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Children's multisensory experiences in museums: how olfaction interacts with color

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This case study was designed to engage children's sense of smell through a story-related museum exhibition. Children's responses to the exhibition, with particular attention to their olfactory perceptions of the odors at the exhibition, were solicited through researcher-child interviews and children's drawings. Responses from 28 children (girls $N = 14$, boys $N = 14$) aged between 4.5–8 years were analyzed after they visited the exhibition using the cross-modal association and multisensory theories. Interview data showed that dark (brown and black) colors elicited children's negative olfactory associations for both positive and negative odors. Children's drawings did not seem to make references to the odors at the exhibitions but rather their preferences for the different story characters. We theorize about the associations between smell and colors in children's responses and distil some key learnings for multisensory museology.

KEYWORDS

museums, color, olfaction, children, cross-modal correspondence

Introduction

The vision of accessible, inclusive and universal museum spaces has been at the core of participatory approaches since the 1970s, and has recently been reinvigorated with the focus on visitors' multisensory stimulation. The complex ways in which senses are combined (multisensory integration) in appreciating the aesthetic qualities of objects and environments (Howes, 2006), have caught the attention of museum researchers and curators. The specific interplay of "hidden senses," such as smell, and the "higher senses," such as vision, are only beginning to be elucidated by research and were of specific interest to us in this project. In particular, we build on previous work that highlighted the lack of attention to the engagement of the olfactory sense in museum exhibitions (Ehrich et al., 2021) and the need to study the complex ways in which senses inter- and intra-act in children's everyday experiences (Kucirkova, 2022). The aim of this study was to examine in detail the ways in which children respond to olfactory stimuli in relation to color and other sensory stimuli in a purposefully designed story exhibition for children.

The ways in which senses combine to impact for example stability and balance is little known. For instance, haptic input can lead to increased stability and this is affected by the child's age, with older children (7–9-year-olds) being more stable in their gait and posture than younger (3–5-year-olds) children (the age factor was independent of different levels of touch, such as not touching, holding an object, lightly touching, and firmly touching, Schmuckler and Tang, 2019). What is less known is the impact of multiple sensory stimulations on children's movements in space.

Embodied learning emphasizes the role of the entire body (and not just the brain) in learning and how bodily interactions can be merged and fused with different interactive technologies that incorporate multi-sensory stimuli and augmented or virtual reality (Dourish, 2001). Ale et al.'s (2022) review of embodied cognition studies in child-computer interaction found that in the past 11 years, no studies focused on smell and taste as primary stimuli for embodiment, possibly stemming from the contextual nature and subjectivity of these stimuli, or limited resources and expertise in this area. The authors recommend that future research prioritizes interdisciplinary collaborations to study these senses – a call that we heeded in our project. Furthermore, Verbeek et al.'s (2022) recommendation for more empirical examples of multisensory museology, motivated our focus on the role of olfaction within children's multisensory experiences in museums.

Multisensory experience

Museums offer multisensory experiences as visitors move around exhibition spaces with their whole bodies, thus engaging their visual and hearing senses, proprioception (sense of movement and bodily awareness of space), olfaction (sense of smell), and in some exhibits, also touch and taste [see for example Park et al.'s (2022) report of food tourists enjoying varied taste experiences in museum restaurants].

Neurological findings confirm that humans perceive their environments through a converged and combined interaction of individual senses (Spence, 2011). The intensity, enjoyment and memory of an experience depends on the extent to which the relationships between individual senses (the so-called cross-modal correspondences) match or mismatch along some physical, semantic or cognitive characteristics (Driver and Spence, 1998; Knoeferle et al., 2015; Wang et al., 2022). According to the multisensory integration theory (Durgin et al., 2007), the congruence or match between individual senses needs to be spatially and temporally aligned for a smooth and enjoyable sensory experience (Spence, 2009). Senses might also counteract each other's influence (the so-called cognitive load theories, see Kirschner, 2002). In addition, the individual's own assumptions, which are based on previous experiences but also inborn differences (e.g., Iarocci and McDonald, 2006), influence the totality of an experience. It follows that the stimulation of individual senses needs to be balanced with the needs of individual visitors who might have sensory sensitivities, which require adjustments to either avoid or enhance the sensory input in museums (Schwartzman and Knowles, 2022).

