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Exploring the sense of smell in shared digital book reading: An experiment

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ABSTRACT

Shared book reading during early childhood contributes to children's development in many important ways. This small-scale experiment, the first of its kind in the emerging field of olfactory research, explores whether reading a digital book with accompanying smell stimulation has a measurable effect on children's engagement, vocabulary acquisition, story comprehension, and overall interest in reading and smell. The study was conducted with 65 4- and 5-year-old Norwegian-speaking children, attending ECEC centers. Olfactory stimulation did not produce higher scores on post-experiment vocabulary and story comprehension, only the control variables of gender and prior vocabulary knowledge significantly predicted vocabulary and story comprehension scores. However, children's engagement was higher for stories with accompanying olfactory stimulation. Future research could integrate odour release into the reading device to not disrupt the reading process, and more reliably test the hypothesis that olfactory stimulation is conducive to reading engagement and learning outcomes.

Introduction

Reading is a foundational language and communication skill, essential for children's success in school and life (Dickinson & Porche, 2011), for building and maintaining relationships (Hebert-Myers et al., 2006) and impacting their learning and mental health in school (Boyes et al., 2018; Roulstone et al., 2011). Shared book reading (SBR) is when an adult reads a book with a child and engages them in activities or conversation about the content of the story. It is recognized as an important practice that promotes later independent reading and should be a regular activity in both home and early childhood education and care contexts (ECEC) (Senechal & Young, 2008). This study examines SBR in Norwegian ECEC with a specific focus on reading stimulated with the sense of smell. We limit our focus to reading of fictional narratives (stories) and the process of reading for learning (rather than learning to read).

Previous shared book reading research

Earlier meta-analyses have affirmed the positive influence of SBR on children's early literacy and reading achievement (Bus et al., 1995;

Scarborough & Dobrich, 1994) and emphasized the role of SBR in enhancing children's language skills (Dowdall et al., 2020; Noble et al., 2019). Today, SBR extends beyond traditional paper and board books to include digital formats, which are increasingly offered to children and offer promising avenues for children's literacy development (Korat & Falk, 2019). A recent meta-analysis of children's learning with digital books concluded that well-designed digital stories can be better for supporting the development of children's vocabulary and story comprehension than traditional books (Furenes et al., 2021). This was further supported by a meta-analysis of e-book interventions in ECEC settings, which found them to benefit children more than print story-book reading or regular childcare activities (Egert et al., 2022). In addition, an earlier study found that four-year-old children learned, on average, 25 % more target words in classrooms with e-books as well as paper books than children in classrooms without e-books (Roskos et al., 2016). Strouse et al. (2023) propose that well-constructed digital books, with built-in prompts, could effectively support dialogue and conversations about the content of the book. They also suggest collaboration between researchers and designers to explore other features that could be integrated into digital books, particularly for children with language delays or those learning a new language. However, there is still

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significant variation in the quality of digital books, with many lacking research-based design and containing distractions that are detrimental to children's learning (Meyer et al., 2021; Sari et al., 2019). While well-designed e-books have shown benefits for children's story comprehension and vocabulary learning (Bus et al., 2015), debates persist over the effectiveness of learning from digital versus print books. That said, researchers agree on the importance of book quality over the medium itself (Courage et al., 2019; Strouse et al., 2023).

New technologies have not only enabled the transition from traditional books to a variety of digital formats, but also the introduction of multisensory approaches, where more senses than just visual (seeing) and aural (hearing) are incorporated into reading activities. Multisensory reading refers to reading that also integrates elements of smell, taste, touch, or the sixth sense of proprioception (Mills, 2015; Kucirkova, 2022). Multisensory reading can be supported with traditional print or digital books, but thus far, much of the knowledge we have about reading focuses on reading stimulated through eyes and hearing. And yet, research indicates that optimal learning is promoted when our senses work together (Mills, 2015; Vannini, 2023) – that humans learn best through multisensory experiences (Charlesworth, R., 2014). Engaging the senses can lead to a deeper understanding of content and enhance memory retention (Gazioğlu & Karakuş, 2023), and may make experiences more interesting and memorable, regardless of one's cultural background (Classen, 1993). It follows that more research on how multisensory reading can engage all senses, and complement visual and textual reading experiences, is needed. Multisensory interactions with children's digital books, despite their possible affordances for learning (see Kucirkova, 2022; Kucirkova & Tosun, 2023), have not yet been extensively studied and were examined in our study.

This study is unique in the fields of SBR and multisensory research, and is the first, to our knowledge, that systematically explores the potential impact of olfactory stimulation on children's digital book shared reading experiences.

Olfaction enhanced shared book reading

In recent years, the concept of sensory reading has garnered attention for its potential to deepen the way we engage with texts (Baines, 2008). This approach goes beyond the traditional boundaries between print and digital formats, moving toward a multisensory interaction with reading materials that elicit embodied (whole body) engagement with stories (Kucirkova, 2022). Central to this discussion is the incorporation of olfactory stimulation, which has shown promise in enhancing comprehension and learning experiences when included in children's reading (Bordegoni et al., 2017; Kucirkova & Tosun, 2023).

Specific scents can activate mental imagery, with different aromas stimulating different brain regions, and these activations are linked to sensing, reading, and learning (Lübke et al., 2022). Additionally, Spinella (2002) found a relationship between smell identification and empathy, suggesting a potential link between olfactory performance and social competences, also important for learning from books.

Research on olfactory stimulation in reading with adults has yielded mixed findings. Some studies have found a connection between smell and reading comprehension, with scents activating regions of the brain not usually activated by reading and enriching the reading experience (González et al., 2006; Lübke et al., 2022), while others have failed to establish a direct correlation (Speed & Majid, 2018; Speed et al., 2022). However, scholars in the field have advocated for the integration of scents into reading materials, citing potential benefits such as reduced reading effort, increased enjoyment, and consequently, enhanced comprehension (Bordegoni et al., 2017). Similarly, Kucirkova (2022) underscores the importance of engaging all the senses, including smell, in early childhood education to explore their potential significance in explaining differences in children's responses to various books.

Efforts to incorporate olfactory elements directly into reading materials have demonstrated promising results, with prototypes of

olfactory books enhancing reader satisfaction and content comprehension in adults (Bordegoni et al., 2017). However, technological challenges still exist around appropriately incorporating odor release technology into print and digital books in a way that balances the integrity, intensity, and pacing of smells while prioritizing safe manipulation by young children. Challenges also remain in understanding and systematically measuring the full extent of the impact of olfaction on reading and learning, particularly among young children. Further research is needed to explore the role of sensory and spatial elements, including olfaction, in enriching early childhood learning experiences (Kucirkova & Kamola, 2022; Kucirkova & Tosun, 2023).

