



Experiment protocol: Exploring the sense of smell in digital book reading

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ABSTRACT

This paper outlines the background and design, and their rationale, for conducting a small-scale experiment to examine the effect of olfactory stimulation on children's reading outcomes. The theoretical underpinnings of the study and its significance for the reading field are outlined, followed by a detailed description of the study procedure, design, measures, and instruments. Sixty-six Norwegian children will be recruited to participate in shared book reading sessions with a specially designed digital olfactory book. We test the hypothesis that olfactory-enhanced reading increases children's engagement in the reading activity and through this engagement, will increase their vocabulary learning, story recall, and overall interest in reading and smell. The study has important implications for children's reading, olfaction media research, and design studies.

Background

Significance

Scientific background

Reading is an essential skill for children to succeed in life, and shared book reading (SBR) with young children has been widely acknowledged for its vital role in effective early childhood education (Sénéchal & Young, 2008). Meta-analytical evidence demonstrates the overall positive effect of shared book reading on multiple aspects of children's learning, including emergent literacy and reading achievement (Bus et al., 1995; Scarborough & Dobrich, 1994). Recent meta-analyses of the impact of SBR interventions highlight the contribution of this reading experience to children's language skills (Dowdall et al., 2020; Noble et al., 2019).

Young children today engage in SBR not only with paper-based books but also digital books. The latter can be accessed in the form of simple e-books or more sophisticated literacy apps from computers, smartphones, and tablets. Digital stories are especially promising for supporting early language and literacy in children with special needs, reading difficulties, or little history of reading at home (Korat & Falk, 2019). To reach these and related benefits, digital books need to be well designed and of high literary quality. This is an important point given the number of studies that show that the quality of popular children's digital books is not of the same quality as paper books, with many digital

books being inadequately designed, with distracting features that hamper children's reading experience and learning (Meyer et al., 2021; Sari et al., 2019).

Notably, the current design of children's digital texts has been found to disregard the importance of affect and sensory stimulation noted by multiliteracy scholars (Leander & Ehret, 2019). Furthermore, many children's e-books contain multimedia features that are distracting, rather than supporting children's story comprehension or primary language learning (Sari et al., 2019), and that leads to less verbal interaction and less bonding between parents and children when reading together (Parish-Morris et al., 2013).

In contrast, a body of evidence documents the learning benefits of well-designed e-books for children's story comprehension and vocabulary learning (Bus et al., 2015). E-book interventions in early childhood settings have been found to not only be more effective than childcare without structured reading activities, but also more effective than print book reading activities, as confirmed by a meta-analysis of 17 studies with 30 different e-book interventions in Early Childhood Education and Care (ECEC) (Egert et al., 2022). Another meta-analysis, which focused on the learning effects of digital books, found that e-reading in the form of digital stories with interactive features aligned with the storyplot, can support children's vocabulary development and story comprehension more than reading paper books (Furenes et al., 2021). Several individual studies further confirm children's greater engagement with digital books than paper books (see, for example, Jones and Brown 2011, Roskos et al.

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2014) and children's overall enjoyment of reading and preference for digital books (Strouse et al., 2019).

The scientific consensus that it is not the medium that matters (paper versus digital book) but rather the medium features (the quality of the book being read with the child), has been an important driving force for children's reading researchers aiming to establish the learning value of children's reading (Courage, 2019; Strouse et al., 2022). This study explores a feature that has not been investigated before, namely that of olfactory stimulation.

Olfactory stimulation refers to the strategic engagement of children's sense of smell during reading. The sense of smell has been suggested to play a role during reading, particularly in relation to autobiographical memory and personally meaningful texts (Chu & Downes, 2000). Studies with adult readers show that reading that activates the sense of smell does so through an activation of readers' mental imagery, and mental imagery is implicated in both reading and olfactory performance (Lübke et al., 2022). Some neurological studies have established that specific smells, such as cinnamon, activate brain regions responsible for olfactory processing (González et al., 2006), but others did not find a close relationship between reading and olfaction (Speed & Majid, 2018; Speed et al., 2022).

Bordegoni et al. (2017) make a powerful case for the added value of specific scents in reading, by suggesting that adding odours could improve not only the immediate reading experience but also the learning generated during the reading session. Their pilot study with an olfactory book prototype with adult readers showed that the integration of odours in reading decreased the reading effort, increased the perception of pleasantness of the reading experience, and increased comprehension of the reading content. Highlighting the role of senses in early childhood education, Kucirkova (2022) proposed that engagement of the olfactory sense during children's reading could spotlight this "hidden sense" and enhance children's awareness of its role in their lives. Researchers recommend focussing on the importance of sensorial and spatial aspects of reading (Kucirkova et al., 2023), especially the sense of smell in story research and design (Kucirkova & Kamola, 2022). This could complement textual and visual pedagogies in ECEC education (Kucirkova & Tosun, 2023).

Better awareness of the scents in our environments is important for being able to detect dangerous situations (e.g., by smelling smoke), and as a biomarker for illnesses (e.g., Alzheimer's or Covid-19, see Moein et al. 2020). Whether olfaction has an inhibiting or learning-promoting effect on reading remains to be shown. Our study will therefore investigate the untapped learning potential of olfaction-enhanced digital books.

Theoretical rationale

The study goes beyond the current state of art by advancing theoretical knowledge in children's reading, notably by expanding Rosenblatt's (1969) transaction theory of reading. Rosenblatt's theory is an influential theory in children's literary studies (see Mills and Stephens 2004, for an overview) and it has laid the foundations for understanding texts as a dynamic, social resource. Rosenblatt (1969, 2018) views reading as an active meaning-making process between reader(s) and text (s), and explains that the readers' life, past and present, and the 'physical condition' and 'particular mood of the moment' shape and influence their affective engagement in reading and foster their reading engagement. Our study aligns with Rosenblatt's theoretical proposition that readers actively respond to the elements of texts they read, and that the greatest readers' responses are achieved with texts that stimulate the entire sensorium (that is not only visual and auditory, but also haptic and olfactory senses). Whether and how the qualitative markers in children's e-books, such as the stimulation of the readers' five senses, might stimulate children's learning, is yet to be established in the literature. In our study, we will foreground three senses: Children's visual sense is stimulated with the story illustrations and text. Children will listen to the book read by an adult, thus engaging their auditory

sense. Finally, the olfactory stimulation is the target condition in the experiment, with attention to its relationship with children's reading comprehension, vocabulary, and engagement.