For children, who are in the early stages of calibrating their sensory apparatus, attention to the ways in which individual senses inter- and counter-act each other is especially pertinent. These complex processes have been predominantly studied with children who have an impairment in one or more senses, often in the context of technologies and remediation approaches. For example Gldenpfennig et al. (2020) studied how specially designed tactile prototypes supported the haptic engagement of visually impaired children and triggered more advanced sensory and cognitive functions. For children with the autism spectrum disorder, who exhibit sensory hypersensitivity or hyposensitivity, innovative, research-based approaches that can improve these children's participation in daily activities, are vital (Schaaf et al., 2015). The

current research and development of accessible sensory technologies can be divided into tools that offer sensory substitution (compensating for lost senses like vision), sensory expansion (broadening current sensory experiences, such as detecting non-visible electromagnetic radiation), and sensory addition (introducing a new sense like magnetoreception, see Eagleman and Perrotta, 2023). But while it is of considerable interest to researchers and software engineers to design environments and resources that would accommodate diverse sensory responses of diverse children, not all types of sensory stimulation (visual, auditory, tactile, taste/smell stimulations) are equally well-studied. Olfactory stimulations are particularly understudied and that is the case especially for young children.

It is widely known that marketing and consumer research with adults and their olfactory experiences of specific products and places is well-advanced (see Spence and Gallace, 2011 for an overview). For example, the use of ambient scents in galleries has been explored theoretically (Spence, 2020) as well as practically (e.g., in the recent Prado Museum exhibition with odours enhancing Jan Brueghel's painting). However, research and practical examples of a fully multisensory experience that includes the engagement of all six senses, of museum visitors, and especially child visitors, is lagging behind. Following the critique that children's educational experiences are focused on the higher senses of vision and hearing, and linguistic and cognitive forms of engagement, the argument for more multimodal (e.g., Jewitt, 2008) and sensory-oriented (e.g., Mills, 2015) learning has been made.

The sensory turn in children's studies has stimulated scholars' interest in the role of bodily movements across museum spaces (e.g., Hackett, 2016) and children's sonic and music experiences in public areas (Gallagher, 2011). The potential of olfaction for children's literacy learning in particular has been recently highlighted (e.g., Mills et al., 2022). As museums increasingly rest on participatory activities and position children as active and cultural citizens and social participants (Harris and Manatakis, 2013), the need for creating inclusive and empowering multisensory exhibitions that engage *all* six children's senses (vision, hearing, touch, smell, taste and proprioception) is even more important. The role of olfaction has been seldom studied in children's museum studies and is the specific focus for our study.

The potential role of olfaction

The loss of olfaction in COVID19 patients during the global pandemic in 2020–2022 led to increased public awareness of the role of smell in fully experiencing the world and leading a fulfilling life (e.g., see Otte et al., 2022). Olfactory researchers have documented the important predictive value of smell in degenerative diseases such as Parkinson's (e.g., Doty, 2012) as well as the direct link between olfactory processing and emotions (Ehrlichman and Bastone, 1992) and between smell and memory (see Wilson and Stevenson, 2003). The close link between the sense of smell and emotional processing has been harnessed for associative learning and studied in relation to learner motivations (e.g., Herz et al., 2004). For example, research shows a positive contribution of peppermint to alertness and memory (Moss et al., 2008), and positive associations between rosemary, lemon and peppermint on memory and learning performance on video-games (Choi et al., 2022). Students' preferences for individual smells

mediate the learning effect, a concept known as the hedonic value of odors. Overall, odors are likely to be an important feature to integrate into museum exhibitions both in terms of enjoyment and the potential for learning.

