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Enhancing Reading Through Olfactory Stimuli: A Research Agenda to Support Struggling Readers

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ABSTRACT

This conceptual paper argues that for children with reading difficulties, multi-sensory approaches to learning, especially in literacy, are essential. Drawing on a state-of-the-art review, we propose that olfactory elements of the learning environment, particularly in reading spaces, have significant implications for how struggling readers engage with texts. Supporting struggling readers may benefit from more intentional consideration of the emotional design of reading encounters. This broader approach includes optimizing environmental factors such as heat, light, sound, and air quality, all of which have been shown to positively impact learning. We explore the potential of olfaction in fostering relaxation within learning spaces, thus creating environments conducive to effective learning. Recognizing the stress that some children experience while learning to read, the paper suggests that specific olfactory stimuli warrant empirical attention. Repeated learning struggles often evoke negative emotional responses, hindering children's engagement with learning. Therefore, the ultimate goal is to inform educational practices and interventions that can mitigate stress and enhance learning outcomes by strategically integrating olfactory stimuli into learning environments.

It's Thursday, and for Jesse, that means it's a day to visit his school's literacy lab, where he gets some extra group-based reading support. Jesse wishes that reading wasn't such a big part of school, and even home sometimes too—his mum always wanting him to read a book in the afternoons. But for Jesse, reading has always been hard. He knew some of the rules, but they didn't seem to work for so many words, and then he couldn't totally understand what he was reading, let alone enjoy it. Having to write things was even worse, and just made him look stupid.

> *He was a bit embarrassed about going to the literacy lab, but the reading there felt more do-able; He did come away from sessions there feeling more positive. The teacher said to Jesse that he should use all his senses to read, and lessons sometimes included air-writing, acting things out. Thinking about it, the room always smelled nice during those sessions...with vanilla or something... Jesse recalls that pleasant smell when thinking of his last experience of reading at the lab. He decides to go again.*

While olfaction is a little-researched aspect of the reading experience, we know that our sense of smell has a direct link to emotion, and emotional engagement is key to the reading experience. Here we propose that pleasant scents may actually enhance motivation to read. This underexplored hypothesis suggests that the strategic use of agreeable olfactory cues could serve as an innovative technique to foster reading engagement, particularly among those who struggle to engage with texts. In this paper, by reviewing relevant literature, we construct a series of theoretical assumptions and identify potential pathways within a theory of change framework. This approach lays the groundwork for future research aimed at

understanding and leveraging olfactory cues to improve reading motivation, particularly among those who struggle to initiate or sustain reading activities.

1 | Aims and Foci of This Paper

Lack of reading motivation among children is increasingly prevalent, with high-paced visual information dominating their attention (Clark et al. 2025). Although the benefits of reading for societal engagement and personal growth are well recognized, the motivational pathways for readers are less known (Parsons and Erickson 2024). Having worked with struggling readers for 15-plus years both as scholars and practitioners, we reflect on a so far little studied motivational aspect of reading: the role of smell. We narratively review relevant literature concerned with smell (olfaction) and its qualities that are conducive to mood changes and mood induction as a possible pathway for influencing reading motivation for young children. For the purposes of this review, our definition of a struggling reader is deliberately broad and refers to any children or young people who experience *persistent* difficulties with reading comprehension and/or single word reading.

We see this exploratory nature of our approach suitable for the currently under-researched role of smell in reading and the highly interdisciplinary nature of the science of olfaction, and the recent calls for innovative approaches to stimulate children's interest in reading (e.g., Szenczi et al. 2024; Smith et al. 2025). The implications of this work include suggested activities and examples designed to inspire future research and practice in olfactory reading. We propose that this approach serves as a compelling counterpoint to the predominantly visual methods that have thus far dominated reading research (see Mills 2015; Mills et al. 2023).

Given the need for a broad, inclusive perspective on an emerging field, our review synthesizes insights from diverse disciplines regarding reading and olfaction. We term our approach "olfactory reading," to integrate perspectives from diverse scientific disciplines, including the science of reading, sociology, psychology, and education with olfaction-related fields such as chemistry, neuroscience, materials science, material culture, history, ethnography/anthropology, and aromatherapy practice. To bring the diverse strands of literature together, we draw on the *state-of-the-art methodology*, which, according to Grant and Booth (2009), tackles more contemporary issues compared to hybrid approaches that merge retrospective and current perspectives. A state-of-the-art review typically yields fresh insights into a topic of interest (olfactory reading in our case) or highlights gaps for further inquiry [see Barry et al. (2022) for methodological principles]. In analyzing the published literature, we sought to leverage the latest knowledge while recognizing the historical foundations of contemporary reading perspectives and olfactory research. Our primary aim was to identify priorities for future research that introduce new dimensions to practice and interventions, thereby enhancing the impact of this work's implications.

