Multisensory Reading in Early Childhood: Systematic Review with Theoretical Guidance for Human Development Studies

Natalia Kucirkova and Lucy Rodriguez Leon

Publication details:

Kucirkova, N. and Rodriguez-Leon, L. (2023) 'Multisensory Reading in Early Childhood: Systematic Review with Theoretical Guidance for Human Development Studies', *Human Development* [Preprint]. Available at: https://doi.org/10.1159/000531633

Abstract

Our systematic qualitative analysis advances the field of human development with an integrative review of sensory research in children's reading of books and e-books. Based on a systematic literature review of 35 papers, we qualitatively synthesise multi-disciplinary literature concerned with children's sensory development and the activity of reading. We map the studies' characteristics, including their methodological designs and primary theoretical concepts (embodiment and materiality). We highlight empirical research gaps and lack of literature attention particularly for critical engagement with sensorial research. We find notable terminological discrepancies across qualitative and quantitative studies and lack of attention to the developmental aspects of children's sensory reading and its dynamic interaction with books' affordances. Our theoretical contribution lies in identifying the emerging area of multisensory m(ai)cro research as a future agenda for studies of children's reading, which we support with a terminological guide and a conceptual framework.

Keywords: multisensory; reading; systematic review; children

The 21st century has brought a new era of interconnected human-technology possibilities to reading and sensory engagement with the reading environment, thus directly impacting children's development. In this paper, we reflect on the evolving evidence base on children's reading in the digital era with an integrative review that synthesises interdisciplinary literature concerned with children's reading and multisensory research. Our focus on the multisensory nature of children's reading is driven by the theoretical proposition that a focus on the sensory interplay, rather than on the reading medium, carries the potential for new theory building in human development studies. Our focus builds on the conceptual foundations of sensory reading studies that highlight that rich reading practices involve the engagement of the full sensorium, including the lower senses — olfaction, gustation and proprioception (Stougaard Pedersen et al., 2021). A synthesis of literature was highlighted as necessary to understand the ongoing disconnect between empirical and theoretical approaches to children's digital reading, with observational and experimental studies focusing on social (e.g. parent-child interaction) or material (e.g. quality of books) aspects but theoretical studies focusing on the socio-material and multisensory interplay in children's reading of digital books (Kucirkova, 2021). Kucirkova's (2021) review was constrained in that it directly built on a previous review by Miller and Warschauer (2014) concerning children's digital reading and only focused on articles published between January 2016 and September 2017 in twenty educational journals.

Although children's development of senses and sensory engagement in various activities are well-established in the child development literature, thus far, children's sensory engagement has not been integrated with studies of reading – a gap addressed by this study with a cross-disciplinary systematic review.

The paper is structured in three parts. In Part I, we conceptually integrate studies on children's reading with technologies, particularly reading of digital books, (fiction and

narratives), with theoretical propositions of sensory reading, which integrates all six senses in reading (Kucirkova, 2022, p.2) and moves beyond medium-focused reading. We then review studies concerned with children's sensory development. In Part II, we report on the methodological characteristics of 35 papers that we identified through a systematic literature search. We map the research landscape of sensory reading with attention to how researchers conceptualise sensory integration and interplay and highlight empirical issues that have been addressed by existing work and that remain to be addressed by future analyses. In Part III, the findings from our conceptual and methodological review are synthesised in the form of a conceptual framework that informs the field of sensory reading studies in early childhood (children aged up to eight years).

Part I: Conceptual review

Children's contemporary reading practices

Research into early reading is a multi-disciplinary and diverse field of study that, over the past four decades, has branched in numerous directions and been shaped by different theoretical lenses and research paradigms. Whilst longstanding cognitive reading models, concerned with the acquisition of skills such as phonological awareness and rapid automatized naming (Vaessen & Blomert, 2010), continue to contribute valuable knowledge and insights, the ways in which reading, and reading development are conceptualised in research has expanded exponentially. From the 1990s, for example, research underpinned by sociocultural theories shifted attention away from 'learning' to read, to focus on how children participate in the reading practices of their communities (Barton & Hamilton, 2000). During the same era, advances in digital technologies and other text production technologies have changed children's early reading practices. Today's children can access texts in multiple formats, including paperbacks, board books, digital books or story apps. The different

formats accommodate different reading needs and interests and are part of the dynamic landscape of children's reading.

