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Sensory Dimensions of Digital Literacy: An Investigation into Gendered Engagement with Olfactory-Enhanced Reading

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ABSTRACT

This article presents an in-depth exploration into the intersection of gender, multisensory learning, and digital literacy in early childhood. The persistent gender gap in reading engagement and achievement remains a significant challenge in education, with interventions traditionally focusing on content selection and social-pedagogical strategies. This study pioneers a novel investigative path by examining the integration of olfaction—the sense of smell—into digital reading environments. We investigate whether olfaction-enhanced digital books can modulate reading engagement, enjoyment, and comprehension among primary school children, and, more critically, whether these effects manifest differently between boys and girls. Drawing upon a robust theoretical framework that synthesizes theories of multisensory learning, embodied cognition, and critical multimodal literacy, this research posits that engaging the sense of smell, a modality with profound and direct connections to memory and emotion, may serve as a uniquely powerful tool to enrich the reading experience. We hypothesize that this sensory enhancement could offer a novel pathway to mitigate existing gender disparities in reading motivation and attitude. The findings are contextualized within the broader goal of designing more inclusive, effective, and sensorially rich digital learning environments that cater to the diverse needs of all young learners.

Keywords: Gender, Multisensory Reading, Olfaction, Digital Literacy, Reading Engagement, Gender Gap, Early Childhood Education, Embodied Cognition, Educational Technology, Human-Computer Interaction.

INTRODUCTION

1.1 A New Chapter in Reading

For generations, the image of a child reading was simple: a child, a book, and a quiet corner. Today, that picture has changed dramatically. The quiet corner might now be filled with the glow of a tablet, and the book itself might talk, animate, and invite interaction (100). We are in the midst of a profound shift in how children experience stories, moving from the familiar comfort of the printed page to a vibrant ecosystem of digital texts (13, 19). These e-books and story apps come with a host of new features—audio narration, moving pictures, interactive games—that promise to make reading a more dynamic and engaging experience (19, 94).

But as with any great change, this digital revolution in reading brings both promise and questions. Does a screen offer the same rich experience as a paper book? A major review of studies found that while well-designed digital books can indeed boost learning, poorly designed ones can be distracting and actually get in the way of comprehension (29). This tells us that the conversation can't just be about "print versus digital." We need to dig deeper and ask: what makes a digital reading experience truly great for a child? It's against this backdrop of exciting new possibilities and important questions that we must tackle one of the oldest and most stubborn challenges in education: the reading gap between boys and girls.

1.2 The Persistent Reading Gap

For as long as we've been measuring it, study after study has shown a consistent trend: boys, on average, tend to lag behind girls in reading skills and motivation (1, 12, 63, 69, 97). This isn't a simple issue; it's a complex puzzle with pieces rooted in our society, our culture, and our classrooms. Often, unspoken social rules label reading as a quiet, calm, and "girly" activity (18, 70). For many boys, this clashes with the pressure to be active, loud, and competitive (41). This can lead to what psychologists call "stereotype threat"—the fear of confirming a negative stereotype (like "boys aren't good readers") can create so much anxiety that it actually causes a child to perform poorly or simply give up on the activity altogether (42).

The books we offer children matter, too. If the library shelves are filled with stories that don't reflect the interests

of many boys—who might be craving more action, non-fiction, humor, or stories about technology and video games—it's easy for them to feel that reading just isn't "for them" (18, 59). The attitudes of parents and friends are also incredibly powerful. A parent's casual comment or a friend's teasing can be enough to reinforce these gendered ideas about reading (7, 20, 46).

The stakes are high. Strong reading skills are the foundation for all other academic success and open doors to future opportunities (2, 37). Educators have tried many creative solutions, from starting "Guys Read" book clubs (18) to using drama and theater to bring texts to life (96). These are fantastic efforts, but they tend to focus on *what* children read or the *social setting* for reading. In this study, we wanted to ask a different kind of question: what if we could change the fundamental *sensory experience* of reading itself?