Hypothesis

Our hypothesis is that through increased engagement in the target condition (story enhanced with olfactory stimulation), children will pay more attention to the books enhanced with olfaction and this will be translated into increased scores on the vocabulary learning and story recall tests. In addition, we hypothesise that children's participation in the intervention will increase their interest in both reading and scents overall. This hypothesis is illustrated in the following logic model (Fig. 1).

Vocabulary learning, story comprehension, and engagement as outcome measures

Vocabulary learning and story comprehension are well-studied and well-established predictors of children's later literacy skills (Parish-Morris et al., 2013), and both will be included in the study. To evaluate story comprehension, we will use the well-established method of story recall, which has been found to be higher with digital than paper storybooks read to children (Matthew, 1997). Even with early CD rom studies, children showed greater story recall with digital than traditional paper-based reading formats (Verhallen de Jong & Bus, 2006). This study also found higher vocabulary learning, as did Bus and colleagues' subsequent studies with more advanced digital reading formats (for a meta-analytical summary see Bus et al. 2015).

The added value of e-books for children's vocabulary learning has been documented in studies with children with special reading and language needs (Korat, 2010) but also with children without reading difficulties (Lee, 2020). Children's receptive knowledge of a word occurs before they can express the word (Ouellette & Beers, 2010). Although receptive knowledge comes first, most e-book intervention studies, including ours, focus on measuring children's expressive vocabulary. For example, Roskos et al. (2016) examined children's expressive language in relation to the usefulness of e-books and found that four-year-olds learnt, on average, 25 % more target words than children without e-books in their classrooms.

Previous studies have documented children's learning is substantial only if the children engage in repeated readings with a text. This is in alignment with both learning theories (Penno et al., 2002), and multimedia theories which posit that children need to have the possibility to listen to the new word on several occasions and thus consolidate its novelty with their working memory (Mayer, 2009). This too is considered in the design of our study, with repeated readings of each book across several days.

Our selective focus on olfaction (rather than, for example, olfaction in combination with other senses) is based on cognitive load theory (Schnotz & Kürschner, 2007) which is supported by numerous e-reading studies demonstrating the theory's explanatory power for learning effects (e.g., Weng et al. 2018). The theory assumes that the human information processing system has a limited capacity and that stimulating several senses simultaneously could overwhelm children and lead to a loss of attention and decreased learning.

In sum, the rationale for our hypothesis is based on studies that show that frequent book reading increases children's story comprehension and vocabulary learning and that olfactory stimulation will enhance the learning process.

Potential confounding factors

The randomisation and design exclude the possibility of potential novelty effects given that all children will read an olfactory book and all stories are about smell. In Appendix A, we provide an example of how randomisation at the individual level ensures that the target condition appears in a random order in the first targeted reading session and how repeated readings further eliminate the concern of novelty effects.

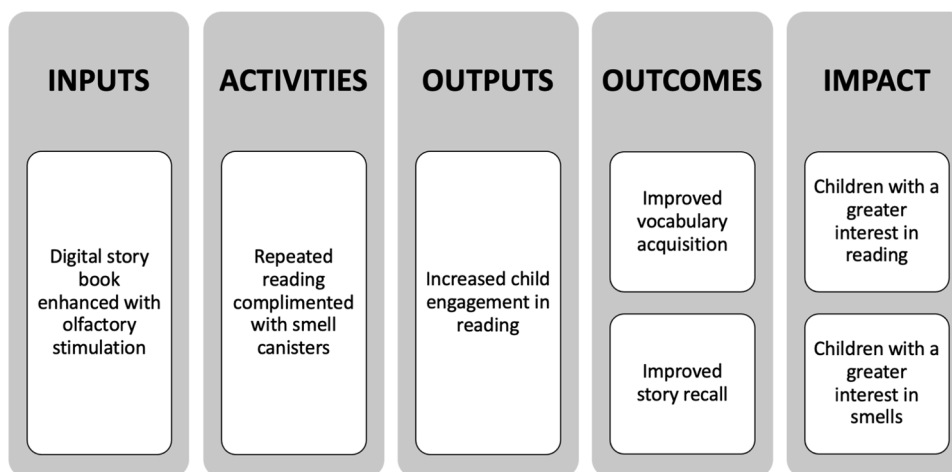


Fig. 1. Logic model for experiment.

Our participants' possible surprise at reading a book with olfactory stimulation cannot be avoided given that such reading is atypical and novel for the ECEC context. Surprise is a popular educational technique to engage children in learning (Brod et al., 2018), but it has only appeared to enhance learning with older children. Specifically, children aged 4 to 5 years are unlikely to use surprise for probability reasoning, but this effect is possible for children aged six and above (Baltes et al., 2007). We thus cannot eliminate the theoretical possibility that any observable effects are due to both olfaction and surprise mechanisms, but consider this possibility only relevant for the cognitively more advanced children in the study.

The children's direct manipulation of the olfactory stimulation might generate further engagement and interest in the target book. This means that the mechanism for any observable effects could be interactivity rather than the olfactory character of the stimulation. A cognitive model of multisensory learning posits that children need to self-generate actions and resources to benefit from the activation of distributed brain networks implicated in positive multisensory learning (James & Bose, 2011). Exploratory neurological studies suggest that learning platforms that capitalise on multi-sensory input *and* children's self-produced actions facilitate learning because they allow the visual and motor systems to interact and form important links for learning (James & Bose, 2011). In the studies reviewed by James and Bose (2011), it was not children's watching or passively perceiving multisensory actions (e.g., watching a teacher read to them), but rather children's direct and active participation, that increased their memory and learning. We have therefore purposefully designed the target book to be interactive and for the child to actively manipulate the olfactory elements of the target book. This design means that we will be not able to determine how much of any observable effects are due to the children's interactive engagement with olfactory containers or the olfaction per se. While disentangling this aspect might be an interesting possibility for future studies, our experiment will contribute knowledge regarding the design of books that contribute (or not) to children's learning through olfactory interaction.

