smell can transmit information by giving precautions when other sensors are occupied or disabled. Other design elements, such as the design concept, identity and context of use in products, are also associated with smell attributes. Moreover, a smell in products can also be used to predict other information that is sensed by other sensorial receptors, such as taste, colour and size. A smell is a dominant factor within leather, wood, edible, beauty and cleaning products. However, it can also be observed that the attributes of a smell are simply added values for other product categories. Therefore, it is essential for designers to understand product application categories when applying smells in their designs.

Studies related to examining users' perceptions of smell reported that a smell can elevate users' emotions, trigger memories, increase experience intensities and initiate behaviour changes. In addition, studies indicated that a smell can be used to recall personal nostalgia, initiate brand recognition and trigger users' episodic data to communicate product usability and improve their proximity to a product. The intensity of the users' product experience may be increased through smells, which relates to their impression of product quality and aesthetics pleasures. Furthermore, users may respond to smells by being motivated to adopt better-eating behaviours. However, the congruency of elements within a product is vital for products to receive positive user responses. Interestingly, although smell incongruency may cause surprise emotions, this response may be complimentary if it is adopted appropriately.

Regarding *appraisals for smell embedded products*, studies within this category are often initiated by the development of new materials. Studies have been conducted using empirical tests to examine consumers' evaluations of product applications that utilise the newly developed scented materials. Therefore, assessment studies for scented products are commonly found in the fields of material engineering and product marketing. For example, these studies' common objective is to test the length of scented material performances, investigate the influence of scented products on customer purchasing preferences and test the segmentation of products within the different stages of consumer interaction.

To summarise, smell-related studies within the industrial design field have examined three different aspects. First, several studies examined smell as design attributes. Second, other studies

investigated users' perceptions of smells in products, and third, some studies appraised smell-embedded products. Next, in terms of *smell as design attributes*, studies indicated that smell transmits information and acts as an element of association and an attribute to predict the sensation from other sensors. Regarding the *users' perceptions of smell in products*, studies indicated that smell affects emotional realms, triggers memories, intensifies experiences and initiates behaviour change. Lastly, within the perimeter of *product appraisals*, studies are commonly conducted to test the performance of newly developed materials and examine customers' preferences and purchasing decisions.

6. Conclusion

Academic investigations on the smells of products should inspire fresh design ideas and spark new design possibilities. Practitioners and product developers should consider theoretical development suggested by academic findings to ensure the effectiveness of innovations and use it to guide their design process and product development decisions.

Based on this systematic review of studies on smells, several areas for future research are recommended. First, throughout the product development process, it would be beneficial for practitioners to understand the smell's attributes. For example, practitioners may first consider whether an intended smell element acts as a primary attribute or adds value to a product. Second, it is recommended that users' perceptions within the perimeter of the smell attributes of materials is applied to or embedded in a product. Responses to the same smell may be tested in different embodiments, design concepts, product categories and target markets. Third, it is recommended that users' appraisals of the smell dimension within the product are evaluated when deciding whether the smell should be embedded in materials or used in the smell diffusing function.

Overall, practitioners, educators and researchers can use this systematic review to address the needs of smell-related sensorial concerns in the current industrial product design field.

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