2 | The Interdisciplinary and Unique Nature of Smell Research

While affirming the developmental significance of conventional literacy in fostering children's reading skills, we challenge common conceptions of literacy confined to a-modal (words/sounds) or bi-modal (words/sounds visual images) frameworks. Instead, we join advocates of multimodal understandings of literacy (see Kress 1997) as a process of active engagement, diverging from cognitivist, ocularcentric, and mentalist paradigms. We foreground olfaction to underscore the sensory richness of smell, which transcends linguistic constructs and has significant socio-emotional and cultural implications (Classen et al. 2002). As such, we posit smell as a language in itself, one that is non-anthropocentric and extends beyond social confines. Our perspective draws from Gibson's ecological theory (Gibson 2014), emphasizing the active perceptual engagement with the environment by animals, insects, and humans alike. It also draws from Howes' sensory anthropology, according to which smell can uproot one's relationship with reality and "provide the conceptual framework for construction of an understanding of the entire universe" (Howes 2002, 71).

We are keenly aware of the transformative potential of olfaction, but we also acknowledge that individual responses to odors are not universally consistent, and some people, notably those with congenital anosmia (if present from birth) or with anosmia (if acquired and irreversible), may never experience smell (Alotaibi et al. 2022; Huynh et al. 2020). For example, while lavender may be relaxing for some individuals, it may not have the same effect on others (see e.g., Lakhan et al. 2016). Furthermore, the prevalence of olfactory dysfunction in the general population varies and is largely dependent on the method used for investigating it: it can reach up to 35.8%, as reported by five studies involving 852 subjects with a mean age of 61.8 years that combined olfactory threshold tests with discrimination and/or identification subtests for the assessment (Desiato et al. 2021).

Aware of this variability, instead of relying on specific aromas for generic experiences, or a universal olfactory capacity, we emphasize the overarching concept that integrating some scents with reading activities can be beneficial for some readers. In particular, we focus on struggling readers and scents and smells that are naturally available, or easy to get, in a given environment.

3 | Struggling Readers

Struggling readers are typically struggling writers too (Tompkins 2002), and they benefit from literacy strategies focused on the meaning of text rather than the skills needed to decipher it (Allington 2013). Struggling readers navigate reading challenges in ways that reflect both their self-perception and the social dynamics of their learning environments: Hall's (2006) yearlong case study reveals that struggling readers are not passive or resistant but often employ alternative strategies to comprehend text, such as listening to discussions, seeking help from peers, or observing others. These adaptive behaviors stem from their desire to learn while managing the risk of exposing their reading difficulties to others. Some

teachers, however, may misinterpret such actions as laziness, especially when students do not comply with expected comprehension strategies (Hall 2006). Hall (2006) recommends that improving reading outcomes requires not only instructional methods but also deeper engagement with students' social and cultural contexts and acknowledgment of their complex literacy experiences.

In alignment with this recommendation, we examine relevant literature in light of its implications for struggling readers' literacy environment, with a specific focus on the immediate and direct environment in which they are expected to read. This environment can be described in the *ambient*, which is the general or pervasive odor that defines a particular environment without focusing on a single distinct scent or smell. The term *ambient smell* refers to the overall or surrounding scent in a particular environment or area. It is the mixture of smells that fill the air in a space, contributing to the atmosphere or mood of the place. For example, the ambient smell of a forest might include the scent of trees, damp earth, and leaves. The ambient smell in a classroom focused on reading may include the smell emitted by print books, the wooden furniture, the collective smell of the clothing, fragrances, and natural smells of students and teachers, cleaning products, etc. Ambient smell contributes to what Bronfenbrenner's ecological theory defines as "microsystems," providing a valuable theoretical framework for integrating the reader and their olfactory environment into a unified spatial concept. We draw on Bronfenbrenner's theory to conceptualize this relationship and its implications for reading engagement.