Policy context

Identifying and capitalising on new and theoretically interesting features is important to advance the field of children's technology (Miller & Warschauer, 2013). More specifically, it has been proposed that e-reading research needs to establish the specific effective features of children's interactions with various types of media (Miller & Warschauer, 2013). Given the centrality of storybooks in children's lives and the importance of sensory engagement for learning and development, it is important to develop engaging reading materials for children. Furthermore, the scarcity of high-quality e-books that demonstrate learning value urges researchers to investigate the learning value of

innovative reading formats.

The study findings will be of relevance not only to e-reading researchers and children's technology researchers but also publishers and designers of children's digital books. Practical implications of this research will be a better definition of well-designed e-books to implement in the school curriculum and family literacy programs, to be considered by app designers when designing effective and educational e-books. Considering the rapidly declining sensory-rich learning in increasingly technologized, urban, and globalized environments, the focus on olfactory design in children's digital books might reinvigorate the interest in children's sensory engagement during reading.

This pioneering work with e-books and sensory engagement will have a significant impact on national ECEC settings, the publishing industry, and international knowledge on e-books. Given that reading is the most tradition- and culture-contingent part of children's education, it carries implications for children's academic success and democratic citizenship.

Intervention

This experiment will test whether a measurable effect can be detected of including olfactory stimulation within e-book reading on preschool-aged children's comprehension, vocabulary, and engagement. Books will be read to each child, by the researcher, and tests will be conducted in a separate room within the ECEC setting. Reading will occur one-to-one and will follow a simple reading protocol to maintain the consistency of the adult's prompts and feedback. One researcher will read the stories to all participating children in all conditions in order for consistency in style of interaction, tone of voice and pronunciation. All reading sessions will be video-recorded, and the testing sessions will be audio-recorded.

Intervention materials

The experiment includes three books, two of which have been specially designed for the purpose of the study. These two books are similar in length, rhythm, and complexity, and both contain a set of target words.

- BOOK 1: (Baseline book) Paper-based book with no reference to smell (a Norwegian book *En flue fløy* [One fly flew]).
- BOOK 2: E-book in 2 versions (Book A, control) talks about smell, and (Book B, target) talks about smell and includes olfactory stimuli (The little bear girl *Ursa* and the hare *Kristjan*, developed for this experiment in Norwegian).

- BOOK 3: E-book in 2 versions (Book B, control) talks about smell, and (Book B, target) talks about smell and includes olfactory stimuli (When the city mouse Sofie visited the forest mouse Cecilie, developed for this experiment in Norwegian).

Olfactory book content

The stories for the target books were commissioned from a professional Norwegian children’s author. The author was provided with instructions regarding the stories’ length, rhythm, structure, references to smell, and a list of target words to embed. Consequently, the two stories that were developed are similar in key markers of reading complexity and olfactory references. The story-plots in both Book A and Book B include references to a story character performing an olfactory behaviour with the verbs sniffing and smelling and referring to the characters’ noses. Both stories are about anthropomorphized animals: Book A is about the little bear Ursa and the hare Kristjan and Book B is about the mice Sophie and Cecilia. The translated versions of the stories are included in the [Appendices B and C](#).

Target words

A set of five target words were embedded in Book A and Book B. The words are central to the book’s main ideas and are unlikely to be known to children of this age. They were drawn from the Norwegian word list developed by the Department of Linguistics and Scandinavian Studies at the [University of Oslo \(2023\)](#). The list consists of 1600 Norwegian words (900 nouns, 500 verbs, 200 adjectives), which are categorized according to their difficulty of acquisition stage. The selected words, verbs and adjectives, are identified in the word list as “late acquisition” (i.e., at adult age), and thus were very unlikely to be known to the children in our target age group. The selected words were balanced for syllable count across the two stories. The list of selected words is included in [Table 1](#).

To support semantic-lexical ease, which is known to be required for vocabulary acquisition (see [Motsch 2013](#)), we have provided contextual information with each of the target words (e.g., “The house was lively. There were many people in it.”)

Olfactory stimuli

Olfactory stimuli will be presented at four points in the books in the target condition. The smells are from the board game “Les boîtes à odeurs” developed by Nature & Découvertes Ltd., placed on a mat in front of the iPad. The stories are written in a way to allow for sufficient time for children to cleanse their olfactory palette between the individual canisters and not become confused or overwhelmed by the smells. The intensity of the smells, and the time necessary to perceive them, has been pilot-tested. At each of the four “sniffing points” in the target condition, the experimenter will pick up the canister and encourage the child to experience the smell.

The smells have a clear role in both Book A and Book B in that they are connected to the main events of story: setting – development –

Table 1

List of target words included in Book A and Book B.

Verbs Norwegian	English	Adjectives Norwegian	English
å avsky (Book A)	to loath/detest	amper (Book A)	fractious/ irritated
å bevise (Book B)	to prove	blass (Book B)	faded
å ense (Book B)	to notice/heed	delikat (Book B)	delicate
å evne (Book A)	to be able to/capable of	livlig (Book A)	lively
å foregå (Book A)	to happen		
å ignorere (Book B)	to ignore		

problem – conclusion. The smells do not represent concrete objects or items but are abstract smells with clear valence for story setting (positive/sweet), development (positive/fresh), problem (negative/musty), and conclusion (positive/sweet). The mixtures of the smells are from “Les boîtes à odeurs” and are more generic than their labels suggest. The selected smells correspond to the following qualities:

- Smell 1: Sweet, playful smell (positive valence), canister named “apricot”.
- Smell 2: Cold, fresh smell (neutral/activating valence), canister named “peppermint”.
- Smell 3: Messy, musty smell (negative valence), canister named “champignon”.
- Smell 4: Sweet, playful smell (positive valence), same canister as smell 1.