The turn to reading practices rather than skills prompted researchers to consider many other dimensions of reading, such as reader agency (e.g., Daniels, 2014), reader motivation (e.g., Troyer et al., 2019), cross-media engagement (e.g., Mackey, 2002), Indigenous literacies (Reese, 2007) and artefactual literacies (Pahl & Rowsell, 2010), for example. More recently, posthumanist scholars have illustrated that reading is a 'more-than-human' endeavour, through directing attention to 'people-materials-text-time-place' relations in reading events (e.g., Hackett, 2021).

Closely related to this paper's focus on multisensory reading is research and scholarship around multimodal reading (Kress, 2010; Kress & van Leeuwen, 2001; Jewitt, 2014; Siegel, 2012). Multimodality scholars argue that making meaning with text involves interpreting combinations of communicative resources, or modes, including written script, image, page layout, colour, and font shape and size. Whilst multimodality is not a new phenomenon, information technologies have widened access to texts that involve non-linguistic forms of meaning-making, such as sound, music, still and moving images, and other visual representations, resulting in new, multi-layered meanings. This work exposes the limitations of previous cognitive models of reading (Kress, 2010; Jewitt, 2014) and has been instrumental in expanding conceptions of early reading. Building on this tradition, most recent multimodal literacies research has focused on the sensorality of reading. For example, Jewitt et al. (2020) consider the sensorial experience of touch screen technologies and how touch is more than functional, as it affects the physical, emotional and social experience of reading. During a study in a special school in England, Pool, Rowsell and Sun (2023) reframed their understanding of multimodality and focused instead on sense-led meaning

making. The authors describe children's sensory, embodied and multimodal practices, that were difficult to capture through traditional multimodal frameworks.

Reading Medium

A key theoretical gap that we identify in the literature, and that we address with this paper, is an emphasis on the medium in contemporary studies of digital reading. Similarly to Jewitt and colleagues' (2020) work, we move beyond the medium emphasis and explore the sensorial aspects of reading. This is in contrast to McLuhan's (1962) thesis that medium is the message and that researchers should prioritise the study of media channels in which content is communicated. McLuhan's (1962) theory has been an influential framework for medium comparison studies (e.g. Ivić, 2019). In these studies, one medium is typically compared to another (the so-called cue-attending studies) to find out which outperforms the other in relation to children's learning. Back in 1984, a hallmark study by Salomon (1984) compared elementary school children's watching of television against reading and showed that television viewing required less mental effort and resulted in lower comprehension. Salomon's earlier thinking has guided medium comparisons (such as TV, book or radio) regarding the extent of mental effort that children invest in the experience, and how much they learn.

Digital versus print book comparisons

More recently, to understand the learning values of children's digital books, studies have compared children's learning with print versus digital books, yielding some mixed results. Some studies showed greater learning rates with print books (Krcmar & Cingel, 2014), some with digital books (Smeets & Bus, 2015) and some found no difference (Neuman, Wong, & Kaefer, 2017). However, differences in research methodologies, children's individual differences and context of reading, need to be taken into account when interpreting the

evidence on digital versus print reading (Courage, 2019). Three recent meta-analyses (Furenes, Kucirkova and Bus, 2021; Schwabe et al., 2022; Savva, Higgins and Beckmann, 2022) all indicate that a key factor influencing children's learning from digital books is not so much the digital format (digital or paper) but rather the features of the reading medium, that is, the book's content and design. These features all together, rather than digitisation of text per se, dynamically shape adult-child reading interactions and children's reading experiences.

Multimodal and multimedia features

Educational researchers have accumulated a body of evidence about the learning benefits of digital books (Korat & Falk, 2019), with an emphasis on four key features - multimedia, feedback-giving, gamification and personalisation of digital books (Zhang et al., 2020). These different features are qualitative markers of digital books that carry implications for children's multisensory engagement in reading – an issue we explore in depth in this article. In doing so, we build on the view expressed by several reading theorists, including multimodal and multimedia scholars (see Mills, 2015 for an overview) that digital-print comparison studies are reminiscent of outdated medium theories. In a related domain, Qvortrup (2006) highlighted the limitations of medium studies in relation to Early Internet research, arguing that the Internet is an evolving and dynamic medium, and thus too complex to be conceptualised and studied in a medium-comparison approach (as modelled by Marshall McLuhan, 1962,1994); digital environments cannot be treated as oral or verbal environments as they are more complex in the ways they generate and perpetuate interactions. Extrapolating from this perspective, children's contemporary reading practices need to be studied in their complexity, rather than through simple examinations that compare new and previous media.