1.3 A Whiff of Innovation: Bringing Scent into the Story

Our investigation sits at the crossroads of digital technology, gender studies, and the fascinating science of multisensory learning. The big idea behind multisensory learning is simple but powerful: we learn best when we engage more of our senses at once (6, 9, 92). Think about it—the world isn't just something we see and hear. We touch, we taste, and we smell. Yet, education has traditionally focused almost exclusively on sight and sound. We believe there's a huge, untapped potential in what are sometimes called the "hidden senses" (52, 73).

Of all these senses, the sense of smell is perhaps the most mysterious and powerful. It has a special, private pathway into the brain—a direct highway to the areas that control our emotions and store our long-term memories (15, 42). This is why a particular scent, like freshly cut grass or a certain perfume, can instantly transport us back in time, bringing with it a flood of feelings and detailed memories. It's a phenomenon known as the "Proustian effect," and it's a clue to the deep connection between smell and our inner world (15).

This connection has incredible implications for storytelling. What if, as a character walked through a pine forest in a story, the reader could actually smell the scent of pine? Researchers have found that even just reading the word "cinnamon" can light up the smell-processing parts of our brain (35). Imagine how much more powerful the experience would be if the scent were actually there. A new wave of research is calling for a "sensory turn" in literacy, urging us to think about how we can create richer, more immersive story worlds for children (52, 87). From scent-enhanced museum exhibits (55) to the first olfactory picture books (56), this is a new frontier in educational design.

1.4 Our Guiding Questions

We know that boys and girls are often encouraged to explore the world and express their emotions in different ways (20, 56). So, we wondered, would adding scent to a story affect them differently? Could the novelty and physicality of a scent-enhanced book make reading feel more like an exciting experiment, helping to break down those old stereotypes?

This led us to the core questions of our study:

1. **Does adding scent to a digital story actually make a difference?** Do children become more engaged, enjoy the story more, and understand it better compared to a regular digital book?
2. **Are there overall differences between boys and girls?** In general, do boys and girls engage with these digital stories differently?
3. **What happens when we put gender and scent together?** This is our key question: Does adding scent have a bigger impact on boys than it does on girls?

Based on everything we know about multisensory learning and the reading gap, we formed a clear prediction:

Our Hypothesis: We believe that while all children would find the scented story more engaging, the effect would be a game-changer for the boys. We predicted that the novelty and richness of the sensory experience would give boys' engagement and comprehension a major boost, effectively closing the gap we typically see between them and their female classmates.

With these questions in mind, we set out to design an experiment that could offer some real insight into how we might use the power of our senses to write a new, more inclusive chapter for childhood literacy.

METHODS

2.1 Our Experimental Blueprint

To get clear answers to our questions, we designed a straightforward experiment (14). We had two main factors we were looking at:

- **The Book's Condition:** Was it a regular digital book, or was it the special olfaction-enhanced version?
- **The Child's Gender:** Boy or Girl.

We then measured three key outcomes: how behaviorally engaged the children were, how much they said they enjoyed the story, and how well they understood it. We used a "between-subjects" design, which means each child participated in only one condition (either scented or not scented). This is important to avoid the novelty of the scented book influencing how a child might react to a regular book afterwards (14, 16). The entire process was carefully planned to meet the highest ethical standards for research with children (26, 27, 81).

2.2 The Young Readers

We worked with 124 children—62 boys and 62 girls—all

between the ages of 7 and 8. They came from four different public schools in a large, diverse city in Norway. We chose this age group carefully. At 7 and 8, children are becoming more confident readers, but their feelings and attitudes about reading are still taking shape, making it a perfect time to see what influences them (25, 71).

We reached out to parents through the schools, and they gave their written permission for their children to participate. We also made sure to get a "thumbs up" from each child before we began, explaining that it was just for fun and they could stop at any time (26). To keep everyone safe and the results clear, we didn't include children with known reading disabilities, fragrance allergies, or conditions like asthma (24).