4 | Theoretical Framework: The Microsystem of Ambient Smell in Reading

Bronfenbrenner's theoretical take on environment (1975, 1977) frames our understanding of the individual research strands to explore with attention to olfaction. The importance of ambient smell in learning environments aligns with this theory as it acknowledges the environmental context as a critical influence on cognitive processes such as reading. Bronfenbrenner's theory, in its simplified form, addresses five main systems: Microsystem: Immediate environment (family, school, peers); Mesosystem: Interactions between different microsystems (e.g., home and school); Exosystem: Indirect influences (e.g., a parent's workplace or community resources); Macrosystem: Societal and cultural influences (e.g., values, laws, economic systems), and Chronosystem: The dimension of time, including life events and historical changes.

In *macrosystems* (Bronfenbrenner 1979), concerns about the impact of climate change, depletion of natural resources, and the presence of toxic or disappearing smells become pertinent. These macro-level factors can affect the quality of air, availability of natural scents, and the overall olfactory ambiance in educational spaces. Hence, addressing macrosystemic influences on ambient smells in learning environments is crucial for fostering environmentally conscious educational practices. Implementing strategies for sustainability, minimizing exposure to harmful odors, and promoting awareness of the broader environmental context contribute to creating learning spaces that align with the principles of ecological responsibility and ecoliteracy.

In the context of ambient smell in learning environments, *the chronosystem* becomes implicated in the dynamic evolution of olfactory stimuli over time. Scents, associated with specific periods or events, can trigger memories and emotions, contributing to a sense of continuity and familiarity within the learning environment. Changes in ambient smell, whether intentional or circumstantial, can represent shifts in the chronosystem, influencing individuals' experiences and perceptions.

And perhaps most importantly for our present focus on struggling readers, Bronfenbrenner's *microsystem*, the immediate and direct environment in which an individual child operates (Bronfenbrenner 1978), becomes intricately connected to each child's idiosyncratic responses to various smells. The olfactory experience within the microsystem is profoundly personal, as scents can evoke memories, emotions, and individualized associations with specific smells. Ambient smells in the learning environment, such as the fragrance of books, the scent of educational materials, or the cleanliness of the surroundings, contribute to the reader's microsystem's sensory landscape. A child's response to these smells is subjective and influenced by personal associations, creating a unique olfactory microenvironment for each learner. As such, understanding the individualized nature of olfactory responses within the microsystem is crucial in creating inclusive and supportive learning spaces.

This understanding hinges on the hedonic characteristics of smell and their relationship to individual detection capabilities and responses.

5 | Key Characteristics of Smells: Hedonic Qualities

Hedonic Characteristics of Smell refer to the affective dimension of odors, specifically how they are perceived in terms of pleasantness or unpleasantness. Hedonic valence is one of the three main attributes used to describe odor, alongside quality and intensity (Rouby and Bensafi 2002).

Several factors influence hedonic perception of an odor, including the odor's concentration and intensity (with higher concentrations often leading to increased unpleasantness, Li et al. 2019), molecular characteristics (whereas larger molecules, especially those containing oxygen, are more likely to be perceived as pleasant, Zarzo 2011) and individual and contextual variability (age, sex, and physiological state, as well as contextual factors like cultural background and exposure frequency influence hedonic perception, Bontempi et al. 2024). That said, odors such as pyridine and thiophene are generally perceived as unpleasant by most people, with a high percentage rating them negatively (Shih et al. 2022) and limonene is typically perceived as pleasant within a certain concentration range (Li et al. 2019). Kirk-Smith (2003) reviewed uses of lavender, particularly "red lavender," in England and the USA and concluded that the primary psychological effect appears to be calming for this population.

Research on the hedonic characteristics of smells has been extensively explored in both architectural design (Xiao et al. 2022) as well as consumer studies (see Spence 2020);

in the latter, specific odors, in varying concentrations and intensities, are strategically employed to stimulate shopping and purchasing behaviors: Spence's (2020) rapid evidence review indicates that consumer behavior can be influenced by pleasant ambient odors, while certain aromatherapy scents are believed to enhance mood and well-being. In the context of shopping malls, studies show that food chain owners intentionally select store locations near enclosed stairwells to ensure that enticing smells reach more potential customers. Conversely, traditional odorless environments like bookstores and train stations have adopted food scents, notably coffee. Spence concludes that there is growing awareness of the marketing potential linked to non-food smells, with rising commercial interest in scent marketing. He suggests that introducing ambient scent deliberately should be distinctive enough to be recognized by consumers and associated with a specific brand, while also providing functional benefits such as improving mood or increasing sales. We extend this suggestion to reading environments, such as for example libraries, that too, could be enhanced with smells to engage the general public in pleasant reading experiences (Ingebretsen Kucirkova and Gausel 2023).