A fixed approach on medium affordances in studies of children's contemporary reading is further complicated as it treats reading as a stable environment and overlooks the highly phenomenological (e.g., Rowsell, 2014), affective (Leander & Ehret, 2019), relational and creative (e.g., Gallagher et al., 2018) subjective and personalized (Burnett et al., 2014) character of interactions that happen between readers and texts. Critical literacy scholars therefore promote the study of dynamic interactions between readers and texts instead of medium comparison (Coiro, 2021). The theoretical framework that has been proposed to understand this complexity is that of multisensory literacies, which sensory reading is a part of.

Multisensory literacies

Embodiment and multisensory reading scholars recognise the dynamic, affective, bodily interaction with, and around, texts (Mangen, 2008; Mangen & Van der Weel, 2016; Mills, Unsworth & Exley, 2017). At the heart of the multisensory turn is the assumption that reading is a sensory activity, which involves the stimulation of visual, auditory, haptic, olfactory, gustatory and proprioceptory senses (Kucirkova, 2022). When children read a digital book on iPads, for example, their visual sense is stimulated with moving images and text presented on the screen, their hearing sense is stimulated with both the book's embedded voiceover, music and background noise or an adult reading the book to them. Unless the child reads a scratch and sniff book, their olfactory sense is not stimulated directly by the book but by the reading context with ambient smells in the room around them, and tastes of foods they eat before, during or after reading. The various touch possibilities on the screen, including swiping, increasing an image size, moving characters on the screen, offer rich haptic and proprioceptory possibilities. Empirical studies of these theoretical possibilities have two related and often intertwined, theoretical antecedents: materiality and embodiment.

Materiality

The theoretical proposition of materiality scholars is that readers' sensory and motor quality of reading experiences can be traced back to the materiality of the reading medium. Research that informs this approach relies on empirical studies that argue that the materiality of paper is superior to that of the screen and this difference plays out in readers' engagement with texts. As Magen (2008, p.416) described, when readers are 'phenomenologically immersed that we typically experience when reading a novel, [this] is related to and at least partly dependent on the very materiality of the print pages of the book itself'. The interplay of body, text and materiality relies on readers' bodily and social experiences (Hillesund, Schihab & Mangen, 2022) and these can be studied in terms of emotions, empathy and aesthetic stance in literary reading but also as inner perceptions and bodily tension with digital texts (Kuzmičová, 2014). Material approaches to children's reading are interwoven with social, critical, multimodal, spatial and sensory perspectives on children's literacy (Mills, 2015) and they use a range of methodological approaches, for example an interview-based documentation of readers' embodied actions with texts (Kuzmičová et al., 2022). A related, but conceptually distinct, term employed by materiality scholars is that of embodiment, which signals a clear conceptual departure from reading as a brain-centric and cognitive process to reading as an embodied process.

Embodiment

Embodiment is a core concept in embodied cognition theories that emphasise that meaning making as grounded in the entire bodily stimulation with the environment, including sensory stimulations and motor interactions with the world. The body is immersed in the environment and interacts with and thus grounds or situates cognition (Wellsby & Pexman, 2014). Scholars who follow the embodied cognition paradigm move away from a neurological approach to cognition that positions linguistic and brain activity at the forefront of interaction (see Kiefer & Trumpp, 2012), and gravitate towards the knowing body and

sensory–motor information transfer in meaning-making, where knowledge is distributed across networks and bodies (Tyler & Moss, 2001). However, the value of embodied cognition for the psychology and cognitive fields has been contested, especially in terms of the lack of novel contribution to qualify for a paradigm shift (Goldinger et al., 2016) and unsystematic reporting undermining the reliability and validity of embodied cognition studies (Zwaan, 2021). Ideas from embodied cognition theories carry direct consequences for pedagogy (Nguyen & Larson, 2015) and design of instructional tools (Pouw, Van Gog & Paas, 2014), including children's reading. Recent studies concerned with embodiment have highlighted the 4Es of reading (embodied, embedded, enacted and extended reading) as a guiding theoretical framework for reading studies with adults and represent a coherent attempt to integrate embodiment and distributed reading studies (Hillesund, Schilhab & Mangen, 2022; van der Weel & Mangen, 2022; Newen, Gallagher, & De Bruin, 2018).