2.3 The Story and the Scents

- **The Digital Story:** We created a simple, charming digital story called "The Forest Adventure." It was about a character who takes a walk through the woods to their grandmother's house to bake cookies. We designed the story specifically to have clear moments for scents. The digital book was presented on a tablet and had a friendly voice reading the story aloud, but we kept it simple—no extra games or flashy animations that could distract from the main experience (13, 86).
- **The Olfactory Cues:** We chose three high-quality, child-safe scents that matched the story perfectly: (1) a fresh **Pine Forest** scent for the walk in the woods; (2) an earthy **Damp Earth** scent for a moment after it rains in the story; and (3) a warm, sweet **Baking Cookies** scent for the happy ending at grandma's house.
- **The Scent Machine:** To deliver the scents, we used a standard ultrasonic diffuser—a device that turns water and fragrance oil into a fine, cool mist. But we gave it a high-tech twist. We hooked it up to a small computer (an Arduino) that we could control from the tablet. This allowed us to program the diffuser to release the exact right scent at the exact right moment in the story, automatically and silently. This setup ensured every child in the scented group had the exact same, perfectly timed experience (67, 68). We hid the diffuser behind the tablet so the children wouldn't be distracted by it.

2.4 The Reading Session

Each child had a one-on-one session with a researcher in a quiet, clean-smelling room at their school. The whole thing took about 25 minutes. After a friendly chat to make the child feel comfortable, they were randomly placed in either the scented-book group or the regular-book group.

- **The Scented-Book Group (31 boys, 31 girls):** These children read the story on the tablet while our special diffuser released the pine, earth, and cookie scents at the perfect moments.
- **The Regular-Book Group (31 boys, 31 girls):** These children read the exact same story on the exact same tablet. The diffuser was in the room, but it was just filled with water and wasn't turned on. This was our "control" to make sure just having the machine there didn't change anything.

While the child was reading, a researcher sat quietly in the corner, observing their behavior. As soon as the story was over, the researcher asked the child a few questions.

2.5 How We Measured Success

We used three different methods to get a full picture of each child's experience:

1. **Observing Engagement:** A trained researcher used a checklist to track the child's behavior. We measured how much time they spent actively looking at the screen versus looking away, and we counted any off-task behaviors like fidgeting or talking about something else (76, 88). This gave us an objective score for their behavioral engagement.
2. **Asking About Enjoyment:** We wanted to know what the children thought themselves. So, we asked them, "How much did you enjoy that story?" and had them point to one of five faces, from a big frown to a big smile. This is a great, kid-friendly way to understand their feelings (71).
3. **Checking Comprehension:** To see what they learned, we gave them a quick, friendly quiz with seven questions about the story. Some questions were about simple facts (e.g., "What animal did they meet?"), and a couple required them to think a little deeper (e.g., "Why do you think the character was happy?"). This gave us a score for how well they understood the story.

2.6 Analyzing the Numbers

We entered all the scores into a statistics program (IBM SPSS) to analyze the results (23, 61, 84). For each of our three measures (engagement, enjoyment, comprehension), we ran a "two-way ANOVA." This is a powerful statistical test that let us look at three things at once:

- The overall effect of the **Condition** (did the scented book work better in general?).
- The overall effect of **Gender** (did boys and girls score differently in general?).
- The all-important **Interaction Effect** (did the scented book affect boys and girls differently?). This was the direct test of our main hypothesis (43).

RESULTS

We analyzed the data to see what story the numbers would tell. We looked at how the olfactory-enhanced book and gender, both separately and together, influenced how

children engaged with the story. Here's what we found.

3.1 Behavioral Engagement: Who Was More Focused?

First, we looked at how focused the children were on the story. The results were clear: adding scents made a big difference. Overall, children who read the olfaction-enhanced book (M=8.91) were significantly more engaged than those who read the standard version (M=7.63). This was a strong, statistically significant finding (p<.001).

But the most fascinating part came when we looked at boys and girls separately. This is where we found a significant "interaction effect" (p=.004), which is a statistical way of saying that the scents affected the two groups differently.