The extent to which individuals like specific odors or not has been the subject of several studies concerned with cultural and individual differences in olfactory hedonics. The reason that hedonic perception of odors is so important is that it constitutes the primary response to odors as acceptable or repulsive (Yeshurun and Sobel, 2010) and that plays an important survival role in avoiding dangerous places (for example those that smell of gas or smoke) and finding suitable mating partners (Herz, 2002). While earlier cross-cultural studies documented significant cultural differences between some odors (e.g., with participants from Germany and Japan who differed on which odors they perceived as pleasant or disgusting, Schleidt et al., 1988), more recent systematic comparative data report many similarities (Arshamian et al., 2022; Oleszkiewicz et al., 2022).

Although hedonic perception might differ across populations, the lack of language and olfactory vocabulary to describe different odors (Cain, 1979; Engen, 1987; Majid et al., 2018) is shared across cultures (at least western cultures, see Majid, 2021). The lack of olfactory language is particularly present among young children who are at the early stages of developing their general awareness of the world and words to describe it (Doty et al., 1984; Cain et al., 1995; Lehrner et al., 1999). Children's olfactory preferences are detectable early on after birth (Schaal, 1988) but change and further develop until adult age (Ventura and Worobey, 2013). Children's olfactory preferences are varied though often food-related (as shown in our studies in Malawi, Kucirkova and Mwenda Chinula, 2023 and Norway, Kucirkova and Bruheim Jensen, 2023). Recent studies show similarities in children's olfactory perception across countries (Oleszkiewicz et al., 2022) and provide evidence for the predictive value of early odor perceptions for later life (Lindroos et al., 2022). The recent evidence is thus gradually strengthening the argument that children's olfactory perceptions, preferences and experiences need to be more intensively studied and stimulated.

With a few exceptions, such as the Montessori kindergarten curriculum, there is a distinct lack of activities that would engage children's sense of smell and increase their awareness of odors in their environment. Smell remains a largely untapped sense for both learning, play and interaction possibilities in early childhood. This gap presents museums with a valuable opportunity, which we were keen to explore and reflect on.

Museums and children's olfaction

Museum studies on children and odors are currently few and far between, yet integrating odors into museum exhibitions has the potential to enhance the overall museum experience and what is learned from the experience (Verbeek et al., 2022). It has been shown that odors dispersed throughout a Viking museum acted as retrieval cues for memories of a museum visit several years later (Aggleton and Waskett, 1999). To the best of our knowledge, our research-based exhibition, which integrated odors with a fictional children's story in a public exhibition at a children's museum, was the world's first. We decided to integrate odors with the story in order to strategically make children aware of their sense of smell during a story experience.

We have described the participatory approach of academia-museum collaboration in conceptualizing, developing and curating the exhibition (Kucirkova and Gausel, 2023) and the story-related findings (Kucirkova, forthcoming). In this article, we reflect on the lessons learnt from the multisensory and cross-modal integration theories.

To gain insight into hedonic perception in children we analyzed children's responses about their favorite smells at the exhibition and possible reasons for their hedonic preferences. Each odor was paired with a color and a story character. This allowed us to explore the ways in which crossmodal associations may influence children's experience of the exhibition. In what follows, we outline the findings based on data collected as part of a research week before the official opening of the exhibition and that we interpret here in light of multisensory and cross-modal integration theories, with attention for their implications for museum curatorship.

Methods

Exhibition design

The public exhibition was a collaboration between our university research center and a local children's museum, as well as several other organizations and their representatives, including an olfactory expert, two children's librarians and a children's publisher. Capitalizing on the power of story to guide experiences and insights from a prior study in which we interviewed children about their multisensory preferences (Kucirkova and Kamola, 2022), the team members conceptualized an exhibition rooted in a fiction story and augmented with a selection of odors. The story was an adapted version of the traditional fairy-tale *The Three Little Pigs*, which we embedded into an adventure trail that children could follow in the exhibition area. The trail was aligned with the main storyline and consisted of houses where the three little pigs hid away from the bad wolf chasing them (the straw house, the tree house and the brick house), as well as added props and areas, such as plastic trees, cushions, pigpen for the Mother Pig or cushions and books inside the houses.