In sum, the integration of olfactory stimulation into reading holds potential for transforming learning experiences, especially among young children, but to date, this potential is largely unexplored. By taking a multisensory approach to reading that incorporates olfaction, educators may advance the creation of inclusive learning environments that cater to individual differences and preferences and may foster enhanced comprehension and engagement among readers of all ages.

Hypothesized outcomes from olfactory enhanced SBR

There is a general acceptance in educational research that student engagement is important for learning (Reschly & Christenson, 2022). For young learners in ECEC, positive engagement with learning activities has been associated with higher academic achievement, and optimal learning behaviors, when they transition into school (Neuharth-Pritchett & Bub, 2022). With primary school-aged children, engagement has been found to mediate the impact of other educational inputs, such as instructional practices, on reading outcomes (Wigfield et al., 2008). The positive connections between children's engagement and outcomes – academic, social, emotional, and behavioral – can be traced when engagement is defined relatively broadly. For example, Neuharth-Pritchett and Bub (2022) define engagement as “a multidimensional construct that consists of behavioural (including academic), cognitive, and affective subtypes. Student engagement drives learning; requires energy and effort; is affected by multiple contextual influences; and can be achieved for all learners” (p. 4)

Engagement may be more difficult to define and measure in young children, and consequently difficult to evaluate in relation to educational outcomes in early childhood education settings. Nonetheless, child engagement in learning activities in ECEC setting, both play-based activities and structured learning activities, is desirable. Young children should be actively engaged in reading texts that include new vocabulary, so as to make the significant gains in language that are required for their necessary growth in literacy in their early years (Jalongo & Sobolak, 2011).

Previous studies have shown that children's learning from SBR is substantial only if the children engage in repeated readings (Penno et al., 2002). For the repetition to be meaningful, the activities should combine the so-called enactive modes with a dialogic style (Jalongo & Sobolak, 2011), which include children's imitating motions or interacting directly with the text, thereby engaging more fully with the text. The multimedia theory also indicates that children need to hear and interact with a new word on several occasions and in multiple formats to integrate that word and its context with their working memory (Mayer, 2009). It is important to note that multimedia learning does not work with all types of stimuli and that children's story comprehension can sometimes be decreased when interactive features are included in the reading experience.

Despite the surging interest in multimedia and repeated reading experiences, to the best of our knowledge, no study has explored children's reading of digital books with olfactory stimulation. Zhou and Yadav (2017) included 72 pre-school children (aged 4–5 years old) in the US, and explored the relationship between engagement, vocabulary learning, and story comprehension. This study explored a different kind of multisensory experience (touch interaction), and combined

paper-based stories and multimedia stories with touch-interactive devices, with and without questioning techniques. Engagement was found to be higher with multimedia stories, which included interactions directly related to the target vocabulary words. Zhou and Yadav (2017) found that the multimedia stories without adult-led questioning was as effective for vocabulary acquisition as paper-based books with adult-led questioning techniques, but no differences were found in story comprehension, possibly due to the complexity of interrogating and ascertaining comprehension in young children (Zhou & Yadav, 2017).

Another study exploring the engagement of 44 toddlers (1–3 years old) in home-based literacy activities, found that children's engagement was the only predictor of vocabulary and morphosyntactic skills, with maternal education, home learning environment, and children's interest having no predictive value (Dicataldo & Roch, 2022). The level of children's engagement was significantly associated with their subsequent expressive vocabulary, indicating that meaningful engagement with interactive, interesting, and appealing materials during literacy activities was essential for language acquisition and development, especially in the first years of life (Dicataldo & Roch, 2022).

Other studies have shown that when children interact with multisensory learning materials, they show higher levels of engagement than with traditional text-based materials, and as a result, demonstrate better recall of the content of those materials (Shams & Seitz, 2008). Based on this theory, and existing literature about the connection between memory and olfaction (Chu & Downes, 2002), and olfaction and attention (Schriever et al., 2024), we hypothesized that learning effects could occur because of children's engagement with the olfactory materials. Therefore, in this study, we evaluated engagement in the reading session with established engagement scales, story comprehension with simple questions about story recall, and vocabulary acquisition with questions about what the children believed that several novel words, included in the stories, meant. We believe this is the first time that engagement, vocabulary acquisition, and story comprehension have been systematically evaluated with olfaction enhanced digital books and shared book reading sessions.

Our hypothesis was that children would be more engaged in the target condition (digital story enhanced with olfactory stimulation) than in the control condition (without olfactory stimulation), and that this engagement would be translated into increased scores on the vocabulary and story recall tests. In addition, we hypothesized that children's participation in the intervention would increase their interest in both reading and scents overall.

Research objective

With this study we hope to advance theoretical understanding about children's reading, and their engagement in multisensory reading experiences. Our research objective is grounded in Rosenblatt's transaction theory of reading (1969, 2018), a highly influential theory in children's literary studies that emphasizes the dynamic, social nature of texts (Mills & Stephens, 2004), and the active process of meaning-making that takes place between readers and texts, influenced by readers' life experiences and current emotional states. Our study aligns with Rosenblatt's proposition that readers actively respond to text elements, emphasizing the importance of stimulating all senses for optimal engagement. While Rosenblatt limited sensory stimulation in reading to the visual and auditory senses, our study explored the impact of olfactory stimulation in children's e-books, in addition to the visual stimulation through story illustrations and text, and auditory engagement through the SBR reading experience.

Material and methods

The broad aim of the present study was to determine whether including olfactory stimulation in digital shared book reading sessions had a measurable effect on young children's vocabulary, reading

comprehension, and engagement. The experiment was conducted with 4 to 5-year-old children attending ECEC in the southeast of Norway. The protocol for the experiment was published in September 2023 (Løkken et al., 2023) and fully describes the materials and methods required for the experiment, which are summarized in the following sections.

Study design

This study was a within-subject experiment with a cross-over design. All participants were read a digital book about smell with accompanying olfactory stimulation (target condition) and another digital book about smell without accompanying olfactory stimulation (control condition). Children were randomly assigned to either group 1 (BOOK A in the control version and BOOK B in the target version) or group 2 (BOOK A in the target version and BOOK B in the control version) with the order of the reading of the books being randomly assigned in session 1 and then reversed in session 2, reducing possible order or novelty effects. Reading sessions were held one day apart. This crossover design removed the variation between participants which exists in a parallel trial where participants only receive either the control or target condition, and therefore removed the need for equivalence testing of the groups prior to data analysis.

The books were read twice to each child. To ensure consistency across the conditions, the experimenter followed the same reading protocol for all children and all reading sessions. There was no deviation from the text at any point, and no engagement in extra-textual talk. If the child made an additional comment or asked a question, the experimenter answered the question or repeated the comment, but did not prompt new questions or explanations. In the target condition, the experimenter encouraged the child to smell the olfactory canisters at the relevant point in the story by asking: "Here, do you want to smell?", passing the canister to the child. After the second reading of each book, the tests of story recall and vocabulary were conducted. The reading and testing sessions were conducted one-to-one, in a quiet space within the ECEC setting. All reading sessions were conducted by the same researcher and followed a simple reading protocol to maintain consistency of child-researcher interactions. All reading sessions were video-recorded, and all testing sessions were audio-recorded and later checked for consistency.