Hedonic characteristics of smells are also strategically used in directing consumer behavior in live performances. Spence (2021) reviewed the use of scents for live performances and found that ambient smell was used to evoke specific moods and serve a narrative purpose.

While scent has often been used merely as an illustrative or what the literature refers to as "pleonastic" element (Spence et al. 2024), there have been instances where olfactory stimulation played a significant evaluative role, particularly in theater but also in opera, musicals, ballet, and comedy. In recent years, there has been a renewed interest in scenting live performances, particularly in highly immersive and experiential multisensory events. For example, Solves et al. (2022) explored whether the addition of olfactory elements (scents) can enhance viewers' enjoyment of audiovisual productions. Using an Empathy and Identification with Characters scale, they compared two groups: an experimental group exposed to scents while watching the multisensory short film *Xmile* and a control group without scents. Their findings suggest that the inclusion of scents leads to a stronger identification with the fictional characters and significantly increases viewers' overall enjoyment of the film.

While high-tech solutions are prevalent in cinema, low-tech methods are more common in live performances, such as theaters. Historically, scents have been used in theatrical productions to harmonize with visual and auditory elements, as seen in the 1891 performance at the Théâtre d'Art, which integrated scents with music and speech (Shepherd-Barr 1999). A reading situation, with its low number of participants and intimate atmosphere, is more akin to a small theater performance than cinema, although digital books that combine audio, visual, and tactile elements bring some characteristics that are akin to a cinema experience. The question that emerges from this literature is: Given the proven potential of smell for enhancing the experiences in consumer and entertainment spaces, how to introduce smell into the reading context?

6 | Smell Integration With Reading

Various methods and strategies can be employed to incorporate smell into the reading context and readers' experiences with texts. One approach involves directly integrating smells into books, tailoring them to the specific experiences of children, whether pleasant or unpleasant, to achieve desired effects. This technique gained popularity with scratch-and-sniff books, and while the smell experience is arguably brief and localized, it has yet to be surpassed by alternative methods. Spence et al. (2024) conducted a narrative historical review, supplemented by a systematic search of databases, online catalogs, and lists, to explore the unique category of children's picture books represented by scratch-and-sniff books. They found that while olfactory augmentation of storytelling and performance is common in other media directed toward adults, such as film and theater, it is less prevalent in children's literature. This asymmetry with scratch-and-sniff picture books highlights their innovative use of scents and their impact on reader immersion and narrative experience. The review discusses possible reasons for the absence of scented books for adult readership and considers potential future uses of scent in digital books (ebooks). It also highlights the limited literary quality of current children's scratch-and-sniff books on the market, a point also made by Kucirkova and Tosun (2023). Similar to the reception of smell in cinemas, where its addition was met with criticism and perceived as a gimmick, the history of scratch-and-sniff books demonstrates a comparable pattern of public resistance to the inclusion of smell into traditional resources. Nevertheless, unlike ambient scents, this method localizes the smell to a specific moment and ties it directly to the book's content, making it particularly relevant for reading research.

Scratch and sniff books are an example of multisensory reading that engages multiple senses in reading (in addition to vision and touch) and that has been proposed as a way to motivate reluctant readers to engage with narratives (Kucirkova and Rodriguez-Leon 2023). With the rise in multimedia reading formats and a global decline in reading for pleasure (see McGeown and Cremin 2025), there is growing interest in developing innovative strategies to re-engage readers. While much of the current research focuses on digital enhancements and emerging technologies such as artificial intelligence to boost reading motivation (e.g., Yılmaz and Aydın 2025), the use of olfactory stimuli as a tool to enhance reading remains relatively unexplored in practice. Though it holds promise for engaging both young and adult readers, this approach has so far been discussed primarily at a conceptual level, with limited practical uptake by book publishers.