While materiality and embodiment are theoretical cousins, they are different from cognitive load theories, which emphasise the limitation of learners' capacity to cognitively process information from multiple sensory channels.

Cognitive theory of learning and cognitive load theory

The main premise of cognitive load theory is that learner's capacity for cognitive processing is constrained by the capacity of working memory. If the cognitive load is too high, it hinders learning, but when it is optimal, it advances learning (Mayer & Moreno, 2003). It follows that the design of reading materials and adults' support of children's reading, need to stimulate cognitive processing relevant to the reading materials, while minimising distracting features in the environment that hamper learning transfer. Such a "germane cognitive load" allocates memory to learning-relevant activities and minimises task-irrelevant information (Sweller, van Merriënboer & Paas, 2019). It is well-established that learners, and young learners in particular, cannot effectively regulate their learning and

need support, in the form of teachers' prompts or well-resourced materials, to benefit from learning situations (Tekin, 2022). Latest neurological studies propose dynamic cognitive load models, where the brain flexibly recruits relevant tissue as the task changes (e.g. reading of different texts) and the load increases (e.g. the complexity of sentences, see Michael et al, 2001). The optimal learning situation is a dynamic exchange of information that selectively stimulates the senses.

In this paper, we interrogate the theoretical contribution of a multisensory focus, informed by the materiality and embodiment theories, on children's reading. Our choice of these theories is motivated by the need to complement current literature about medium differences (which became quite pronounced over the past decade) with more attention to the sensory side of reading. Sensory reading is a nascent research area and as such, requires a conceptual clarity to establish its connection to multisensory developmental studies. In appraising the interdisciplinary literature on children's multisensory reading, we were guided by the developmental perspective on children's multisensory engagement.

Developmental multisensory research

Multisensory research is a vibrant field in psychophysical, neurophysiological and developmental studies, concerned with perceptual, behavioural and neural mechanisms of action, cognition and attention (Ernst, 2008). Developmental science has been interested in understanding how senses interact in multi-sensory perceptions, with, for example, the different sensory thresholds for individual children (e.g., for children on the autistic spectrum, Kwakye et al., 2017), or hedonic attributes of various sensory stimulations (e.g. children's pleasant and unpleasant perception of odours in foods (Roberts et al., 2022).

Of particular interest in developmental multisensory research is the question of how senses interact and intra-act with each other: some senses are integral to an experience when they combine, for example the gustatory and olfactory senses to the perception of flavour (Spence, 2013), while other senses dominate an experience, for example the haptic experience of touch dominates affective responses in social interactions (Spence & Gallace, 2011). A key learning principle in multisensory studies is that of sensory integration: learning benefits occur only if multisensory perception of a situation is integrated with the features of the event/situation (Lehmann & Murray, 2005). Memories that are deeper encoded are better remembered (Craik & Lockhart, 1972; Lockhart & Craik, 1990) and a multisensory integration contributes to the depth of the encoding process (Chatterjee, Hannan & Thomson, 2016).

The key mechanism influencing multisensory integration is attention (Talsma et al., 2010). The sensory competition for attention in some situations is stimulus-driven (bottom-up) and in other situations top-down (Quak, London & Talsma, 2015). Whilst the literature on how selective attention in early childhood works with various senses and activities is limited, a solid evidence base exists concerning infants' amodal processing. Rooted in Gibson and Carmichael's (1966) theory of a unitary perceptual system where all senses work together, empirical studies with infants' multisensory integration highlight the ability to process amodal (that is independent of any sense) attributes of the environment, such as rhythm, intensity and tempo (see Bahrick & Lickliter, 2012).

Furthermore, multisensory developmental studies have documented age-related differences in sensory responses over time. Indeed, children don't develop the ability to optimally integrate their senses until they are between eight and ten years old (Dekker & Lisi, 2020), with clear processing differences between children and adults (Verhaar et al., 2022). As for the associations between sensory engagement and digital interactions, correlational

studies show positive associations between children's development of fine motor skills and active scrolling on touchscreen devices (Bedford et al., 2016; Moon et al., 2019). The multisensory developmental perspective thus emphasises the individual brain–body–environment connections and outlines how senses are coupled and integrated in the child's developmental process.