When we dug into the numbers, the story became even clearer. For boys, the effect was dramatic. Boys who read the scented book (M=8.87) were vastly more engaged than boys who read the regular book (M=6.94). This was a huge, statistically significant leap (p<.001). For girls, however, the story was different. While they were also a bit more engaged with the scented book (M=8.95) compared to the regular one (M=8.32), the difference was small and not statistically significant (p=.152). In essence, the scented book took boys from being significantly less engaged than girls to being just as focused.

3.2 Self-Reported Enjoyment: Did They Have Fun?

Next, we looked at how much the children said they enjoyed the story. Here, too, the scented book was a clear winner. Children in the olfaction-enhanced group gave the story a significantly higher enjoyment rating (M=4.58 out of 5) than children in the control group (M=4.10), and this was statistically significant (p=.001).

However, unlike with engagement, we found no interaction effect here. This means that while both boys and girls enjoyed the scented story more, the boost in fun was about the same for both groups. The scents simply made the experience more pleasant for everyone.

3.3 Reading Comprehension: What Did They Remember?

Finally, we looked at the scores on the comprehension quiz. The pattern here looked remarkably similar to what we saw with behavioral engagement. Overall, children who experienced the scented book scored significantly higher (M=5.76 out of 7) than those who read the unscented version (M=4.98), a statistically significant result (p=.002).

And once again, we found a crucial interaction effect between the condition and gender (p=.025). Just as with engagement, the benefit of the scents was not spread evenly. Boys who read the olfaction-enhanced story scored dramatically higher on the comprehension quiz (M=5.68) than boys in the control group (M=4.45), a highly significant improvement (p=.001). For girls, the difference between the scented (M=5.84) and unscented (M=5.51) conditions was very small and not statistically significant. The added sensory layer helped the boys not only to pay better attention but also to understand and remember the story much more effectively.

Table 1: A Snapshot of the Scores: Mean Scores (and Standard Deviations) for All Measures

Dependent Variable	Group	Boys (n=62)	Girls (n=62)
Behavioral Engagement	Olfaction-Enhanced	8.87 (1.31)	8.95 (1.21)
(Composite Score 1-10)	Control	6.94 (1.35)	8.32 (1.33)
Self-Reported Enjoyment	Olfaction-Enhanced	4.55 (0.62)	4.61 (0.58)
(Pictorial Scale 1-5)	Control	4.03 (0.91)	4.16 (0.80)
Reading Comprehension	Olfaction-Enhanced	5.68 (1.09)	5.84 (1.15)
(Score 0-7)	Control	4.45 (1.29)	5.51 (1.18)

DISCUSSION

Our journey into the world of sensory-enhanced reading gave us some truly fascinating results. The findings offer a compelling new perspective on how we can make reading more engaging for all children, and they give us a powerful

clue about how to tackle the stubborn reading gap between boys and girls.

4.1 The Simple Power of Scent

The first big story from our data is that adding scent to a digital book works. It's not just a gimmick. Across the board, children were more focused, had more fun, and understood the story better when their sense of smell was part of the experience. This is a real-world demonstration of what multisensory learning theory tells us: our brains are wired to learn best when we take in information through more than one sense at a time (92, 93). We transformed reading from a simple see-and-hear activity into a see, hear, and *smell* activity, and the result was a richer, more immersive experience for the children.

The boost in enjoyment makes perfect sense—the pleasant smells of a pine forest and baking cookies likely put the children in a good mood, and we all know it's easier to learn when we're happy (42, 54). But the jump in focus and comprehension is even more important. It shows that the engagement wasn't just superficial. The scents seemed to act like an anchor, pulling the children deeper into the story's world and helping them to build a stronger, more detailed mental picture of what was happening. It's a great example of "embodied cognition"—the idea that our thinking is deeply connected to our physical, sensory experiences (11, 90). By smelling the forest, the children weren't just processing words; in a very real way, they were *there*.

4.2 A Bridge Across the Reading Gap?

The most groundbreaking discovery of our study, however, was how differently the scented book affected boys and girls. Just as we predicted, the benefits were not shared equally. For boys, the olfaction-enhanced book was a game-changer. It took them from being significantly less focused and understanding less of the story to performing at the exact same high level as the girls. In the control group, we saw the familiar reading gap. In the scented group, that gap vanished.