Scratch and sniff books are so far the only method for directly combining smell with fictional narratives for young readers. For digital reading, attempts such as the so-called "obooks prototypes," which deploy digital hotspots to activate scent release via Bluetooth-connected cartridges, have not been commercialized yet for various reasons, including high cost of production. Research on readers' responses to scratch and sniff books is limited; an exception is a study by Kucirkova and Bruheim Jensen (2023), which, to our knowledge, has been the only study to empirically examine parents' and children's responses when

reading scratch and sniff books together at home. The authors found that children's early reading can be stimulated with the inclusion of smell and that together with their parents, the children showed more interest and positive engagement in the reading sessions when the smell was part of the book. It was both the act of jointly scratching the book page and musing over the specific smells it emitted that motivated the families to read together.

Building on this research, we suggest that scratch-and-sniff books may offer a promising approach for reluctant readers by leveraging the effects of smells and scents. However, these books may need to be supported by the guidance of adults who can mediate the interaction, especially if the smells are unclear in terms of what they represent and require interpretation or discussion with other readers. Since the smells in scratch-and-sniff books are initially on the pages but become part of the surrounding environment once activated, we consider them a transient part of ambient smell—at least when they are actively triggered by the reader.

In the following section, we review literature on ambient smell in the broader context of learning, rather than specifically in relation to reading, due to the limited research available on the direct connection between reading and ambient smell.

7 | Ambient Smells and Learning

In a speculative, yet relevant paper for our focus, Almansour (2024) describes how the use of ambient smells can improve the teaching situation and children's classroom experience. The author suggests that the use of aromatherapy can have positive effects on learners by providing psychological and emotional support, reducing stress, and improving the classroom environment. It is well-established that aromatherapy, using specific essential oils, can positively impact psychological conditions by stimulating the olfactory system and affecting the limbic system, which is linked to emotions and memory (e.g., Nan Lv et al. 2013). Almansour (2024) proposes that essential oils extracted from plants like eucalyptus and peppermint can improve attentiveness and that ambient aromas, such as rosemary essential oil, can enhance working memory performance in children. Further, a promising study by Ma (2022) found that exposure to an ambient aroma of sweet orange increased the presence and persistence of positive academic emotions (joy, hope, positive high arousal) in a classroom of middle room children, compared to a no-aroma control classroom. Overall, aromatherapy is presented as a natural, subtle tool to support learning by improving focus, attention, and memory retention in the educational setting. While introducing aromatherapy into traditional classrooms is not common practice, it is very common to use smell as part of outdoor activities and outdoor learning.

Nature as a place for learning for young children is emphasized in various early childhood curricula, including the so-called playful learning early childhood curricula, such as Montessori or those of Nordic countries (Størksen et al. 2024). For example, the Norwegian "Rammeplan" places great emphasis on children spending extensive periods of time outdoors. Despite the prevalent assumption that nature and outdoor learning are beneficial, the extant literature on outdoor learning does not seem to contemplate the key reasons for the beneficial effects but rather argues for the need of outdoor learning and studying the associations between time spent outdoors and students' learning and well-being outcomes.

Indeed, empirical literature on outdoor learning and exercise in green spaces shows associations between exposure to natural environments and stress reduction, although many studies are of poor methodological quality and the mediating effects are difficult to ascertain (Thompson Coon et al. 2011). The systematic review by Thompson Coon et al. (2011) found tentative evidence for the added beneficial effects of performing physical activity outdoors in natural environments, but the findings are limited by being based on self-reported mental well-being measures, defined in various ways in the reviewed studies.

Furthermore, Thyssen's (2019) study provides a broader context for outdoor learning by examining the role of smell in early childhood education, particularly in open-air schools in Western Europe during the 1900s to 1960s. It highlights how smell was integrated into sensory experiences in both health and education in Belgium and Luxembourg and underscores the significance of odors in shaping health, social status, and identity, noting that some smells represented urban environments or poverty and slums, which were often unpleasant and contributed to negative attitudes toward children, especially from working-class backgrounds. Alongside other senses, smell was used in outdoor education to influence learning methods and processes, particularly as a tool for reforming and "reodorizing" children, especially in working-class communities. Sensory education was employed not only to promote esthetics but also to foster a sense of morality and belonging among children.