Materials

Three books were used in the study – a regular paper-based book, and two digital books specially designed for the study. The paper-based book was used as a baseline measure of children's engagement with reading, vocabulary acquisition, and story comprehension, and was a simple story, with no reference to smell. The data from the baseline book were not used for the analyses in this present paper. Both digital books included storylines about smell and could be read either with olfaction enhancement (target condition) or without olfaction enhancement (control condition). Both digital books were similar in length, rhythm, and complexity, and all contained a set of target vocabulary words that would be unfamiliar to a typical 5-year-old, and of comparable difficulty. The olfaction enhancement was delivered at four points in the story and was provided with smell canisters from the board game "Les boîtes à odeurs" (Nature & Découvertes Ltd), which were placed in front of the iPad during the reading of the book in the experimental condition. The smells were carefully selected to be of similar intensity and quality, to complement the story without being directly referred to in the text, and to follow a pattern of positive – neutral – negative – positive valence. The smells were inserted into the story at points that are connected to the main events of story: setting the scene – development – problem – conclusion. The smells did not represent concrete objects but were abstract smells connected with the context of each main event. As such, the olfactory stimulation was designed to engage the children with storyline in general, and not connect directly with the target vocabulary words.

Research questions

The research questions for this study, as published in the protocol were:

- RQ1. Does reading to children a book with olfactory stimuli increase their vocabulary learning of words embedded in the story?
- RQ2. Does reading to children a book with olfactory stimuli increase their comprehension of the story?
- RQ3. How does children’s engagement with reading a book with olfactory stimuli compare to that with a book without olfactory stimuli?
- RQ4. Do parents observe an increase in child’s interest in reading and awareness of smells after participating in the experiment?

During the data analysis for this study (after publication of the protocol), a fifth research question was identified and explored:

- RQ5. Do the control variables of child gender and prior learning significantly predict vocabulary learning and story comprehension in this study?

Participants

The participants in this study were 65 Norwegian speaking children from 4 year old (n = 13) and 5 year old (n = 52) ECEC class groups (data on the exact age of children were not gathered), with no language based special education needs (as reported by ECEC staff). The children were recruited from five ECEC centers from two municipalities in the south-east of Norway, and therefore comprise a convenience sample based on geographical proximity and the settings’ willingness to participate. The plan, included in the study protocol, was to recruit a total of 79 children from six ECEC settings, considering a target sample of 66 children (determined by a power analysis) plus 20 % to allow for attrition. However, the recruitment process was more complex than expected, likely due to general system stress and resistance to yet more research within ECEC centers post COVID. That said, we managed to recruit 67 children within the established timeline, and had only 2 drop out, so the final sample of 65 was not a substantial deviation from the protocol. The two children that exercised their personal agency by indicating that they did not wish to participate or continue in the study, were invited on a second occasion to rejoin, but they declined and were withdrawn from the study. No data were retained on these 2 children.

The gender of the children in the study was reported by ECEC staff and corresponded to a category of either “boy” or “girl”. This categorization was an acknowledgment of the gender identities informed to the center by parents and recognized within their educational environment (Liben & Bigler, 2002). The sample of children in this study comprised 33 boys and 32 girls.

Measurement

Data on baseline measures, responses during the reading sessions, and post-experiment outcomes were gathered for all 65 children. The baseline measures included a general olfactory test to check if they were able to smell (a requirement for being included in the study), and a general language test to check their general language competence, the Cross-linguistic Lexical Tasks (CLT) developed for children aged 3 to 6 (Haman et al., 2015). No children were excluded due to an inability to sense odors. Scores on part 1 of the CLT (vocabulary identification) were used in this study as a control variable representing child’s prior vocabulary knowledge.

During the reading sessions, children’s participation was video recorded, and their engagement was evaluated using The Minnesota Teaching Task, as adapted by Moody et al. (2010) for reading books and later by Richter and Courage (2017) for reading digital books. This tool

contains the three subscales of persistence (active engagement and participation during the reading session), enthusiasm (expressive engagement, vitality, and eagerness during the reading session), and compliance (cooperation, following the researcher’s instructions, and complying with the expectations of the session). The researcher that coded the videos assigned ratings from 7 (highest engagement) to 1 (lowest engagement) for each of these subscales, and a combined engagement variable, the average of the three subscales, was also calculated. To ensure validity of the coding, the research team discussed the coding definitions and scales, and then two researchers independently coded 20 % of the participants. Discrepancies were discussed and resolved, and once the agreement on the coding criteria was reached, the remaining participants were coded by one researcher.

Children’s vocabulary acquisition from the intervention was tested by repeating sentences from the books that included the target words and asking children what the words meant. Children scored either 0 (no correct answer), 1 (partially correct answer), or 2 points (correct answer) for each vocabulary word. There were 5 target words in each book.

Children’s reading comprehension was measured with an adapted version of the Paris and Paris (2003) narrative comprehension test. The test was adjusted to include questions from our study’s stories. The researcher asked the children to retell the story, with five questions accompanied with pictures from the story. For example, the researcher asked: “What happened here? Why did this happen?” and pointed to the relevant picture. The answers were scored as either 0 (no correct answer), 1 (partially correct answer) or 2 points (correct answer) per question.

The descriptive statistics for the scales used for each of these variables are presented in Table 1. The coefficient of reliability (Cronbach’s Alpha) for each scale was above 0.83, indicating a good level of internal consistency. The significant gender difference observed on the scales of prior level vocabulary and post-test comprehension, are consistent with previous research showing that girls tend to score higher than the boys on similar tests in the early years (Meland et al., 2016; Moser & Reikerås, 2016).

Finally, a parent questionnaire was sent out 14 days after the last reading session, containing questions about the child’s interest in reading and preference for various scents and smells post-experiment. A copy of the parent’s questionnaire, and additional information on all measures in this study, are included in the published protocol.

Analysis

For comparing differences across groups for single outcomes, repeated measures T-tests were used for categorical variables (as each child has a score for both the control condition and the target condition), and simple linear regressions for continuous variables. For combined outcomes, repeated measures MANOVA were conducted. For the final analysis, exploring whether any of our variables together or independently predicted post experiment vocabulary and comprehension scores,

Table 1
Descriptive statistics of scales used.