The design of the exhibition followed the Nordic tradition of nature-based materials wherever possible with fairly muted colors and reasonable space between the individual props (the exhibition needed to be regulated for the number of visitors to allow for sufficient space). The exhibition was specifically designed for children aged 3–8 years, so all props were child-sized. Nevertheless, there were elements that adults accompanying children could choose to use, such as for example QR codes on posters above the piglets' houses. The QR codes activated a voice-over for the individual story parts.

Unlike the pigs and their houses, the wolf's story character was not visually represented in any of the posters or images at the exhibition. However, sounds of the wolf's whines and his threat that he will blow the piglets' house down was played throughout the exhibition at regular intervals from the ceiling loudspeakers. While the exhibition was clearly multisensory with the possibilities for children to move around, sit on cushions and touch all props with their various materials and textures, we were particularly keen to integrate olfactory stimulation into the adventure trail. This was achieved through the selection of five specific odors (aromas) that were embedded in specially designed smell boxes.

Olfactory stimulus design

The smell boxes were made of wood and were of 16 × 16 × 16 cm size. Each box corresponded to a specific place in the story conceptually and spatially on the adventure trail. The odors were combined as odor mixtures with the following associations: (1) Mother Pig's pigpen with unpleasant smell of a pig farm, pee and poo and yellow color; (2) Pretty Pig with a sweet smell of fruit and candies and pink color; (3) Reading Pig with a somewhat neutral smell of pine and forest and a green colour; (4) Clever Pig with a positive smell of chocolate and cocoa and brown color and (5) Wolf's Smell with a negative smell of a wet dog and animal fur and a black color. Each box was easy to open and close with a wooden handle and was screwed to a fixed place inside the pigs' houses or a tree stump in case of the wolf. We called these places "stations" and designed the adventure trail along these, with pink piglets' and red wolf's footsteps stickers on the floor. The odors were in infused cotton balls placed at equal distances under a perforated plate that was screwed to the bottom each box. The color of the boxes' handles and the perforated plate inside were intended to visually and olfactorily represent the characteristics of the story characters (for example sweet and pink for the vain personality of the Pretty Pig).

Study design

Participants

While the museum employees, five of which were active project team members, could informally observe children's interactions during the exhibition, we did not conduct a formal evaluation of public response to the exhibition. We judged the response based on the daily footfall and the fact that the exhibition was extended by 4 months by the museum, very positively covered in national and international media, and requested to be replicated by two other European children's museums in 2023. Our reflection here is based on the observations of children who participated at the research week before the exhibition opened and we had ethical permission to use their responses for research articles. These children were local children from two kindergartens located in the museum's proximity. The children lived in Norway and all spoke Norwegian. Fourteen girls and 14 boys, aged between 4.5–8 years, took part. They visited the exhibition in two groups, the first one had 8 boys and 6 girls on day one and the second had 6 boys and 8 girls on day two of the research week.

To understand children's odor hedonic perception, that is whether they liked or disliked the five odors presented in the smell boxes at the exhibition, we used two non-verbal methods: drawings and pointing.

Drawing method

Drawing is a well-established and popular visual method in qualitative research studies with children, especially if children might struggle to verbalize their feelings and thoughts (Literat, 2013). We selected the drawing method both because of the impoverished language both adults and children have for various smells, as well as its documented power in design evaluation studies with children (e.g., Barendregt and Bekker, 2013), in supplementing researcher observations (e.g., Plowman, 2015) or representing social dynamics (Martikainen and Hakoköngäs, 2022).

We supplied the children with an A4 paper with black-and-white printed faces of the main characters in the Three Little Pigs story (the Mother Pig, The Pretty Pig, The Reading Pig and the Clever Pig) presented in a vertical column with their key props (e.g., Reading Pig holding a book). Children were supplied with a stack of pencils that corresponded to the colors of the stations. These were: yellow for the pig farm and Mother Pig, pink for the Pretty Pig, green for the Reading Pig, Brown for the Clever Pig and Black for the wolf. We also added the colors of orange and purple, which did not appear in any of the stations. The children were invited to color in their favorite pig and draw whatever they liked on a separate or the same sheet of paper after they visited the exhibition. There were six pencils in each color so that if children did not want to share, everyone had equal access to the colors and sheets of paper. The drawing area was set up at the exhibition's entrance with a table big enough for the group of children who visited the area at that time. In addition to the drawing materials, we placed a set of smell boxes on the table. The boxes were exact replicas of the smell boxes inside the exhibition but in a smaller size. This was to prompt children's memory about the smells and to facilitate the pointing method. Figure 1 captures the drawing area with all boxes as prompts for children's experiences.