Empirical evidence suggests that outdoor activities can improve cognitive, linguistic, social–emotional, and motor skills of preschool children: Yıldırım and Akamca's (2017) study and Dowdell et al. (2011) summarize literature that shows that overall, natural environments support children's imaginative play and the development of positive relationships. Whether smell played a role in these positive associations is not known, but there is one study that seems to get at the possible mechanisms implicated in beneficial aspects of natural environments that are related to smell: Martinec Nováková et al. (2018) demonstrated that diversity in children's olfactory environment affects variation in their olfactory abilities and odor awareness. This study involved 153 preschool children whose olfactory abilities were assessed using the Sniffin' Sticks test, and their odor awareness using a questionnaire. The children were retested 1.5 years later, controlling for age and verbal fluency effects. Parents provided information on their children's exposure to different odors and their own odor awareness. Results showed that children's odor identification and discrimination scores were influenced by parental odor awareness, though the effects were relatively small. This effect size was similar to that of gender and age. This study was among the first to demonstrate that the diversity of odors in children's environments impacted their olfactory abilities and awareness. Enhanced olfaction has been associated with mental well-being and adaptive behavior (e.g., Lane et al. 2010).

Consequently, this enhancement could potentially alleviate stress factors associated with reading practice in struggling readers.

8 | Ambient Smells as Mediators in Stress Reduction

For a struggling reader, going into a learning situation that necessitates reading, there is a high risk for the presence of more negative emotions. As well as the potential difficulty of the learning activity for the young person and the stress this may present, the situation may be exacerbated by the impact of accumulated previous experience of setbacks and/or negative feedback (from others, or self-talk). Extensive evidence now demonstrates that positive emotions generally result in positive learning outcomes, whilst the opposite is true for negative (i.e., unpleasant) emotions (see meta-analytic reviews, e.g., Barroso et al. 2020; Loderer et al. 2020). More specific to reading, low mood can impact cognitive resource allocation for comprehension (Bohn-Gettler and Rapp 2011). It can also reduce the ability to engage in effective decision-making (Isen 2000), which can make more complex reading tasks involving, for example, inference or linking multiple pieces of information together a significant challenge. Daley et al. (2014) have reported a direct link between middleschoolers' physiological response to the perceived threat posed by a reading activity and their resulting reading comprehension, with a lower threat physiological states during reading resulting in higher levels of comprehension.

The current, more dominant discourse on best practice reading instruction for struggling readers necessarily focuses on optimal instructional strategies, including systematic letter-sound (phonic) teaching to build word reading skill (Slavin et al. 2011), with vocabulary and strategy instruction increasingly emphasized as children move from "learning to read," to "reading to learn" (Chall 1983; Rapp et al. 2007). Indeed, not without notice here, instructional methods for children with specific reading difficulties such as dyslexia are often recommended to be "multisensory" or multimodal (International Dyslexia Association, n.d.). The employment of senses in this context is task specific and is grounded in cognitive psychology ideas of learning that consider multimodal presentation of information advantageous to both laying down well-specified representations of information, as well as information retrieval (e.g., Mayer and Moreno 1998). As a result, multisensory literacy lessons may involve, for example, reinforcing a spelling pattern through hearing the sound of the word, writing the spelling with pens, fingers or touchscreens, as well as potentially recreating the spelling pattern with 3D letter shapes or pictograms.

However, even as educators enact these principles across the globe, a significant group of readers continues to struggle (OECD 2023). There are a host of reasons for this, including macrosystem variations in educational provision and microsystem individual differences in component cognitive skills needed for reading, that is letter-sound mapping and sustained attention. However, another factor may be the relative lack of attention to supporting children's emotional readiness for learning, as well as emotional resilience in the face of learning difficulties. Indeed, Immordino-Yang and colleagues highlight the vital role played by a well-regulated emotional rudder (Immordino-Yang et al. 2019), that is, the capacity to make appropriate decisions and apply reasoning has both an emotional and cognitive component.

Supporting struggling readers may thus benefit from more consideration for the emotional design of reading encounters (Um et al. 2012). Discussion of methods to optimize reading motivation typically, and rightly, center upon characteristics of the text or instructional activity, with authentic, high-interest texts selected at an appropriate level of challenge all recommended as tools to help foster positive reading experiences (Parsons and Erickson 2024). Here we support a wider lens of consideration for emotionally sensitive instructional design. Established bodies of research exist that document the impact of the classroom environment on learning, with the optimization of heat, light, sound, and air quality all shown to have positive impacts on children's learning (Barrett et al. 2015). An integral part of instructional design could include attention to ambient smell.