The following is an example of the “sniffing point” in the story:
 Story text: The little bear Ursa pokes her snout in and sniffs.
 Experimenter: Ask the child: Would you like to smell it? Gives the third canister to the child.

Reading protocol

To ensure consistency across the conditions, the experimenter will follow the same reading protocol for all children and all reading sessions. The experimenter will not deviate from the text at any point, and not to engage in extra-textual talk about either of the stories, unless the child asks for it. In those situations, the experimenter will answer the child’s questions, repeat their utterances, but not prompt new questions or explanations. In the target condition, the experimenter will encourage the child to smell the olfactory canisters at each of the four points in the Book B by saying: ‘Here, do you want to smell?’ , and gives the canister to the child ([Fig. 2](#)).

Research plan

Research questions and hypotheses

This experiment aims to evaluate the relationship between children’s olfactory reading and learning outcomes. It will investigate the learning value of olfactory books and explore whether there are learning gains in addition to engagement effects. The broad hypothesis is that children



Fig. 2. The olfactory book set-up, with the four canisters and the iPad display of the story.

will show greater comprehension, vocabulary, and engagement under the intervention target condition than the control condition (H₁).

The research questions and hypotheses for this study are:

RQ1 Vocabulary learning:

Does reading children a book with olfactory stimuli increase their vocabulary learning of words embedded in the story?

H₁: Children will have better vocabulary learning from the story with olfactory stimuli than the story without olfactory stimuli.

RQ2 Reading comprehension:

Does reading children a book with olfactory stimuli increase their comprehension of the story?

H₁: Children will have a more detailed comprehension of the story with olfactory stimuli than the story without olfactory stimuli.

RQ3 Reading engagement:

How does children's engagement with reading of a book with olfactory stimuli compare to that with a book without olfactory stimuli?

H₁: Children will be more engaged with the story with olfactory stimuli than the story without olfactory stimuli.

RQ4 Post experiment awareness of smell:

Do parents observe an increase in child's interest in reading and awareness of smells after participating in the experiment?

H₁: Parents will observe an increase in child's curiosity and talk more about smells after the experiment.

Design

Procedure

The experiment will include three books, all as similar as possible in length, rhythm, and complexity, and utilizing different (but equivalently) complex vocabulary:

- Baseline book: Paper-based book with no reference to smell.
- BOOK A: E-book in 2 versions (1) talks about smell (control), and (2) talks about smell and includes olfactory stimulation (target).
- BOOK B: E-book in 2 versions (1) talks about smell (control), and (2) talks about smell and includes olfactory stimulation (target).

As summarized in Fig. 3 all children will be read the baseline book twice (baseline session and reading session 1) and will be tested for comprehension and book specific vocabulary after the second reading. Children in group 1 will be read BOOK A in the control version and BOOK B in the target version, and children in group 2 will be read BOOK