Name of scale	Number of items	Cronbach’s Alpha	M	SD	Group comparison by gender	
					t-statistic	p-value
CLT vocabulary	64	0.837	58.0	4.58	3.14	<.001 **
Post-test vocabulary	10	0.839	1.1	066	1.13	.26
Post-test comprehension	8	0.848	1.5	.76	2.51	.01 *
Engagement	6	0.898	4.8	.71	1.27	.21

Note: M = mean, SD = standard deviation, *p < .05. **p < .01.

a series of multiple linear regression were conducted, with experimental and control variables. All analyses were conducted in R version 4.4.0 (R Core Team 2024) and RStudio version 2024.04.1 + 748 (Posit Software, PBC, 2024). Alpha was set at 0.05, and *p*-values are represented with the standard notation of *** *p* < .001, ** *p* < .01, and * *p* < .05.

Ethics

This study was approved by the Norwegian Data Center for Ethics (NSD, 615,584), and all personal information has been kept confidential and protected. The children were recruited by the staff in the ECEC settings, by providing the children’s parents information about participating in the project. Parents either gave or withheld their consent for their child’s participation, and they were informed they had the right to withdraw from the study at any time.

When collecting data, the researcher was sensitive to the children and their needs. Children were invited to participate at a moment that would not disrupt play or interactions between the children. ECEC staff talked with the children prior to participation, specifically about who the researcher was, and what they would be doing when they came to the center. The researcher was sensitive to the child’s willingness to participate, allowing a skeptical child to be accompanied by a friend, or to choose to wait until after lunch, for example. Some children were shy to meet the researcher, so the researcher spent time in the environment, helping put on shoes and jackets and sitting by the table when the children were drawing, for example, to help them feel secure. Some children that were not included in the sample due to language limitations or lack of parental consent, were really interested in the reading activities and felt excluded. For these children, the researcher held a general reading session, but they were not included in any data gathering, or in the audio or film recordings.

Results

Before beginning the formal analyses for this study, we explored the correlations between our variables, presented in Table 2. Significant positive correlations were found between the baseline general vocabulary scale (CLT) and target condition vocabulary (*r* = 0.25, *p* = .049) and comprehension (*r* = 0.36, *p* = .004), between vocabulary and comprehension in the target condition (*r* = 0.59, *p* < .001), and between vocabulary and comprehension in the control condition (*r* = 0.72, *p* < .001),

Olfactory stimuli, vocabulary, and comprehension

Our first research questions focused on a hypothesized direct relationship between olfactory stimulation, vocabulary acquisition, and reading comprehension.

In both cases our hypothesis was one-sided – that children would have improved vocabulary and comprehension scores from the story with olfactory stimuli (target condition) than from the story without olfactory stimuli (control condition).

A repeated measures T-test was used to compare the mean of the

vocabulary score between the control and target conditions. No significant difference was found between the mean vocabulary scores (control = 1.11 (sd = 0.69), target = 1.16 (sd = 0.75), *t* = 0.223, *p* (one-sided) = 0.412, Cohen’s *d* = 0.03), indicating that the olfactory stimuli in this experiment did not increase vocabulary learning of the words embedded in the story in a significantly measurable manner. A second repeated measures T-test was used to compare the mean of the comprehension scores between the control and target conditions. Once again, no significant difference was found between the mean comprehension scores (control = 1.50 (sd = 0.85), target = 1.51 (sd = 0.81), *t* = 0.082, *p* (one-sided) = 0.468, Cohen’s *d* = 0.01), indicating that the olfactory stimuli in this experiment did not increase comprehension of the story in a significantly measurable manner.

To double check these null findings and ensure that there was not a combined effect, we conducted a repeated measures MANOVA exploring the combined outcome of vocabulary and comprehension as predicted by control/target. No significant combined relationship was found (*Wald-Type Statistic* = 1.053, *p* = .591).

The similarity of the vocabulary and comprehension scores, grouped by control or target condition, is evident in the box plots in Fig. 1.

For story comprehension, the distribution of the upper and lower quartile scores are lower for the target condition than the control condition, while the minimum, maximum, and median scores are the same. However, despite being visually distinct, these groups are not statistically significantly different.

Olfactory stimuli and child engagement

Our second focus was on a hypothesized direct relationship between olfactory stimulation and child engagement.

Our hypothesis was again one-sided – that children would be more engaged with the story with olfactory stimuli (target condition) than the story without olfactory stimuli (control condition). The variables used for engagement were the measures of persistence, enthusiasm, and compliance, and the mean of these three variables, simply named engagement.

A repeated measures T-test was used to compare the mean of child engagement between the control and target conditions. A significant difference was found between the mean engagement scores (control = 4.19 (sd = 0.66), target = 5.29 (sd = 0.80), *t* = 9.089, *p* (one-sided) < 0.001). Engagement was significantly higher under the target condition, and the effect size, as measured by Cohen’s *d*, was *d* = 1.14, indicating a large effect. This significant difference is evident in the box plot in Fig. 2.

In addition, we explored each of the three subscales of engagement, and found a similar relationship for each. There was a statistically significant difference between target and control conditions for each of the three engagement subscales, with engagement being higher with the olfaction enhanced stories. Enthusiasm displayed a somewhat greater difference than persistence and compliance (see Table 3).

Further information on the relationship between engagement and the outcomes of reading and comprehension is provided by the

Table 2
Correlations (Pearson) between variables (*n* = 65).

Variable	1	2	3	4	5	6	7
1. CLT vocabulary TARGET CONDITION		−0.05	.25*	.36**	−0.13	.22	.23
2. Engagement			−0.02	−0.05	.17	−0.12	−0.26**
3. Vocabulary				.59**	−0.04	.21	.12
4. Comprehension CONTROL CONDITION					−0.15	.04	−0.02
5. Engagement						−0.01	.11
6. Vocabulary							.72**
7. Comprehension							

Note: **p* < .05. ***p* < .01.