Pointing method

Our placing of the mini smell boxes in the drawing area was motivated by the objective to ascertain children's olfactory preferences and stimulate a conversation about their olfactory memories from the exhibition. So that children did not need to describe in words or colors which smell they liked most and which they liked least, the researcher asked them to point to the relevant smell box. If the children did not remember the box's smell from the color of the handle, the researcher

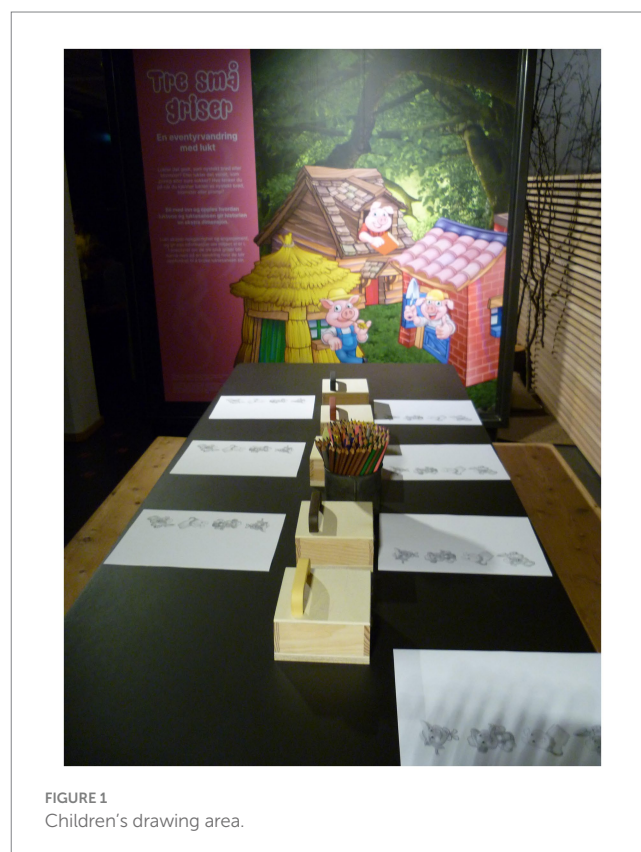


FIGURE 1
Children's drawing area.

encouraged children to open the box and asked them directly whether they like or dislike the smell. These answers were noted down, together with children's verbatim responses about the associations they had with the smells.

Results

Pointing method

Children's answers to the researcher's interview question about which box they liked and which one they disliked and additional comments, are summarized in [Table 1](#).

Children's responses to the individual smells indicated that for most of them, the fragrances in the brown, black and yellow boxes were perceived as unpleasant, while the fragrance in the pink box as pleasant. Children generally described the odors with one of two strategies: they either evaluated the smell (e.g., good), or identified the source of the smell (e.g., candies). Only one child used both strategies. Children's pointing to the boxes with the darker colored handles and their accompanying comments indicated that they did not distinguish the chocolate fragrance as positive but rather perceived all three boxes (yellow, brown, and black) as negative. The imitation of the poo smell in the yellow box placed at the beginning of the adventure trail seemed to have influenced children's perception and primed them for a negative perception of all subsequent smells. Furthermore, the choice of colours on the handles and inside the boxes may have influenced children's responses.