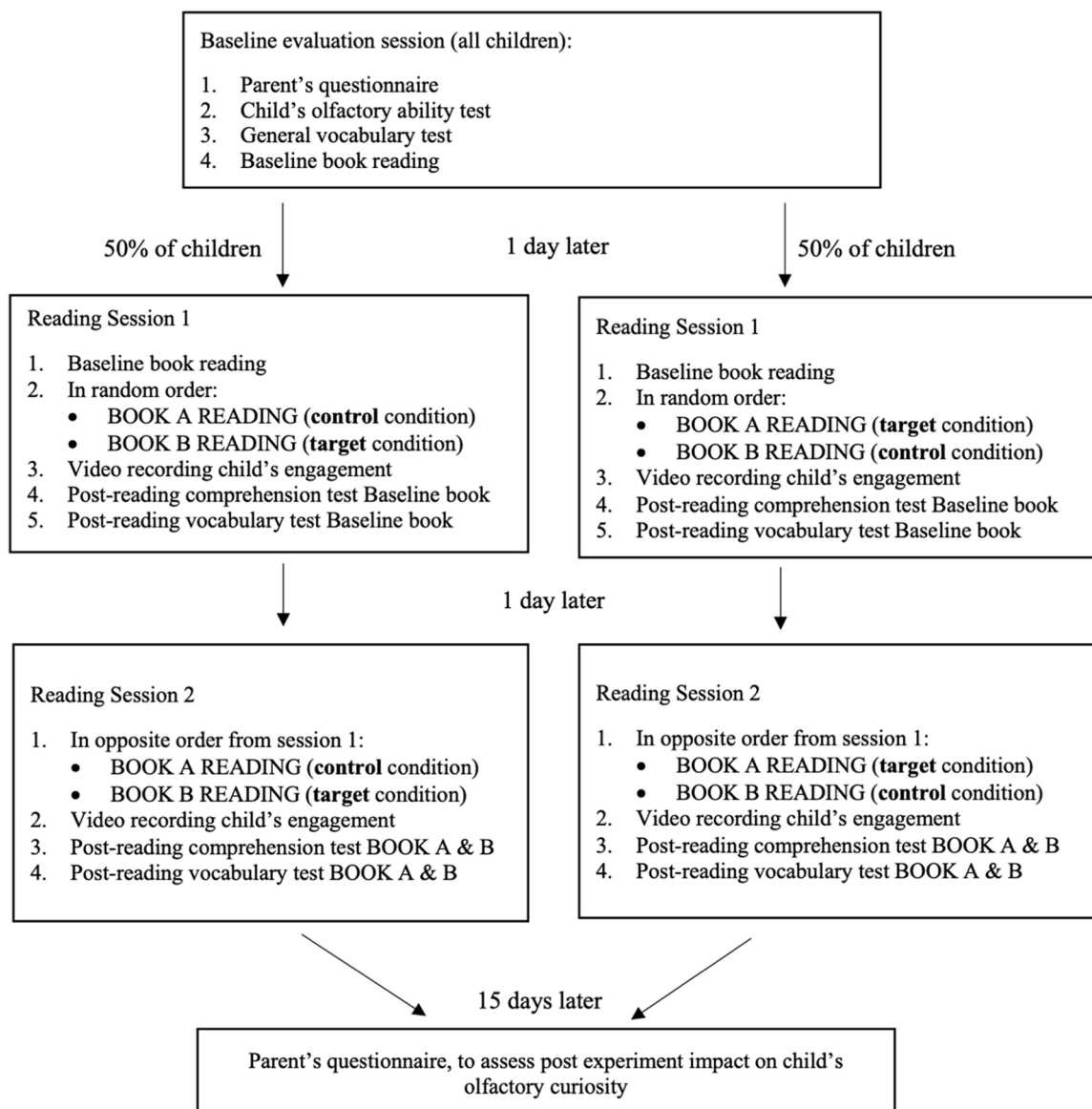


Fig. 3. Flow chart of intervention design.

A in the target version and BOOK B in the control version. These books will be read on two occasions, 1 day apart, with the order of the reading of the books being randomly assigned at the child level (session 1) and then reversed (session 2) to eliminate any possible order effect. Children will be tested for comprehension and book specific vocabulary after the second reading.

The procedure for each child will be:

Day 1: The researcher meets and greets the child and administers the olfactory ability test and the general vocabulary test. The parent survey responses will be collected. The researcher reads the baseline book to the child.

Day 2: The researcher meets the child and re-reads the baseline book to the child. The researcher then reads Book A & B to the child, in the pre-randomized order. The researcher administers a text-specific vocabulary test and a story recall test for the baseline book.

Day 3: The researcher meets the child and re-reads Book A & B to the child, in the opposite order from Day 2. The researcher administers a text-specific vocabulary test for Book A & B, and a story recall test for Book A & B.

The study's unit of randomization is at the individual level (child) and the children will be randomly assigned to two groups. The intervention will be counterbalanced across these groups and in its target and control condition.

Participants

The desired sample for this study is 66 Norwegian speaking children, aged 4 to 5 years old, from six ECEC centres in the south of Norway. An additional 20 % will be recruited to the study, to allow for attrition, making a total of 79 recruits. The inclusion criteria are that the child is a Norwegian speaker and does not have special educational needs, based on ECEC's staff reports. The sample is therefore a convenience sample, selected by the researcher through geographical proximity. The staff in the centers recruit eligible children by attaining parental authorization.

Measurement

In this study, we use established and validated measures of children's language and olfactory knowledge, as well as researcher-developed measures of vocabulary learning, story recall, and engagement. We recognise that established and validated measures are often attributed higher research value (see [Wolf and Harbatkin 2022](#)), but in this study, the methodological choices needed to be guided by the intention to evaluate specific elements of an intervention that capture new, and thus far little explored, constructs of olfactory impact on learning.

Baseline measures

General language test. The Cross-linguistic Lexical Tasks (CLT), developed for children aged 3 to 6 ([Haman et al., 2015](#)), will be used to measure baseline general vocabulary. The test has been validated in the Norwegian context and includes words that are expected to be understood by children in this age group. The test includes "Find the word" and "Say the word" items for both nouns and verbs with a pictorial recognition task.

General olfactory test. The children's board game "Les boîtes à odeurs" developed by Nature & Découvertes Ltd., which is safe to use for children between 3 and 10 years and includes a set of canisters with common smells, will be used to test children's general olfactory ability. We will present children with three canisters from the box with the common concrete smells of lemon, soap and fennel, which are different in quality and intensity from the target smells in the experiment. We will ask children to say whether they could smell it, and if they like or dislike the

smell. Children's preferences will be marked as yes/no in relation to their ability to name a preference for the smell ('Yes' means the child either likes or dislikes the smell, 'No' means the child reports not smelling anything).

Baseline book story recall and vocabulary. Differences between reading traditional paper-based books and digital books are not a focus of this present study. The baseline measures of story recall and vocabulary acquisition from the baseline (paper-based) book are therefore not counterfactual measures (they will not be compared to the experimental conditions) but are collected as possible moderators of the experiment outcome, for example, if it is found that some children have particular difficulties or exceptional abilities in story recall and vocabulary acquisition.

Outcome measures

There are two primary outcome measures in the study: children's vocabulary acquisition and story comprehension, as well as two secondary outcome measures: child engagement during the reading session, and child interest in reading and smell.

Vocabulary acquisition. Children's word acquisition from the intervention will be tested with a researcher-developed vocabulary test. The test will be based on the sentences included in the target books (Book A and Book B). Children get either 0 (no answer, or an incorrect answer), 1 (partially correct answer), or 2 points (fully correct answer) per word. For example, "The house was lively. What does that mean?" (researcher asks and child provides an answer). A level 1 answer is when the child provides no, or a non-sensical, answer, a level 2 answer is when the child provides an approximate definition (e.g., "busy"), and a level 3 answer is when the child provides the definition corresponding to the word's meaning in the story (e.g., "with many people" or "animated"). The details for vocabulary assessment are included in [Appendix D](#).

Story comprehension. Children's comprehension of the stories will be measured with an adapted version of the [Paris and Paris \(2003\) Narrative Comprehension of Picture Books](#) task measurement of narrative comprehension. This measure has shown strong validation and reliability markers, and correlates with measures of early reading skills. The protocol developed by [Paris and Paris \(2003\)](#) will be adjusted to include story prompt questions accompanied by a guided "picture walk". The experimenter will ask the child to retell the story with five prompt questions, each accompanied with a picture from the story. For example, the experimenter will ask: "What happened here? Why does this happen?" And point to the relevant page showing the conflict in the story. The answers will be scored as 0/1 for correct and incorrect. The question structure follows the five main elements of the story comprehension test, with the focus on the book's story characters, setting, initiating event, problem, and outcome/resolution (see [Appendix E](#) for the story re-telling prompts).