We were interested in finding out how this perspective contributes to sensory reading studies. We aimed to find out about the characteristics of sensory reading research in terms of the methodologies, disciplines and studies' developmental foci. The purpose of the review was not to determine outcomes or impacts in the empirical literature but rather to map the field for an understanding of which academic communities are engaged in this research, which methods they follow and how do they approach developmental differences in children's multisensory engagement. To capture more recent and contemporary perspectives of sensory reading, we focused on studies published since the turn of the millennium. In alignment with the developmental perspective, we focused on children aged birth – 8 years, and we also included children with special educational needs in this age group or older if they were part of the same study. The focus on the young age group was guided by both the reading literature regarding young children's development of reading skills and the sensory literature regarding children's development of optimal sensory integration. The inclusion of children with special needs was guided by our ethical commitment to inclusivity in data interpretation.

Our analysis was guided by two main questions:

1, How has multisensory reading with children been conceptually framed by studies from diverse disciplines?

2, What are the methodological characteristics of research concerned with multisensory reading in children?

Part II: Systematic literature review

Method

Study design

Given that multisensory reading is an emerging field in early childhood studies, it exhibits a considerable diversity in representing research evidence. This means that a meta-analytic systematic review was not possible and instead, a qualitative systematic review methodology was followed, with the procedures outlined by Tieken & Auldridge-Reveles (2019) and modelled by Hakimi, Eynon & Murphy (2021). Similarly to previous qualitative systematic reviews, we identified, analysed, compared and contrasted literature, with the focus on multisensory approach to studying reading in early childhood.

Literature search strategy

Articles and manuscripts published internationally, written in English, were searched using EBSCO (including databases, Educational Resources Information Centre (ERIC), Education Research Complete, APA PsycInfo and SCOPUS). In each database search, fields were set to title, abstract and keywords. The initial search took place in May 2022 and was repeated in August 2022.

Searches were limited to empirical studies published in peer reviewed academic journals and unpublished doctoral theses between 2000 and 2022. Standard Boolean operators were used to connect search terms in each query and to expand the search to include synonyms. Synonyms were drawn from academic literature and our combined academic knowledge. We used the papers by Mangen & Van der Weel (2016) and Mills, Unsworth & Exley (2017) to derive the initial list of keywords and supplemented these with

the keywords recommended by a subject librarian based at (institution's name withheld), specialising in literature searches. The resultant search statement is itemised in Table 1 and Table 2 includes our inclusion and exclusion criteria.

Table 1 to be inserted about here

Table 2 to be inserted about here

Analysis and coding of selected studies

Each study was coded according to a set of methodological characteristics, which were based on previous qualitative systematic searches. The selection of the key codes was guided by our objective to map a nascent field dispersed across various disciplines and to identify empirical research gaps.

- Study design / methodology
- Methods used
- Sample size
- Participant age range
- Participants' gender
- Inclusion of participants with Special Educational Needs (SEN)
- participants socio-economic status (SES) or settings' SES context (if stated)
- Setting type or context in which data were gathered (School / preschool setting, home setting, community space, Lab)
- Geographical area or country of research
- Disciplinary background (defined through the authors' affiliations, the journal's discipline, and any position statements in the articles.)
- Reference to multisensoriality and / or embodiment

- Reference to individual senses

To explore how notions of multisensory engagement has been perceived in early childhood literacy research, we firstly examined which individual senses were mentioned in each paper. In addition to the five traditional senses, we searched for reference to proprioceptive and vestibula senses. While the five traditional senses are well-known, proprioception has been only recently added as an official term in multisensory studies (Cuturi et al., 2022), especially in research concerned with children with special needs (e.g., Wang et al., 2022). Our initial search found no reference to proprioception but the keywords of 'movement' and 'kinaesthetic' learning were widely mentioned. We therefore took these as substitute terms for proprioception. Reference to individual senses in each paper were reviewed and an interpretation was made regarding whether the researchers presented individual senses separately or as integrated, and thus, how it fitted with the developmental literature.

Given that some sensory aspects rely on the full development of anatomical features, the sensory engagement of 0-8-year-olds in reading is different than that of adults, which raises the conceptual question of how sensory reading studies conceive of the role of individual senses in the reading activity. Guided by the insights of our initial literature review on sensory integration, we were particularly interested in whether the authors foreground specific senses or whether the studies conceive of all six senses as an integrated ensemble.

Findings

The PRISMA Flow Diagram depicts the flow of the studies through the different phases of our systematic review (Figure 1).