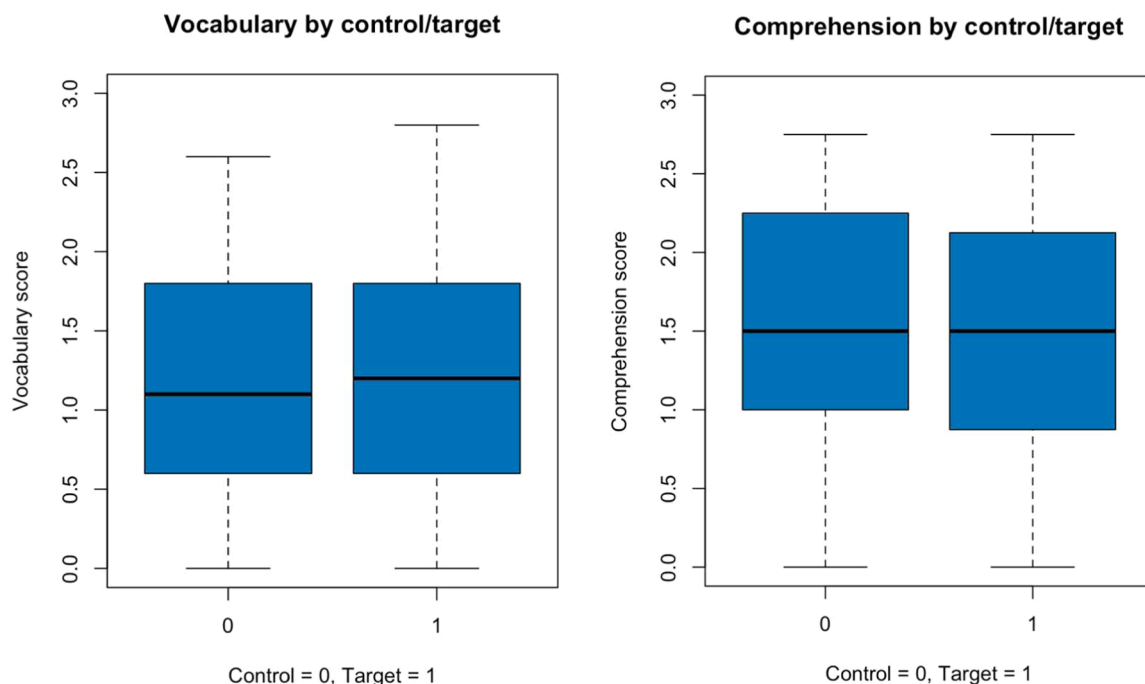


Fig. 1. Post-test of vocabulary and comprehension scores, by control and target book condition.

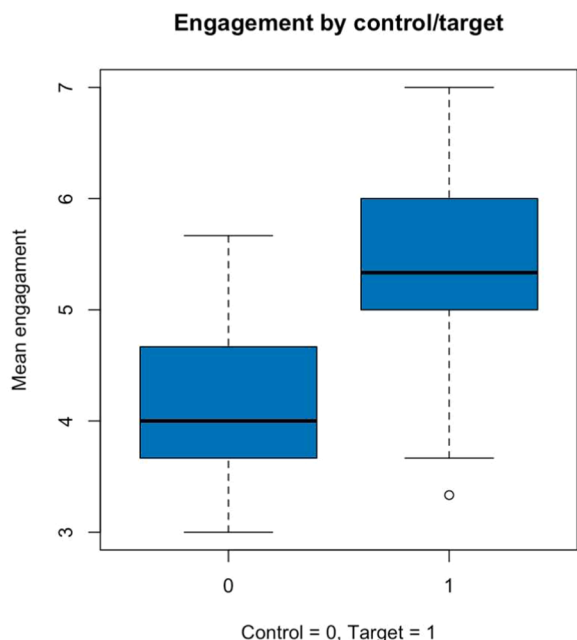


Fig. 2. Post test of child engagement, by control and target book condition.

Table 3
Descriptive statistics and repeated measures T-test results for three engagement subscales.

	Mean difference	T-test t statistic	T-test p-value	Cohen's d
Persistence	1.02	7.166	<0.001	.896
Enthusiasm	1.44	9.635	<0.001	1.20
Compliance	.81	6.091	<0.001	.761

correlations in Table 2. All four relevant correlations are nonsignificant: between Target engagement and Target vocabulary ($-.02$) and comprehension (-0.05), and between Control engagement and Control vocabulary (-0.01) and comprehension (0.11).

Child interest in reading and awareness of smells

In our initial project design, we proposed exploring the impact of the experiment on children’s interest in reading and awareness of smells through a follow-up survey with parents.

However, very few parents (21 of 65) replied to our questionnaire, despite two reminders. We cannot, therefore, draw any conclusions based on this data, but provide a brief description of the responses. Six parents reported an increased interest in reading from their child after the experiment, nine parents reported no noticeable difference in their child’s interest in reading, and six parents are unsure whether their interest was caused by the experiment or not. When it came to the awareness of smell, nine parents reported no noticeable difference in their child’s awareness of smells after the experiment, and twelve reported that they had noticed an increased interest in smell. When asked to elaborate, parents provided comments such as:

- “When he notices a smell, he wants to know what the smell is.”
- “She frequently asks what smells and wants to know where the smell is coming from.”
- “She commented that it smelled good on Sunday when I was baking bread.”
- “We have the impression that she wants to smell more food and flowers, and maybe uses her senses more consciously.”

Predictors of post experiment vocabulary and comprehension scores

In exploring our research questions 1–3, we did not find evidence that olfactory stimulation was directly related to post reading vocabulary or story comprehension. Although child engagement was higher when books were accompanied by olfactory stimulation, vocabulary and comprehension scores were not higher in the presence of higher child engagement.

To conclude our analysis, we wanted to assess whether any of the variables in our data set were significantly associated with our outcome variables (vocabulary and comprehension), including the typical control variables of child gender and prior learning. We therefore conducted hierarchical multiple regressions with each outcome as the dependent variable, and with the independent variables of child gender (1=girl), CLT1 (pre-test vocabulary assessment), mean engagement score, and target condition (1=olfactory stimulation) entered in that order, based on our research questions. The results of these analyses are displayed in Table 4.

These results confirm our earlier findings, that neither engagement nor olfactory stimulation were associated with vocabulary and comprehension scores in this study. They also show that the only variable that consistently predicts these scores is the child’s prior level of vocabulary (as measured by the CLT), and in the case of comprehension, also the child’s gender. Girls, and children with higher pre-study vocabulary levels, consistently scored higher on the post-study comprehension questions. However, the control variables only explained 9 % and 16 % of the variance in those two scores respectively (R^2 vocabulary =0.09, R^2 comprehension =0.16).

Discussion

In this study, we found a significant and positive relationship between olfactory stimuli and children’s engagement with shared book reading (our third research focus). The results did not, however, support our hypothesis of a direct relationship between olfactory stimulation, vocabulary acquisition, and reading comprehension. We discuss all the findings in the order that the study was described in our published protocol (Løkken et al., 2023) and in light of published literature. We then reflect on the limitations and strengths of this study and future directions for work in this field.

Contrary to our expectations based on previous research on the use of electronic storybooks with young children (for example, Bus et al., 2015; Zhou & Yadav, 2017) and on the incorporation of odor into reading and learning experiences (for example, Bordegoni et al., 2017; González et al., 2006; Lübke et al., 2022), we did not find a significant relationship between olfactory stimulation and our two outcome measures, vocabulary acquisition and reading comprehension. Notably, our experiment did not result in the improved vocabulary acquisition that Zhou and Yadav (2017) found with children of the same age. This may be due to the ambient, rather than specific, nature of the smells that we incorporated into the stories, whereas Zhou and Yadav (2017) used multimedia interactions that were directly associated with the target vocabulary.

Our findings are consistent with previous studies with adults that have found that olfaction does not directly affect learning outcomes (Speed & Majid, 2018; Speed et al., 2022), but they should not be interpreted to indicate that a relationship between olfactory enhanced shared book reading, vocabulary acquisition, and comprehension does not exist; rather, we conclude that in this small-scale, short duration

experiment, no such relationship could be detected.