Child engagement. The effect of smell-enhanced reading on children's engagement will be measured through video-based analysis of children's embodied response to the digital book, appearing in the two experimental conditions: with and without olfactory stimulation. 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, will be used to measure children's engagement during reading.

The measurement tool contains three sub-scales, examples of behaviour, and detailed scoring protocol. The coder will practice coding with sample videos and assign ratings from 7 (highest engagement) to 1 (lowest engagement) for the following subscales:

- Persistence, which captures child's participation in the session by focusing on children's pointing behaviour towards the book and

commenting on the pictures and text. Highest score reflects child’s active engagement in reading from the beginning to the end of the session.

- Enthusiasm, which captures the child’s expressive engagement during the reading session, as indicated with smiles, laughter, genuine interest. Highest scores are allocated to sessions where the child shows visible signs of enjoying the session and eagerness to be read more.
- Compliance, which captures the child’s willingness to cooperate during the reading session by following the adult’s instructions, responding to the adults’ questions and directions. Highest scores are given to sessions where children are attentive through the entire reading session and willing to comply with the reading activity (Richter & Courage, 2017).

Definitions of codes with examples are based on previous studies, are included in the Appendix F, and will be refined with pilot data. The videos will be scored at the level of the entire second reading session with each book. The combined score from all three subscales will be checked for reliability. Reliability will be established between two coders, with 20 children, and with 80 % taken as acceptable agreement.

Children will also be asked which book they preferred after the reading sessions and why, and this data will also contribute to the assessment of engagement.

Child interest in reading and of smell. The parent questionnaire contains questions about the child’s general interest in reading and preference for various scents and smells. Parents are asked to indicate child’s interest in reading and the importance of olfactory stimulation for the child (see the Appendix G for the full Parent Questionnaire). Parents’ answers will be solicited before the intervention’s start (as soon as they sign the consent to participate) and at the end of the intervention (15 days after the child’s participation in the last reading session). Their answers will be compared for pre- and post-effects as part of the main analysis.

Analysis plan

Data analyses will be conducted in SPSS (IBM). Differences in the

Table 2
Expected timeline and distribution of research tasks.

Activity	Spring 2023	Autumn 2023	Spring 2024	Autumn 2024	Spring 2025	Autumn 2025
<u>Baseline evaluation:</u> Parent’s questionnaire, Child’s olfactory ability test, General vocabulary test and book reading (baseline).						
<u>Reading Session 1</u> with video recording of child’s engagement, post-reading comprehension test and post-reading vocabulary test baseline book.						
<u>Reading Session 2</u> with video recording child’s engagement, post-reading comprehension test and post-reading vocabulary test BOOK A & B.						
Parent’s questionnaire						
Analysing data						
Writing articles and presenting findings						
Publishing						

dependent variables (vocabulary learning, story comprehension, engagement) between the two experiment conditions (with and without olfactory stimulation) will be explored by variance analyses (MANOVA). Alpha will be set at 0.05, and p-values will be reported with the standard notation of *** $p < 0.001$, ** $p < 0.01$, and * $p < 0.05$.

Sample size, power, and effect size

An a priori power analysis (conducted using G*Power 3.1) was used to determine that a medium effect (0.15, following Kraft, 2020 revision of Cohen, 2013 rubric) could reliably be detected with a sample of 66 children and statistical power of about 0.80. A medium effect may be optimistic for this type of study, however this sample size is larger than similar studies testing minor enhancements in digital books with one or two sessions (see, for example, Lauricella 2014 with $n = 39$ and Zipke 2017 with $n = 25$), and similar to the proposed sample size for an experiment comparing book vs tablet reading in ECEC (Mangen et al. 2019, $n = 72$).

Timeline

The expected timeline for the project is outlined in Table 2.

Ethics

The project’s protocol has been officially reviewed and approved by the Norwegian Data centre for Ethics (NSD, 615584). The ECEC settings have contacted the parents of eligible children and helped us to ensure that they have received information about the project in writing, along with the project’s aim, purpose, data collection plans and timeline. Parents will give or withhold consent for children’s participation, following the Norwegian national requirements for the protection of children’s interests (FN 2019, art. 2). The consent form will state clearly that parents have the right to withdraw from the study at any time. Given that young children can generally see the consequences of and understand what participation is, their participation in research studies should also be voluntary, informed, and actively expressed (NESH, 2016). Children are a vulnerable group, and as such, data collection with

children requires knowledge of their developmental needs (Befring, 2020; NESH, 2016), and respect must be shown to protect the individual integrity of the participating children (NESH, 2016). We will therefore make sure that the experimenter remains sensitive to whether children wish to participate, or continue participating, in the study, that children’s safety and security is at all times prioritised (Fossheim et al., 2013), and that the experimenter is sensitive to the child’s needs and her/his role in the child’s experience.

All personal information will be confidential and protected. Personal information will not be stored, and results will be presented such that individuals or institutions cannot be identified. Parents will be informed about how the child’s information will be used. Given the personal and sensitive nature of the data, we will use the University Centre (reference withheld for anonymized peer review) for information Technology (USIT) system Services for sensitive data (TSD) for data storage. The raw data will be stored in two separate files in a server that only project members can access. One of the project team members will keep all the personal information and codes of participants, so that all material can be securely stored and deleted after the project’s end in 2025. One project member will have the access code for TSD and keep this information at the project location.

Conclusion

In conclusion, this is the first study to examine the impact of olfactory stimulation on children’s digital reading engagement and learning. The question of technology’s impact on children’s learning is

Appendix A. Randomisation of participants

Table 3.

Table 3
Randomization of participants and allocation to experimental conditions (first 10).