Figure 1 to be inserted about here

Methodological characteristics of reviewed studies

The 35 papers that were included for the analysis, comprised 13 qualitative studies and 22 quantitative studies and were published between 2000 to 2022. Qualitative studies ranged in sample size from 1 to 43 participants, and included case studies, ethnographies, autoethnographies and descriptive studies. Sample size in quantitative studies ranged from 6 to 2219 participants, and included randomised controlled trials, pre – post intervention testing and quasi-experimental studies.

Table 3 provides an overview of the characteristics of the studies and reveals that nine studies reported including children with SEN, whilst eight studies stated that children with SEN were excluded from the sample. Two studies included a single participant which, in both cases, was male. Most (twenty-four) studies were conducted in classroom environments, and only three studies included infants under 1-year of age. Two studies with children with SEN had children of higher chronological age than eight: Schlesinger and Gray (2017) included children with dyslexia aged nine-years and Robinson and Moore (2019) focused on children with learning disabilities, and their participant group included 14-year-olds. The studies were almost entirely conducted in WEIRD (Western, Educated, Industrialized, Rich, and Democratic) countries; fifteen in Europe, thirteen in North America, four in Australia, one in China, one in Hong Kong and one in South Africa. The lack of perspectives from Global South contexts is unsurprising in many respects, as the search excluded articles written in languages other than English, and the databases used are heavily weighted toward literature from WEIRD countries.

References to developmental theories were by and large, absent in the multisensory studies we reviewed. Thirteen studies claimed that the intervention led to developmental gains but did not address / mention developmental theory. Three notable exceptions were noted in papers by Zhou et al. (2022), Labat et al. (2020) and Schröder et al. (2020). Zhou et al. (2022) commented on age-related sensitivity of audiovisual synchrony perception but this

was not supported by the authors' later findings. Labat et al. (2020), discussed, in relation to the start rotation principle that, sensorimotor learning is not age-related and did thus not further explore age differences in sensory perception. Finally, Schröder et al. (2020) made a developmental reference to the age sensitivity in relation to visual form perception of children. Apart from these three brief references, we did not find any specific references to the developmental nature of children's sensory engagement. The child's age or developmental stage were not considered as an aspect that could affect their multisensory reading experience. Furthermore, none of the reviewed studies adopted an explicitly developmental framework with a comparative, longitudinal or cross-sectional design to understand children's multisensory development in reading. The characteristics of all studies are detailed in Table 3.

Table 3 to be inserted about here

Theoretical characteristics of the reviewed studies

Of the studies that focused on multisensory learning, behaviours and interventions, all eighteen mentioned visual and auditory senses, and thirteen referred to touch and / or proprioception. Only one of these studies (Labat et al., 2015) mentioned smell and taste, although they were mentioned in the review of literature and were not included in analysis of data.

In the thirteen papers that discussed embodiment, embodied learning or embodied cognition, ten papers made reference to vision and hearing as individual senses, nine mentioned proprioception, six touch, three smell and two mentioned taste. Notably however, two of these papers did not refer to any senses individually. Rather one of these papers discussed how we experience the world through our senses (Aspán, 2020) and the other referred to sensorality and sensory perception (Pacheco-Costa & Guzmán-Simón 2021).

Of the four papers that discussed both multisensory and embodiment, one study (Glenberg, Goldberg & Zhu, 2011) referred to two individual senses, whilst three papers (Labat et al., 2020, Zhou, 2021 and Robinson, Moore & Harris, 2019) referenced four or five individual senses.

In addition, we reviewed each paper to develop an understanding of whether senses were perceived as integrated or separately in the included studies and this yielded the following findings: across all the papers, eleven discussed senses from an integrated stance. In two papers (Labat et al., 2020 and Labat et al., 2015), integration of senses was discussed in the introduction, yet senses were addressed separately in the findings or discussion. With one exception (Loubser et al., 2016), studies of multisensory learning all perceived of senses separately, whilst nine of the thirteen studies focusing on embodiment, embodied learning or embodied cognition discussed senses from an integrated stance (see Table 4 for details).

Table 4 to be inserted about here

Thus, overall, our review found a disconnect between the developmental literature on sensory integration and sensory stimulation and sensory reading studies. While all studies that referred to multisensory stimulation and reading discussed at least two and more senses, they did not discuss the developmental tendencies in children's sensory engagement. References to developmental literature were minimal, indicating that current sensory studies of reading do neither consider a developmental sequence nor variation of sensory engagement of younger or older children. The finding that extant studies treat senses as a static attribute of children's reading complicates the research agenda with a fixed approach that we elaborate on in Part III.