Drawing method

[Figure 2](#) shows an arbitrary selection of children's drawings, illustrating the diversity with which children interpreted the coloring task. We systematically analyzed all 28 drawings in relation to the presence and choice of colors and children's choice of their favorite story character. We looked for any references to smell in children's drawings. In total, 26 children engaged with the task and out of these, two children chose to use only the black color. There was a clear match between the color of the story characters as depicted at the exhibition in four children's drawings; a somewhat ambivalent match in another four children's drawings who colored in several characters as their favorite and some of them had the same color as the exhibition story depictions. However, for the vast majority ($N = 18$), there was a clear mismatch

between the colors children chose and the colors we chose for the individual story characters at the exhibition. We could not identify any olfactory references or qualities in children's drawings. As for the characters, the Mother Pig and the Clever Pig were the most popular characters among the children, according to their drawings.

Discussion

Overall the combination of odors with the story trail as part of the museum exhibition was enjoyed by the children. We used the coloring/drawing method as a way to assess the children's associations with odors without requiring them to verbalize them, which is difficult for children and adults. However, on reflection, we note that this method was not well-suited for the purpose of detecting children's associations and memories from the exhibition. Children's drawings seemed to be a reflection of their spontaneous engagement in the drawing task and their memory of the story of *Three Little Pigs*, not the olfactory qualities of the exhibition. None of the children commented on the different smells in terms of story characters other than two comments associating the wolf with all bad smells. This does not imply that the odors were not beneficial to the museum experience, but perhaps that such an association task needs to be more clearly related to the odors the children smell, for example by asking for the associations immediately after the children smell the odors.

Indeed, it seemed like other parts of their experiences with the exhibition, particularly with the story characters, dominated children's drawings. In a related project in Malawi, where the researchers asked children to portray smells via drawings, we noted a similar methodological limitation of drawings in that the children captured their story experiences but not olfactory references, as was intended by the researchers (see [Kucirkova and Mwenda Chinula, 2023](#)). The embodied cognition theory provides a useful explanatory framework for these findings in that it explains that bodily interactions generate various cognitive responses (see [Wilson, 2002](#)). In particular, spatial movements (in our case children moving in the exhibition space) connect to specific images, places and colors in the brain – results of which we noticed in children's drawings.

The reactions to the odors and the verbalized associations are informative about hedonic odor perception in children. Children's strong emotional response to the yellow, brown and black boxes

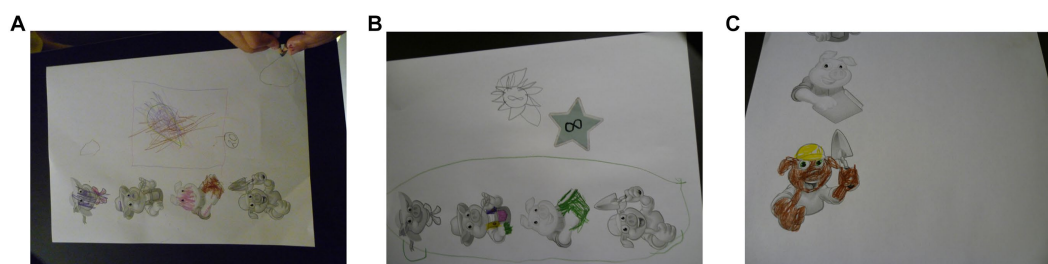


FIGURE 2
Children's drawings.

TABLE 1 Summary of children's favorite smells from the exhibition, as prompted by the smellboxes (translated from Norwegian).