Participant	Day 1	Day 2	Day 3				Expectation: Test results will be higher for:
01	Baseline book	Baseline book	Book A, target	Book B, control	Book B, control	Book A, target	Book A
02	Baseline book	Baseline book	Book B, control	Book A, target	Book A, target	Book B, control	Book A
03	Baseline book	Baseline book	Book B, control	Book A, target	Book A, target	Book B, control	Book A
04	Baseline book	Baseline book	Book B, target	Book A, control	Book A, control	Book B, target	Book B
05	Baseline book	Baseline book	Book B, target	Book A, control	Book A, control	Book B, target	Book B
06	Baseline book	Baseline book	Book B, control	Book A, target	Book A, target	Book B, control	Book A
07	Baseline book	Baseline book	Book A, target	Book B, control	Book B, control	Book A, target	Book A
08	Baseline book	Baseline book	Book A, target	Book B, control	Book B, control	Book A, target	Book A
09	Baseline book	Baseline book	Book A, control	Book B, target	Book B, target	Book A, control	Book B
10	Baseline book	Baseline book	Book A, control	Book B, target	Book B, target	Book A, control	Book B

Appendix B. Book A

The little bear girl Ursa and the hare Kristjan.

This is the hare Kristjan. And this is the little bear, Ursa. Kristian and Ursa are good friends. But it has been a while since Ursa last visited Kristjan. The little bear Ursa likes to visit hare Kristjan. It is lively at the hare’s cave because there are always many other hares there too. At home it is a little bit boring. But Ursa has forgotten where the hare lives. “It doesn’t matter,” Ursa thinks, “I’ll sniff my way!”

Outside the first cave along the path, she sees a small gate made of twigs. This is probably where the hare lives. She pokes her snout in and sniffs. “How strange”, Ursa thinks, “is this how it smells at the hare’s cave?”

“What is going on here?” says a stern voice. It’s a beaver. *He* lives in the cave! “Oh, sorry!” says Ursa. “I’m not able to find hare Kristjan’s cave. Do you know where he lives?” “I am Justin,” says the beaver. “Continue walking along the path.” He points with his paw.

“It is easy to find the hare’s cave. It smells like buckwheat there”, Ursa thinks. She continues to walk on along the forest path. Look! What a beautiful cave! The entrance is red and white. This is probably where the hare lives. The little bear Ursa pokes her snout into the cave. She sniffs. “How strange”, Ursa thinks, “this is not how it smells at the hare’s cave?”

“And what is going on here?” says a soft voice. It is a fox. *He* lives in the cave! “Excuse me!” says Ursa, “I am looking for hare Kristjan’s cave.” “Ahhh, the haaaare ...along...there...” says the fox, licking his mouth. He points with his tail.

Ursa continues walking. “Do you want me... to take you there?” says the fox? “No thanks,” says the little bear Ursa.

It is very messy outside the third cave. The little bear Ursa pokes her snout in and sniffs.

“Maybe the hare lives here, after all?” “Ugh!” Ursa rubs her snout with her paw. “I detest that smell!” she shouts. Suddenly, out of the cave comes an

irritated wild boar, howling and screaming! Ursa gets scared. She runs down the path as fast as she can.

“Ursa! Come in here! Hurry up!” hare Kristjan shouts. There he stands – at the end of the path! Together they throw themselves into hare Kristjan’s cave. Ursa is laying on the floor. She is completely exhausted. But it feels nice and safe here. There are many other hares there too. They stand around looking at Ursa.

Ursa takes a deep breath. She draws in the nice smell through her snout. At hare Kristjan’s cave, it smells exactly as it *should*.

Ursa stays in Kristjan’s cave all day, along with all the other hares. The youngest hares get to sit on the bear Ursa’s lap. Everyone is having a good time and eating crackers and cheese.

“I must apologize to the wild boar,” says Ursa. “I guess I was a bit rude.” In the evening, when Ursa is going home, Kristjan wants to follow her, but Ursa says: “You’d better stay here, because you must watch out for the fox. I think he’s got an appetite for hare.”

Appendix C. Book B

When the city mouse Sofie visited the forest mouse Cecilie.

This is the city mouse Sofie. She and the forest mouse Cecilie are good friends. But it has been a long time since Sofie (last) visited Cecilie. The forest mouse has now sent a letter to the city mouse: “I invite you for hot chocolate in the forest. Greetings from the forest mouse Cecilie.”

Sophie thinks the colors in the forest are a little faded. The lights in the city shine brighter, she believes. But where does Cecilie live? Sofie has forgotten. “It doesn’t matter, thinks Sofie, “it smelt so good at the forest mouse’s home. And it will probably still smell like millet.” Outside the first cave along the path is a small gate of twigs. She pokes her nose in and sniffs.

Oh, it doesn’t smell so good in here! “Who’s there?” says a stern voice. It’s a beaver. *He* lives in the cave!

“Oh, sorry” says Sofie, “I am looking for forest mouse Cecilie’s cave. Do you know where she lives?” “Really? I think you are a thief!” Justin the beaver growls. “Prove that you are looking for the forest mouse!” Sophie takes out the letter from Cecilie and shows it to him.

“Oh well. Move on then.” He points with his paw.

“I guess it’s not that difficult to find Cecilie’s cave. It smells so delicious there” Sofie thinks.

She skips along the forest path. Look! What a beautiful entrance! The entrance is decorated with leaves and heather. This must be where the forest mouse lives. The little city mouse Sofie pokes her nose into the other cave. She sniffs inside. “How strange,” Sofie thinks, “it smells better here than at the beaver’s cave. But not like millet.”

From inside in the near-darkness, the city mouse can hear someone digging in the ground.

It’s a lemming! *He* lives in the cave. “Hi!” says Sofie, “perhaps you can tell me where the forest mouse Cecilie lives?” The lemming doesn’t notice her. He just keeps digging.

“There’s no time to lose,” he says suddenly. “Gotta’ make the cave bigger. More kids!” “Very well,” thinks the city mouse, “I’ll find her myself”.

The entrance to the third cave is painted red and white. It looks very pretty. The city mouse likes it here. She pokes her nose in and sniffs. “Well, well, what do we have here?” says a soft voice. Sofie jumps backward. A fox sneaks out of the cave. The fox smells of...old mouse poo. “I must say you smell delicate!” says the fox and jumps towards her.