Part III: Theoretical integration

Our review aimed to provide theoretical clarity on multisensory approaches to children's digital reading and a focused methodological review of the literature in this area. In this section, we supplement our systematic literature review with a critical appraisal of published studies to identify factors that can guide the empirical development in sensory reading.

In order to understand the potential of multisensory reading for human development research, we critically reviewed the ways in which notions of 'multisensory', 'multisensory learning' and 'embodiment' have been conceptualised across early childhood literacy research. We identified how the studies refer to these key terms and what their key theoretical antecedents are. This analysis, together with the findings from our systematic review, led us to the identification of research gaps and a recommended conceptual framework for empirically addressing them in future research.

Our critical review of the literature proceeded in three stages, First, we examined the terminological consistencies and inconsistencies across the studies in relation to the use of the key terms. Second, we summarised the key definitions used by the individual studies and third, we connected these findings with the findings of our qualitative literature review and systematic search to propose a conceptual framework.

Terminology (in)consistencies

Our search statement identified studies that referred to both the terms / concepts of multisensory and embodiment.

- 13 papers discussed embodiment, embodied learning or embodied cognition, of which 8 were qualitative and 5 were quantitative.
- 18 papers discussed multisensory learning, multisensory behaviours or multisensory interventions, of which 4 were qualitative and 14 quantitative

- 4 papers discuss both groups of terms, of which 3 were quantitative and 1 was qualitative

Definitions of multisensory across the studies

When we extracted definitions of the terms multisensory and embodied / embodiment from each of the 35 studies, we noted that the terms had been conceptualised in various ways across the papers. We analysed these extracts to draw out different understandings of the terms, with the exception of one paper (Blomert & Willems, 2010), where we were not confident that we could accurately decern what the authors had intended when using the terms. The findings of our analysis are synthesised below.

Zhou et al. (2022) reported research that examined eye tracking in young children whilst watching an on-screen storyteller, and thus the term multisensory was used in the context of the study. Roskos, Burstein, & Byeong-Keun (2012) discussed 'multisensory behaviours' (i.e. Looking, Touching, Listening, Moving, Gesturing) for the purposes of creating a typology for a framework for observing young children's engagement with eBooks. Therefore, when comparing and contrasting understandings of the term multisensory, it is important to note that the term is always used in a particular context.

However, at its simplest, the term multisensory was defined as learning, or a teaching approach, that engages two or more senses. In thirteen of the eighteen papers using the term multisensory, we found that multisensory approaches to the teaching of reading were presented as involving the addition of a haptic or kinaesthetic element to the traditional phono-graphic approach to decoding (Oliva-Maza et al., 2021; Neumann, Hood & Neumann, 2009; Bøga, Dietrichsonb, & Isakssonc, 2021; Zettler-Greeley et al., 2018; DiLorenzo et al., 2011; Labat et al., 2015; Ecalle et al., 2021; Schlesinger & Gray, 2017; Neumann, 2014; Bara et al., 2004; Zafrana, Nikoltsou & Daniilidou, 2000; Labat et al., 2020; Zhou, 2022). This

included activity such as tracing the letter shape in the air, associated actions or feeling a cut-out letter shape made of sandpaper, for example. It was suggested in two papers that these additional sensory stimuli served as mnemonics or mnemonic devices that aid the retention of information.

There were also two examples of the term multisensory being used in ways that intersects with the term embodiment. Loubser, Pienaar & Klopper (2016) discussed the recognition and perception of sensory information and, 'the ability of the brain to engage with the world outside through the senses to subsequently provide meaning to these sensory stimuli' (p.54). Similarly, focusing on sensory stories with children and young people with severe and profound learning disabilities, Robinson, Moore & Harris (2019) discussed how including music, textures, smells, tastes and visual images may enhanced children's experience, enjoyment and engagement.