Our findings that children were more engaged with the story with olfactory stimuli (target condition) than with the story without olfactory stimuli (control condition) are consistent with the higher engagement rates with multisensory reading reported by earlier research (Charlesworth, R., 2014; Cosentino & Giannakos, 2023; Gazioglu & Karakuş, 2023). Multisensory reading stimulates several senses simultaneously (Kucirkova, 2022) and has been predicted to result in greater engagement in reading (Mills, 2015). Other studies have found that the stimulation of the sense of smell increases enjoyment (Bordegoni et al., 2017), and enriches the experience of storytelling (Kucirkova & Kamola, 2022). Such interaction with the text activates an enactive mode of learning, resulting in better engagement, and theoretically, in increased vocabulary acquisition (Jalongo & Sobolak, 2011). We observed the increased engagement but did not see it translated into measurable learning effects. The design of the study may be the explanation for these null findings, as the intensity of the olfactory stimulation and its duration may have underpowered the possibility for engagement to translate into actual learning gains.

The only factors that were found to be predictive of children’s performance on the outcome tests of vocabulary acquisition and story comprehension, were the child’s earlier vocabulary identification (measured by the CLT, Haman et al., 2015), and gender. This is unsurprising and supported by previous literature, which has found a relationship between oral language and story retelling, stable across ages in young children (Ralli et al., 2021), and prior vocabulary levels have been found to be unique predictors of concurrent narrative comprehension in children of this age (Silva & Cain, 2015). The fact that being a girl was positively associated with reading comprehension in our study, is also in line with other studies where girls have been observed to score higher than the boys on similar tests in the early years (Meland et al., 2016; Moser & Reikerås, 2016).

Incorporating odour into shared book reading with young children was found to increase the child’s engagement and, anecdotally, as reported by the parents, their interest in smell. Some parents reported an increased interest in reading and an increased awareness of smells in everyday life, attributing that to the activity of the experiment. Additionally, ECEC staff mentioned in informal conversations with the researcher, that the children had talked about different scents and the content from the stories in the books.

The finding that olfactory enhancement of books increased children’s engagement with the learning activity, suggests that new learning strategies for multisensory activities in ECEC may be promising for increasing child engagement, and potentially, learning. These strategies could extend beyond reading to other activities throughout the day, such as play sessions, indoor group sessions, and outdoor activities. Integrating multisensory learning resources in ECEC from an early age, including olfaction (Kucirkova & Kamola, 2022; Kucirkova & Tosun, 2023), could engage more children in play and learning experiences, regardless of cultural background (Classen, 1993).

Limitations and future directions

In light of the non-significant findings, we suggest that future studies examining olfactory stimulation in reading could focus on engagement as the direct outcome of olfactory enhanced reading, with language learning as a distal outcome, employing more complex methods such as structural equation models to explore these distal outcomes. It could also be argued that a similar experiment with a longer duration and a larger sample size might yield statistically significant results. However, the duration of reading was determined based on pilot data, and the desired sample size was calculated as part of the experimental protocol. We propose that possible limitations include our choice of language learning as a direct, not distal, outcome, our choice of target vocabulary words, and our design decisions about the use of olfactory enhancement in the form of smell canisters.

Table 4
Regression results.

	Vocabulary		Comprehension	
	All variables	Control variables only	All variables	Control variables only
(intercept)	-1.42	-1.42	-1.71	-1.46
Gender	.03	.03	.35*	.33*
CLT1	.03***	.03***	.03***	.03***
Engagement	-0.01		.06	
Target condition	.06		-0.09	
F	2.93	5.87	5.78	11.47
p	.02	<0.01	<0.01	<0.01
R2	.09	.09	.16	.16

Note: *** $p < .001$, ** $p < .01$, * $p < .05$.

It may be that the target vocabulary words embedded in the story were too difficult for young children to learn over such a short period, or that our decision to use olfaction enhancement related to the settings in the stories rather than the target words, limited the possibility of a measurable effect. The improvement in vocabulary that was detected in a similar study with multimedia books (Zhou & Yadav, 2017), included interactions directly related to the target words. It thus might be that we needed to connect the olfactory stimulation to the target word to see measurable effects. Furthermore, findings by Zhou and Yadav (2017) would suggest that an effect on vocabulary is more likely to be detected than on comprehension, due to the complexities of measuring comprehension and story recall reliably in young children. Future studies could focus on vocabulary learning only.

In addition, a significant limitation is the technical challenge of releasing the scent during reading. The olfaction canisters (Nature & Decouvertes Ltd) that we used in this study may have distracted the children from vocabulary learning and story comprehension. It would be beneficial to develop technological devices where olfaction can be integrated into the reading device, maintaining the same intensity of odors, and ensuring safe manipulation for children. This way, children could be exposed to the smell and engage with the reader and the digital book without being distracted by the physical manipulation of the smell canisters.

A methodological limitation is that the coding of engagement in this study was not blind to the intervention. When coding the data, it was possible to see which reading session involved the target book and which involved the control book. This issue could be addressed by the development of a device that automatically releases the odor; however, it is still probable that the researcher coding the engagement data would be able to tell when the child was being read to in the target condition and when in the control condition. Any possible bias that may result from this should therefore be acknowledged as a possible limitation in this study.

Our methodological recommendation for further research is to develop and use digital devices that integrate olfaction more seamlessly into the reading process. This may prevent children from being distracted by the smell delivery method when reading. We recommend exploring designs that include dialogue and communication around the sensory book, as these elements have been shown to drive vocabulary learning and story comprehension (Strouse et al., 2023), so that children can interact with the target vocabulary words (Mayer, 2009; Shams & Seitz, 2008) to gain a deeper understanding of the content (Gazioğlu & Karakuş, 2023). Finally, investigating how multisensory reading affects interactions between the researcher and the child, as well as among the children themselves, might provide further insights into this little explored area.

In conclusion, our small-scale experiment showed a specific impact of reading olfaction enhanced digital stories on typical reading outcomes in young children. We found a significant positive relationship with child engagement, but no detectable relationship with vocabulary acquisition or story recall. Given the theoretical possibility for a significant relationship between children's increased engagement and learning outcomes, we recommend future research in this little explored area, with emphasis on more seamless olfactory stimulation of reading.