Why would this happen? We have a few ideas. First, the experience may have successfully reframed what "reading" means for boys. By adding a cool, physical, almost scientific element—the diffuser, the scents—the activity may have felt less like a quiet, passive task and more like an active, multisensory exploration. This could have helped to sidestep the negative stereotypes that can sometimes make boys feel like reading isn't for them (12, 42).

Second, the scents may have provided a more direct "way in" to the story for boys. Some research suggests that boys can be more drawn to action and plot than to a story's emotional undercurrents (74). A smell is a concrete, real-world thing. You don't have to infer the smell of a pine forest; it's just there. This direct sensory information might have made the story world feel more immediate and real, providing a powerful hook that captured their attention in a way the words alone might not have.

This isn't to say that boys are "sensory learners" and girls are not. What it suggests is that for a group of children who are, on average, less likely to be intrinsically motivated by a traditional story, adding a powerful, immersive sensory layer can act as a potent catalyst. It can level the playing field, allowing them to engage with and understand the text just as deeply as their peers.

4.3 What This Means for the Real World

These findings have exciting implications. For researchers and theorists, it's a strong vote for the idea that reading is an embodied, transactional experience (89, 90). It's not just about decoding words on a page; it's about the entire sensory and emotional world a reader brings to, and takes from, a text. It encourages us all to take a "sensory turn" and think about the whole child when we study literacy (52, 87).

For educators, parents, and app developers, the practical takeaways are huge. This study suggests we can help close the reading gap not just by changing *what* kids read, but by changing *how* they experience stories. While putting scent diffusers in every classroom might be a stretch, the principle is what matters. It's a call to make literacy more experiential. This could mean using drama, building story-related crafts, using tactile objects, or finding other ways to bring stories to life off the page and into the real, sensory world.

For the educational technology industry, this is a challenge to think beyond the screen. How can our digital devices connect with the physical world to create more powerful and immersive learning experiences? This study is a proof-of-concept that the future of digital literacy might be much more multisensory than we've yet imagined (73, 80).

4.4 Where Do We Go From Here?

Of course, every study is just one step on a longer journey. It's important to acknowledge our limitations and think about what's next.

1. **Can We Repeat This?** Our experiment used one story in a single session. The exciting effects we saw could be partly due to the novelty of the experience. We need more research to see if these results hold up with different kinds of stories (like non-fiction), with different age groups, and over longer periods of time.
2. **Why Did It Work?** We have some good theories, but we don't know for sure *why* the scents had such a powerful effect on boys. Future studies could include interviews with the children to get their perspective, or even use tools like EEG to look at brain activity during reading.
3. **Isolating the Scent:** To be even more certain it was the scent itself, future experiments could include other kinds of novelty, like a book with haptic feedback (vibrations) or even a book with scents that *don't* match the story, to see if the congruence is important.
4. **In the Wild:** We conducted our study in a quiet,

controlled room. The next big step is to see if these ideas can work in the busy, sometimes chaotic, environments of real classrooms and homes.

5. **All Kinds of Learners:** We focused on gender, but future research should explore how multisensory reading might affect children from different backgrounds and with different learning needs, like those with ADHD or on the autism spectrum, who often have unique ways of processing sensory information (24, 82).

CONCLUSION

In the end, our study tells a hopeful story. It shows that a simple, creative idea—adding the sense of smell to a digital book—can make reading more fun, focused, and meaningful for children. More importantly, it offers a promising new tool in our quest to close the persistent gender gap in literacy. We saw that a carefully designed, multisensory experience can lift boys' engagement and comprehension to meet the high levels of their female peers.

This research challenges all of us who care about children's literacy to think outside the book. It reminds us that the magic of a story is not just in the words, but in the world it creates in a child's mind. By engaging the "hidden senses," we can make those worlds more vivid, more memorable, and more accessible to all. The journey to creating a generation of lifelong readers may require us to not only open their eyes and ears but also to engage their noses, hands, and hearts in the process. The path forward is an exciting one, full of rich, sensory possibilities waiting to be explored.

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