Olfactory sensitivity is an early-developing behavior, observed from birth and even prenatally (Schaal 2015). Less is currently known about individual differences, though air pollution in urban areas appears to reduce sensitivity (Calderón-Garcidueñas et al. 2010; Sorokowska et al. 2015). Variation, both improvements and reductions, in olfactory sensitivity has been reported in learning differences including ADHD and autism, respectively, and linked to mood and motivation-related dopaminergic circuitry (Schecklmann et al. 2012). Within the general population, positive relationships have been observed between olfactory sensitivity and general well-being (Joshi and Hummel 2024).

Thus, we conjecture that early childhood experiences able to offer access to a diverse, pollutant-free olfactory environment can play a role in enabling an optimal response to educational environment-based aromatic interventions. These, in turn, can increase positive academic emotions, offering another tool in the complex alchemy of reading support. This premise is at the heart of our proposed theory of change that explains how odors could motivate struggling readers and positively impact their reading experience.

9 | Proposed Theory of Change for Olfactory Reading

A theory of change, intended as a catalyst for empirical investigation, is presented in Figure 1. The theory of change explains that the state-of-the-art review offers evidence that an individual's olfactory sensitivity could be a neglected source of support in literacy learning. Although individually tuned for specific preferences, and negatively impacted by urbanization, olfaction appears capable of physiological regulation of emotion, with positive ambient aromas increasing the presence and persistence of positive academic emotions. Positive academic emotion can directly facilitate learning, but also enables achievement motivation, which will help struggling readers in their efforts to learn to read and understand at both the word and connected text level. Instances of success then create a positive cycle of emotion and learning.

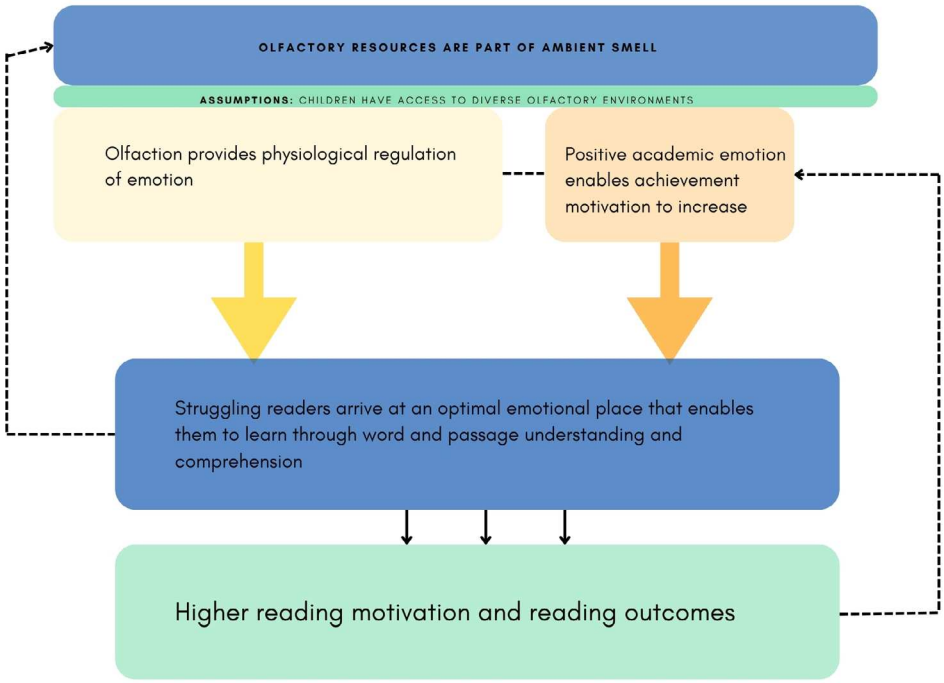

FIGURE 1 | Theory of change for olfactory reading.

This theory of change proposes that incorporating olfactory resources into the ambient environment can improve reading motivation and outcomes, particularly for struggling readers. The model is grounded in the assumption that children are regularly exposed to diverse olfactory environments, with access to pleasant or contextually relevant smells. The first key component of the model highlights that ambient smell can be strategically shaped or selected to include olfactory resources that benefit readers. It assumes that children's environments, such as classrooms and homes, are sufficiently varied and adaptable to introduce beneficial scents. The first pathway in this process focuses on the physiological regulation of emotion, where the presence of pleasant or appropriate scents can positively influence children's emotional and physiological states. Research in sensory and emotional psychology indicates that olfactory stimuli can directly affect mood and arousal, suggesting that relevant scents may elicit calming or stimulating effects that help maintain or achieve an optimal emotional state. The second pathway connects positive academic emotions with increased achievement motivation. The positive emotions elicited by ambient smells foster a supportive emotional climate for learning, which in turn enhances children's motivation to engage with reading tasks.