CRedit authorship contribution statement

Ingrid Midteide Løkken: Conceptualization, Methodology, Resources, Investigation, Data curation, Writing – original draft, Writing – review & editing. **Janine Anne Campbell:** Methodology, Formal analysis, Visualization, Writing – review & editing, Supervision. **Philip S. Dale:** Conceptualization, Methodology, Writing – review & editing. **Natalia Ingebretsen Kucirkova:** Conceptualization, Methodology, Resources, Writing – review & editing, Supervision, Project administration, Funding acquisition.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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References

- Baines, L. (2008). *A teacher's guide to multisensory learning: Improving literacy by engaging the senses*. Association for Supervision and Curriculum Development.
- Bordegani, M., Carulli, M., Shi, Y., & Ruscio, D. (2017). Investigating the effects of odour integration in reading and learning experiences. *Interaction Design and Architecture(s) Journal*, 104–125. <https://doi.org/10.55612/s-5002-032-007>
- Boyes, M. E., Tebbutt, B., Preece, K. A., & Badcock, N. A. (2018). Relationships between reading ability and child mental health: Moderating effects of self-esteem. *Australian Psychologist*, 53(2), 125–133. <https://doi.org/10.1111/ap.12281>
- Bus, A. G., Takacs, Z. K., & Kegel, C. A. (2015). Affordances and limitations of electronic storybooks for young children's emergent literacy. *Developmental Review*, 35, 79–97. <https://doi.org/10.1016/j.dr.2014.12.004>
- Bus, A. G., Van Ijzendoorn, M. H., & Pellegrini, A. D. (1995). Joint book reading makes for success in learning to read: A meta-analysis on intergenerational transmission of literacy. *Review of Educational Research*, 65(1), 1–21. <https://doi.org/10.3102/00346543065001001>
- Charlesworth, R. (2014). *Understanding child development*. Wadsworth Cengage Learning, 9th edn.
- Chu, S., & Downes, J. J. (2002). Proust nose best: Odors are better cues of autobiographical memory. *Memory & Cognition*, 30(4), 511–518.
- Classen, C. (1993). *Worlds of sense: Exploring the senses in history and across cultures*. Routledge.
- Cosentino, G., & Giannakos, M. (2023). Multisensory interaction and analytics to enhance smart learning environments: a systematic literature review. *IEEE Transactions on Learning Technologies*, 16(3), 414–430. <https://doi.org/10.1109/TLT.2023.3243210>
- Courage, M. L., Kim, J. E., & Hassinger-Das, B. (2019). From print to digital: The medium is only part of the message. In *Reading in the digital age: Young children's experiences with E-books. literacy studies*, 18. Springer. https://doi.org/10.1007/978-3-030-20077-0_3
- Dicaldo, R., & Roch, M. (2022). How does toddlers' engagement in literacy activities influence their language abilities? *International Journal of Environmental Research and Public Health*, 19. <https://doi.org/10.3390/ijerph19010526>
- Dickinson, D. K., & Porche, M. V. (2011). Relation between language experiences in preschool classrooms and children's kindergarten and fourth-grade language and reading abilities. *Child development*, 82(3), 870–886. <https://doi.org/10.1111/j.1467-8624.2011.01576.x>
- Dowdall, N., Melendez-Torres, G. J., Murray, L., Gardner, F., Hartford, L., & Cooper, P. J. (2020). Shared picture book reading interventions for child language development: A systematic review and meta-analysis. *Child development*, 91(2), 383–399. <https://doi.org/10.1111/cdev.13225>
- Egert, F., Cordes, A. K., & Hartig, F. (2022). Can e-books foster child language? Meta-analysis on the effectiveness of e-book interventions in early childhood education and care. *Educational Research Review*. <https://doi.org/10.1016/j.edurev.2022.100472>
- Furenes, M. I., Kucirkova, N., & Bus, A. G. (2021). A comparison of children's reading on paper versus screen: A meta-analysis. *Review of Educational Research*, 91(4), 483–517. <https://doi.org/10.3102/003465432199>
- Gazioğlu, M., & Karakuş, N. (2023). The impact of multisensory learning model-based tale-telling on listening skills and student opinions about it. *Frontiers in Education*, (8) <https://doi.org/10.3389/educ.2023.1137042>
- González, J., Barros-Loscertales, A., Pulvermüller, F., Meseguer, V., Sanjuán, A., Belloch, V., et al. (2006). Reading cinnamon activates olfactory brain regions. *NeuroImage*, 32(2), 906–912. <https://doi.org/10.1016/j.neuroimage.2006.03.037>
- Haman, E., Luniewska, M., & Pomiechowska, B. (2015). Designing cross-linguistic lexical tasks (CLTs) for bilingual preschool children. eds. In S. Armon-Lotem, J. de Jong, & N. Meir (Eds.), *Assessing multilingual children: Disentangling bilingualism from language impairment* (pp. 196–240). Multilingual matters