Sofie gets very scared. She runs down the path like a New Year’s firecracker. “Sofie! Come in here! Hurry up!” cries the forest mouse Cecilie. There she stands – at the end of the path!

Together they throw themselves into Cecilie’s cave. Sofie is laying on the floor. She is completely exhausted. But it feels good and safe. Cecilie’s cave smells so delicious – and of millet! Sofie takes a deep breath. She draws in the good smells through her nose. “It’s good you got away from that horrible fox, says Cecilie. “Yes, that was close,” says Sofie. But he ruined my pretty dress.” A large piece of her dress is torn. “It doesn’t matter,” says the forest mouse Cecilie, “here in the forest the animals ignore the clothes you are wearing.” “Yes, I have noticed that. The fox would probably rather eat me than the dress,” says Sofie.

They look at each other - and then they laugh. The rest of the day they enjoy themselves eating nuts, raisins, and drinking delicious cocoa.

Appendix D. Vocabulary assessment

Book A

1 Ursa thought the hare was lively.

What does lively mean?

1 The beaver says "What’s happening here?" with a stern voice.

What does to happen mean?

1 Ursa says that she is unable to find the hare Kristjan’s cave.

What does unable to mean?

1 Ursa says she loathes the smell.

What does loathe mean?

1 A wild boar suddenly emerges from the cave.

What does emerge mean?

Book B

1 Sofie in the book thinks the colours in the forest are a bit faded.

What does faded mean?

1 In the story, the beaver Justin told Sofie to prove that she is looking for the wood mouse.

What does prove mean in this sentence?

1 In the story, it says that the lemen does not notice Sofie.

What does notice mean?

1 The fox says that Sofie smells delicate.

What does delicate mean?

1 Cecilie says that the animals in the forest ignore the clothes you wear.

What does ignore mean?

Appendix E. Story re-telling prompts

- 1 Who are the characters in this story? [the experimenter points to the cover page of the book]
- 2 Tell me what happens at this point in the story? Why did this happen? [the experimenter points to p. 7 in the middle of the story]
- 3 What happened here? Why does this happen? [the experimenter points to p.12 with the conflict in the story]
- 4 This is the last picture in the story. What do you think happens next? Why do you think so?

Appendix F. Engagement analysis protocol

The ratings will be from 1 (highest engagement) to 7 (lowest engagement) for the subscales:

- Persistence: This reflects the extent to which the child is goal directed and maintains participation in the completion of the reading task. Examples include pointing to pictures and words, turning pages, and commenting on the book. At the high end of the scale, the child is actively engaged in the reading and does not need to be directed by the adult. He or she wants to finish the story. At the low end, the child puts no effort into completing the task, is reluctant to become involved, spends time off-task, or is involved only when the reader directs his/her attention.
- Enthusiasm: This scale captures the affect with which the child approaches, expresses enjoyment, and completes the book reading activity. Examples include smiling and laughing, turning pages, showing excitement, and making positive comments. At the high end of the scale, the child acts with vigor, confidence, and eagerness to read the story; takes an active interest in the book and is focused on it; enjoys the reading interaction. At the low end, the child shows little enjoyment in the Book And seems disinterested and reluctant to participate in the reading activity.
- Compliance: This scale measures the degree to which the child shows willingness to cooperate during the session, listen to the experimenter, and comply with her requests and expectations. Examples include making timely responses, staying seated, and following directions. At the high end of the scale, the child is attentive to the cues and directions of the adult, matches his/her own behaviours to that of the adult, and follows instructions. At the low end, the child is inattentive and unwilling to comply either covertly or overtly with the experimenter's directions." (Richter & Courage, 2017)

Appendix G. Parent questionnaire

Hello, this study is about smell and reading and we therefore want to know a little more about the role of these two aspects in your reading habits at home.

- 1 First, who is answering this questionnaire? (Mother, Father, Both/Together, Other)
- 2 What language do you speak at home?
 - 1 Norwegian
 - 2 Other language, namely (open comment)
- 3 What is your highest level of education?
 - 1 Junior high school
 - 2 Secondary school
 - 3 University/college
 - 4 Prefer not to answer
- 4 What is your partner's highest level of education?
 - 1 Junior high school
 - 2 Secondary school
 - 3 University/college

- 4 Prefer not to answer
- 5 Don't have a partner
- 5 The gender of the child

Boy / Girl / Other

- 1 The child's age
- 2 Why do you read with your child? Tick all that apply
 - 1 Because it's cozy
 - 2 To provide experiences with literature
 - 3 To calm the child down
 - 4 To promote reading and writing skills
 - 5 To initiate conversations
 - 6 It's a routine
 - 7 Other (open comment)
 - 8 I don't read with my child
- 3 Which digital books do you read with your child?
 - 1 We only read paper books together
 - 2 Different apps on iPad/tablet/phone
 - 3 Various titles on PC
- 4 What is required for you to read digital books more often with your child? Tick all that apply
 - 1 Access to more interesting digital books
 - 2 Access to more digital books in Norwegian
 - 3 Access to digital books on the devices we have at home (e.g., Kindle instead of iPad)
 - 4 That my child likes digital books
 - 5 That the reading session becomes a positive experience
 - 6 That my child asks for digital books
 - 7 Other reasons (open comment)
- 5 Does your child have an interest in reading?
 - 1 No interest
 - 2 Little interest
 - 3 Moderate interest
 - 4 A great deal of interest in reading
 - 5 Extra high interest
- 6 How often do you talk about smells at home?
 - 1 Very often
 - 2 Often
 - 3 Sometimes
 - 4 Almost never
 - 5 Never
- 7 What is your child's favourite scent?
- 8 If you had to choose one scent to add to the books you read with your children at home, what scent would it be? (you can describe it here)
- 9 How important are the smells around you in the room when you read with your child?
 - 1 Not important at all
 - 2 Not really important
 - 3 Neutral
 - 4 Somewhat important
 - 5 Very important
 - 6 Don't know

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