Boy/Girl	Which box did you like?	Which box did you dislike?	Comments
B	Green	Brown	It smells good (green)
B	Pink	Brown and Black and Yellow	It smells like candies (pink) It smells like poo (brown, black, yellow)
G	Pink	Black and Brown	Because the box smells like pee
G	N/A	All	Everything is poo
B	None	All	The wolf pooped everywhere
G	None	Yellow	The box smells like someone pooped inside
B	None	Brown, Black, Yellow and Green	It's disgusting ("ekelt")
B	None	Yellow and Brown	Poo!
B	None	All	(no response but child held his nose)
G	Pink	Brown and Yellow	It smells a bit like strawberries (pink)
G	Pink	Brown	It smells nice
G	Green	Yellow, Brown and Black	It smells like leaves (green) Because it smells bad (yellow, brown, black)
B	Pink	Black and Yellow	Because mother pig
G	None	Black, Yellow, Green, and Brown	Strawberries, yummy!
G	None	Black and Yellow	It smells a bit like strawberries and a bit like poo
B	None	All	(No verbal response)
B	Unclear	Brown	(No verbal response)
B	Green	Yellow	Candies, it smells like candies.
B	Pink	Yellow, Brown, and Black	Because I like it.
G	Pink	Brown and Black	Because it smells like chocolate (pink) Like candies (pink)
G	Pink	Brown, Yellow, Black	(No verbal response)
B	None	Black, Yellow	Like strawberry candies
B	Pink	Brown, Yellow	(No verbal response)
G	Brown	Unclear	(No verbal response)
B	None	Brown, Yellow, Black, Pink	It is the wolf's poo there
G	Pink	Brown	(No verbal response)
G	Pink	Yellow	Because I like it (pink) Because it is poo (yellow)
G	Pink	Black, Brown	I do not like poo (brown, black,)

with their mentions and pointing to the boxes, and the children's adamant that all smelled like 'poo' can be explained by their young age and reflects their current preoccupations and interests (Brown, 2016). The influence of peers during the exhibition who poked each other and laughed about the unpleasant poo smells, would have further intensified the social influence on children's responses. Nevertheless, there was a clear pattern in children's likes for the pink and dislike of the brown boxes. One explanation is that these abstract smells were particularly well composed for this particular group of children. Another explanation, one that aligns with the multisensory theory, is that of sub-additive effects of color and odor simultaneous stimulation. All odors had matching colors but while in the case of the black color and the negative wolf's smell this was a reinforcing effect, in the case of cocoa and the brown color this was a sub-additive effect with the color interfering with olfactory perception. This explanation carries implications for future museum studies and we elaborate on it below.

The explanatory value of the multisensory theory

The associations conveyed through the posters and olfactory boxes did not seem to be picked up by the children as neither of their comments regarding the individual odors mentioned the pigs and very few of the drawings matched the colors of the pig characters. What seemed to be a clear pattern was children's responses to their most and least favorite smells and their corresponding colors in the pointing task. In drawings, 18 of the children's drawings had arbitrary colors. The black and brown colors were attributed to the wolf character, even though in the exhibition, the brown color was associated with the positive chocolate smell in the brick house of the Clever Pig.

Unexpectedly, the odor of chocolate was perceived as unpleasant. This is striking considering it is typically experienced as highly pleasant in adults (Dravnieks et al., 1984), and is likely to be a smell

encountered frequently by children in positive contexts. According to the multisensory theory, this was a sub-additive effect of color and olfaction, where the sensory dominance of the visual sense (color brown) took over the olfactory sense (smell of chocolate). Whilst there was sensory congruence in that the color matched the smell quality (semantic congruence) and there was temporal and spatial congruence in that the colors were directly on the handles and the plate, thus not far from the olfactory experience in time or space, the dark brown color prompted children to think that the smell inside the box was the same or similarly unpleasant smell as that in the black wolf box (see Figure 3). Our finding corresponds to studies with adult participants, which found a crossmodal correspondence between odor and color, whereby a change in one directly impacts the other. For example, a study with wine-tasting studies with adult participants found that the color of the wine glass changed the wine tasters' evaluation of the wine's odor (Morrot et al., 2001). The color brown is likely to have negatively influenced the perceived pleasantness of the odor due to existing associations between brown and disgusting objects (e.g., poo and rotten food; Palmer and Schloss, 2010). It is possible that seeing the color brown before smelling the odor already lead to negative associations.

Another possible influence of color that we had not anticipated was the color congruence between the color of the pigs depicted on the posters (pink), and the pink color of the smell box for the candy odor. Whilst the odor of candy is likely to be perceived as highly pleasant anyway, it is possible the color congruence heightened such pleasant associations. Other visual features of the smell boxes may also have influenced perception of the odors. Angular shapes, such as the one used in our smell boxes, tend to be associated with more intense and unpleasant odors (Demattè et al., 2006). If our unpleasant smells had been presented in round boxes, children may have perceived them more positively (see also Adams and Doucé, 2017). Furthermore, the fact that children physically manipulated the box to open and close it added haptic stimulation, which could have intensified the perception of the odors by potentially making them too intense at the first encounter. Supportive evidence for this interpretation comes from adult studies (e.g., Delwiche and Pelchat, 2002), so we can only speculate on this interpretation. It has been suggested however that some associations between odor and shape, texture, and color may not develop until after age 6 (Speed et al., 2021). Future work should aim

to disentangle the effect of such multisensory features on children's odor experience in museum contexts.