- Hebert-Myers, H., Guttentag, C. L., Swank, P. R., Smith, K. E., & Landry, S. H. (2006). The importance of language, social, and behavioral skills across early and later childhood as predictors of social competence with peers. *Applied Developmental Science, 10*(4), 174–187. https://doi.org/10.1207/s1532480xads1004_2
- Jalongo, M. R., & Sobolak, M. J. (2011). Supporting young children's vocabulary growth: the challenges, the benefits, and evidence-based strategies. *Early Childhood Education Journal, 38*, 421–429. <https://doi.org/10.1007/s10643-010-0433-x>
- Korat, O., & Falk, Y. (2019). Ten years after: Revisiting the question of e-book quality as early language and literacy support. *Journal of Early Childhood Literacy, 19*(2), 206–223. <https://doi.org/10.1177/1468798417712105>
- Kucirkova, N. (2022). The explanatory power of sensory reading for early childhood research: The role of hidden senses. *Contemporary Issues in Early Childhood. https://doi.org/10.1177/1463949122111169*
- Kucirkova, N., & Kamola, M. (2022). Children's stories and multisensory engagement: Insights from a cultural probes study. *International Journal of Educational Research, 114*. <https://doi.org/10.1016/j.ijer.2022.101995>
- Kucirkova, N., & Tosun, S. (2023). Children's olfactory picture books: Charting new trends in early childhood education. *Early Childhood Education Journal, 1–10*. <https://doi.org/10.1007/s10643-023-01457-z>
- Liben, L. S., & Bigler, R. S. (2002). The developmental course of gender differentiation: Conceptualizing, measuring, and evaluating constructs and pathways. *Monographs of the Society for Research in Child Development, 67*(2), 147. <https://doi.org/10.1111/1540-5834.t01-1-00187>. vii.
- Løkken, I. M., Campbell, J. A., Kucirkova, N. I., & Dale, P. (2023). Experiment protocol: Exploring the sense of smell in digital book reading. *International Journal of Educational Research Open, 5*, 100285. <https://doi.org/10.1016/j.ijedro.2023.100285>
- Lübke, K. T., Blum, T. C., & Pause, B. M. (2022). Reading the mind through the nose: Mentalizing skills predict olfactory performance. *Brain Sciences, 12*(5), 644. <https://doi.org/10.3390/brainsci12050644>
- Mayer, R. E. (2009). *Multimedia learning*. New York: Cambridge University Press, 2nd ed.
- Meland, A. T., Kaltvedt, E. H., & Reikerås, E. (2016). Toddlers master everyday activities in kindergarten: A gender perspective. *Early Childhood Education Journal, 44*(4), 349–358. <https://doi.org/10.1007/s10643-015-0718-1>
- Meyer, M., Zosh, J. M., McLaren, C., Robb, M., McCaffery, H., Golinkoff, R. M., et al. (2021). How educational are “educational” apps for young children? App store content analysis using the Four Pillars of Learning framework. *Journal of Children and Media, 15*(4), 526–548. <https://doi.org/10.1080/17482798.2021.1882516>
- Mills, K. A. (2015). *Literacy theories for the digital age: Social, critical, multimodal, spatial, material and sensory lenses, 45*. Multilingual Matters.
- Mills, H., & Stephens, D. (2004). Theory in practice: The legacy of Louise Rosenblatt. *Language Arts, 82*(1), 47. <https://www.proquest.com/docview/196859888?pq-origsite=gscholar&fromopenview=true>
- Moody, A. K., Justice, L. M., & Cabell, S. Q. (2010). Electronic versus traditional storybooks: Relative influence on preschool children's engagement and communication. *Journal of Early Childhood Literacy, 10*(3), 294–313. <https://doi.org/10.1177/14687984103721>
- Moser, T., & Reikerås, E. (2016). Motor-life-skills of toddlers – a comparative study of Norwegian and British boys and girls applying the early years movement skills checklist. *European Early Childhood Education Research Journal, 24*(1), 115–135. <https://doi.org/10.1080/1350293X.2014.895560>
- Neuharth-Pritchett, S., & Bub, K. (2022). Early childhood engagement. Eds. In S. Christenson, & A. Reschly (Eds.), *Handbook of research on student engagement* (pp. 285–299). Springer International Publishing
- Noble, C., Sala, G., Peter, M., Lingwood, J., Rowland, C., Gobet, F., et al. (2019). The impact of shared book reading on children's language skills: A meta-analysis. *Educational Research Review, 28*. <https://doi.org/10.1016/j.edurev.2019.100290>
- Paris, A. H., & Paris, S. G. (2003). Assessing narrative comprehension in young children. *Reading Research Quarterly, 38*(1), 36–76. <https://doi.org/10.1598/RRQ.38.1.3>
- Penno, J. F., Wilkinson, I. A., & Moore, D. W. (2002). Vocabulary acquisition from teacher explanation and repeated listening to stories: Do they overcome the Matthew effect? *Journal of Educational Psychology, 94*(1), 23–33. <https://doi.org/10.1037/0022-0663.94.1.23>
- Ralli, A. M., Kazali, E., Kanellou, M., Mouzaki, A., Antoniou, F., Diamanti, V., et al. (2021). Oral language and story retelling during preschool and primary school years: Developmental patterns and interrelationships. *Journal of Psycholinguistic Research, 1–17*. <https://doi.org/10.1007/s10936-021-09758-3>
- Reschly, A., & Christenson, S. (2022). Jingle-jangle revisited: History and further evolution of the student engagement construct. Eds. In S. Christenson, & A. Reschly (Eds.), *Handbook of research on student engagement* (pp. 3–24). Springer International Publishing
- Richter, A., & Courage, M. L. (2017). Comparing electronic and paper storybooks for preschoolers: Attention, engagement, and recall. *Journal of Applied Developmental Psychology, 48*, 92–102. <https://doi.org/10.1016/j.appdev.2017.01.002>
- Roulstone, S., Law, J., Rush, R., Clegg, J., & Peters, T. (2011). Investigating the role of language in children's early educational outcomes. Research Report DFE-RR134. <https://research.qmu.ac.uk/bitstream/handle/20.500.12289/2484/DFE-RR134.pdf?sequence=1&isAllowed=y>
- Roskos, K. A., Sullivan, S., Simpson, D., & Zuzolo, N. (2016). E-books in the early literacy environment: Is there added value for vocabulary development? *Journal of Research in Childhood Education, 30*(2), 226–236. <https://doi.org/10.1080/02568543.2016.1143895>
- Sari, B., Takacs, Z. K., & Bus, A. G. (2019). What are we downloading for our children? Best-selling children's apps in four European countries. *Journal of Early Childhood Literacy, 19*(4), 515–532. <https://doi.org/10.1177/1468798417744057>
- Scarborough, H. S., & Dobrich, W. (1994). On the efficacy of reading to preschoolers. *Developmental Review, 14*(3), 245–302. <https://doi.org/10.1006/drev.1994.1010>
- Schriever, V. A., Zscheile, L., Gellrich, J., & Hummel, T. (2024). Odor identification performance in children age 3–6 years. *Pediatric Research. https://doi.org/10.1038/s41390-020-1083-3*
- Senéchal, M., & Young, L. (2008). The effect of family literacy interventions on children's acquisition of reading from kindergarten to grade 3: A meta-analytic review. *Review of educational research, 78*(4), 880–907. <http://www.nifl.gov/partnershipforreading/publications/html/lit.ed.gov>
- Shams, L., & Seitz, A. R. (2008). Benefits of multisensory learning. *Trends in Cognitive Sciences, 12*(11), 411–417. <https://doi.org/10.1016/j.tics.2008.07.006>
- Silva, M., & Cain, K. (2015). The relations between lower and higher level comprehension skills and their role in prediction of early reading comprehension. *Journal of Educational Psychology, 107*(2), 321–331. <https://doi.org/10.1037/a0037769>
- Speed, L. J., Iravani, B., Lundström, J., & Majid, A. (2022). Losing the sense of smell does not disrupt processing of odor words. *Brain & Language, 235*. <https://doi.org/10.1016/j.bandl.2022.105200>
- Speed, L. J., & Majid, A. (2018). An exception to mental simulation: No evidence for embodied odor language. *Cognitive Science, 42*(4), 1146–1178. <https://doi.org/10.1111/cogs.12593>
- Spinella, M. (2002). Relationship between smell identification and empathy. *International Journal of Neuroscience, 112*(6), 605–612. <https://doi.org/10.1080/00207450290025680>
- Strouse, G. A., Troseth, G. L., & Stuckelman, Z. D. (2023). Page and screen: Storybook features that promote parent-child talk during shared reading. *Journal of Applied Developmental Psychology, 86*. <https://doi.org/10.1016/j.appdev.2023.101522>
- Vannini, P. (2023). *The routledge international handbook of sensory ethnography*. Taylor & Francis.
- Wigfield, A., Guthrie, J. T., Perencevich, K. C., Taboada, A., Klauda, S. L., McRae, A., et al. (2008). Role of reading engagement in mediating effects of reading comprehension instruction on reading outcomes. *Psychology in the Schools, 45*(5), 432–445. <https://doi.org/10.1002/pits.20307>
- Zhou, N., & Yadav, A. (2017). Effects of multimedia story reading and questioning on preschoolers' vocabulary learning, story comprehension and reading engagement. *Educational Technology Research and Development, 65*, 1523–1545. <https://doi.org/10.1007/s11423-017-9533-2>