The model assumes that the emotional link between pleasant smells and academic contexts will generalize to reading activities, transferring the positivity elicited by olfactory cues to a greater eagerness to engage with texts. Furthermore, both pathways converge to benefit struggling readers by creating an "optimal emotional place" in which stress and anxiety are reduced, focus is heightened, and perseverance with reading tasks is improved. It is assumed that struggling readers, who typically face barriers to comprehension and sustained reading, will be particularly responsive to supportive sensory cues. Ultimately, this process leads to higher reading motivation and improved reading outcomes, as emotional and motivational barriers are addressed.

The model suggests that these changes in emotional regulation and motivation are strong predictors of better reading performance and can be sustained over time when olfactory stimuli are consistently integrated. The overarching assumption about children's access to diverse olfactory environments emphasizes the practical feasibility of the model, noting that without the ability to modify or control ambient smells, the proposed pathways may have limited impact.

In sum, the proposed theory of change suggests that olfactory stimulation influences reading motivation and outcomes by regulating emotions and enhancing academic motivation. By fostering a positive emotional environment, struggling readers can reach an optimal state for learning, leading to improved reading engagement and, consequently, comprehension. The assumptions highlight the need for further research into how olfactory stimuli can be systematically integrated into reading contexts and experiences.

10 | Implications for Research and Practice

The theory of change asserts that well-chosen ambient smells can foster an environment conducive to emotional regulation, sustained motivation, and enhanced reading skills for struggling readers. Building on this foundation, future research could explore the broader implications of olfactory interventions across academic domains, for example, in mitigating mathematics anxiety and enhancing numeracy skills (see Dowker et al. 2016). By examining the potential of ambient smells to alleviate the stress and cognitive barriers that often impede performance in mathematics, scholars can better

understand how emotional regulation may serve as a common pathway to reduce stress in foundational learning for children who struggle with traditional learning activities. Such interdisciplinary investigations will not only refine our understanding of the sensory-environmental factors that support learning, but also inform the development of comprehensive strategies aimed at fostering optimal learning contexts for all children.

Some easy-to-implement activities for practitioners include "smell walks" (Ingebretsen Kucirkova 2024), where teachers take students outside to experience fresh air and nature-based smells and thus provide a sensory break from the classroom that could promote stress reduction. Teachers and educational professionals could also create "scent stations" in the classroom, where different scents, such as vanilla for relaxation or citrus for energy, are used during various learning activities. For instance, calming scents could be introduced during fiction reading sessions, while energizing scents could be used during non-fiction reading sessions.

Intrinsic to the theory of change is also acknowledgment of individual differences. As noted earlier, individual affective responses to smells can vary. Equally, the relationship between a reader's emotional state and the text they are reading will not be unidirectional (see Pekrun 2021); the content of the text and the individual's subjective response to this will also modulate the reader's affective state in real-time (Karolides 1992).

This theory of change thus has two key implications for reading researchers. The first, relevant to all reading research, is that we must pay more attention to the wider sensory properties of reading experiences in both designing, interpreting, and reporting research findings. Secondly, and alongside the interdisciplinary research agenda just outlined, the theory needs empirical testing across different reader groups, reading activities, and texts.

11 | Conclusion

How best to support *all* struggling readers remains an urgent question with incomplete answers. This state-of-the-art review aims to accelerate insights by broadening the traditional scope of inquiry to include factors that may have been overlooked in conventional reading research. It draws on emerging studies that conceptualize reading as a multisensory activity—not limited to visual stimuli alone—and incorporates the idea that smell can play a meaningful role in reading engagement. While olfactory input alone may not be sufficient to engage the most reluctant readers, it represents a promising, underexplored dimension in the broader landscape of reading motivation.

The theory of change outlined in the paper underscores the importance of considering multisensory dimensions—in this case, smell—as part of the reading "microsystem" in Bronfenbrenner's ecological framework. By acknowledging that emotional and motivational factors are deeply embodied, it positions olfactory cues as a powerful yet underutilized tool to support reading achievement. We hope this will stimulate further empirical inquiries into this exciting topic of research.

Conflicts of Interest

The authors declare no conflicts of interest.

Data Availability Statement

The authors have nothing to report.

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