Limitations and recommendations

Although we carefully planned the exhibition in a way to avoid sensory overload and only selectively represented sounds and touch (and no taste stimulation) in the exhibition, we underestimated the crossmodal correspondences between colors and odors and this omission led to children's negative perception of the chocolate odor in the story/exhibition. Children's knowledge of the world and the presence of their peers at the exhibition may have further influenced our results. It could also be that the odor and color were incongruent alongside other dimensions such as texture or shape but what seems the most plausible explanation, is the design misalignment between the brown color and the chocolate's positive olfactory qualities representing the warm home of the Clever Pig.

The drawing method seemed adequate for capturing children's perceptions of their favorite story characters, but it was limited in gauging their sensory preferences (beyond their visual and color preferences). Children's pointing responses could have been influenced by the presence of other children in the drawing area. Although each child was requested to individually point to the box with their most and least favorite odor, some children could see each other's response and this may have influenced their own judgment – a methodological limitation well-documented in child food consumption studies (e.g., Cullen et al., 2001; Olsen et al., 2019).

These study limitations are not uncommon in design-based studies, although the dynamic nature of innovative research and design-based studies means that they are often underreported. Future studies could employ experimental or quasi-experimental methods to formally study these patterns. Here, we highlight the correspondences between colors and odors as an understudied and little understood area in children's interactions with the environment and stories. Colors have been studied in marketing research since the 1970s in relation to their emotional value of colors to appeal to customers and make their products stand out (Wheatley, 1973). The inclusion of colors is natural in any public exhibition and is considered in relation to a number of dimensions, including music and spatial appeal (Monti and Keene, 2016), but rarely in relation to olfaction. Yet, studies, including the present research, show that immediate discrepancy between colors and odors might play a role (Welch and Warren, 1980). Future research could explore how culture-specific odors are and how they might add to children's visual experiences at museum exhibitions.

What is clear is that odor-color associations are an important area of research and aspect to take into account when designing a multisensory exhibition for children. Colors, rather than odors, seem to drive children's hedonic perceptions, something that Ernst and Banks' (2002) theory explains as the maximum likelihood estimation (MLE) account of multisensory integration. According to the theory, there is a clear dominance of some sensory modalities over others and our findings provide indirect support for it. Our findings are also in alignment with Spence's (2011) conclusion that it is not only how closely in time and space two sensory stimuli are but also the correspondence between stimuli's qualitative attributes that leads to the totality of an experience.



FIGURE 3
Smellbox inside the straw house.

Conclusion

As we engage in “sensploration” and as the science on the intimate connection among all senses advances (Spence, 2022), museums need to be more cognizant and knowledgeable about sensory additions, sensory incongruencies and overload. Finding the right sensory balance will vary from exhibition to exhibition as the combination of sensorial inputs and their perceptions by visitors is unique to each context. Nevertheless, museums would benefit from keeping abreast of the insights from multisensory studies and following the general principles of multisensory theories in designing their exhibitions. This recommendation is particularly pertinent for children’s museums, as children with emerging linguistic and cognitive capacities are more vulnerable to sensory overload than adults (Veenendal, 2009) and the sensory dominance of the visual sense.

Data availability statement

The datasets presented in this article are not readily available because the dataset was destroyed upon completion of the study as agreed with the participants and the Ethics Body. Requests to access the datasets should be directed to natalia.kucirkova@uis.no.

Ethics statement

The studies involving humans were approved by NSD- Sikt Norwegian Research Data Centre. The studies were conducted in accordance with the local legislation and institutional requirements.

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Author contributions

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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