Definitions of the term embodiment across the studies

The concept / theory of embodied cognition was prevalent and presented as an established theoretical framework for the study of cognition or the development of knowledge in six papers. Authors of these papers discussed how bodily and emotional engagement are essential components of learning, rooted in engagement with the social, cultural and physical environment (Kim & Tscholl, 2021), and how motor systems play a role in the development of cognition (Schröder et al., 2020). It was suggested that language development and comprehension (along with all cognitive processes) are shaped by a person's sensory motor experience (Caselli & Pyers, 2019) and bodily systems of perception, action, and emotion (Adams, Glenberg, & Restrepo, 2019). In addition, it was proposed that embodied cognition involves a cognitive simulation process (Walker et al., 2017).

The term embodiment was also presented from different perspectives. Discussing the idea of learning as embodied, Pacheco-Costa & Guzmán-Simón (2021) and Wason-Ellam, (2010) suggest that meaning making emerges through sensory perception which goes far beyond simply recognising sensory input. What we experience through our senses, and how we perceive and interpret sensory input shapes how we know the world (Aspán, 2020). It was noted that embodied literacies are enacted through movement, gesture and sound which cannot be disaggregated from the 'materiality and speciality' of the context (Powell & Somerville, 2021). Thus, literacy involves 'embodied acts' or felt senses (Hedemark & Lindberg, 2017) as well as muscular actions and bodily communications (Kim & Kim, 2017).

The terminological issues identified in this brief analysis show significant conceptual instability across the field, which could be taken as a sign of its emerging character but also as a symptom of undertheorization. The assumptions, epistemologies and theories are not identified in the studies, making it difficult to ascertain the reasons for their theoretical choices; indeed, most authors do not justify their use of one or the other term, with embodiment, embodied cognition and multisensory used interchangeably. In what follows, we reflect on the areas of congruence and missed points in the current literature.

Current research gaps and recommendations for the future

The findings from our systematic research review and critical review of literature show a lack of theoretical precision on multisensorial aspects of reading and various, often ambiguous, interpretations of multisensory and embodied aspects of children's development. There seems to be a conceptual consensus in the studies that when it comes to sensorial engagement in reading, the book, the child and the adult reading with the child, can selectively engage their senses according to the sensory characteristics of the reading medium. Individual senses inter- and intra-act with each other and their dynamic interplay constitutes the core of the theoretical constructs of embodiment, materiality and children's development. We capture

these concepts in Figure 2. The dynamic nature of children's sensory reading is represented with the connecting points between individual senses that are interconnected with the readers and the reading medium. Figure 2 also shows that in specific contexts, for example when a parent shares a book with the child, some senses become foregrounded, such as vision, hearing and touch (as the parent and child jointly look at the story illustrations and hold the book) and the child listens to the parent reading (this is illustrated in the Figure with the thicker blue lines).

Figure 2 to be inserted about here

Social sensory reading

A significant gap revealed by our systematic literature review but also by our critical appraisal of the literature relates to the lack of theoretical or empirical attention to the notion of power, societal and ethical issues concerning sensory reading. While the importance of embodiment, children's developmental progress and sensory interplay are key research foci for developmental studies, they are also indicative of the individual-centric focus on children's development. Such a micro-focus on the individual reader and the individual reader(s)' interaction with the reading medium is at odds with the macro aspects of human development more broadly and reading more specifically. The concept of "m(ai)cro" introduced by Rogers et al. (2021) seems particularly pertinent to highlight the micro-macro processes and signal avenues for future research developments.

Rogers and colleagues (2021) make it clear that the social justice agenda compels developmental researchers to shift the primary attention from the individual (micro) to the societal relationships (macro) levels and acknowledge their vital role in human development. A mutually influencing, dynamic and simultaneous macro-as-micro processes occur at each moment and in each context of development and, we argue, also sensory reading.

Senses are not power-neutral, and the call for m(ai)cro human development studies resonates with us. We recommend that future research advances sensory reading with acute attention to the importance of shared macro characteristics in individual responses to sensory stimulation that carry historical and societal biases, prejudices and injustices and capitalises on the differences in sensory development as a possibility to practically demonstrate how diversity plays out in children's reading. As a case in example, Kapoor (2022) analysed the politics of smell and how different casts have used smell as an inclusion or exclusion criterion into lower and higher societal structures. Odours emanate from the material (bodies of readers, objects such as books) and are part of the power relationships in the society (Kapoor, 2022). It follows that the study of odour is not about a simple act of smelling physical odours but also about an understanding of odour as a symbol of pollution and purity, reflected in prejudices and caste systems that have reproduced over centuries and across countries. In Kucirkova & Kamola (2022), the researchers highlight children's selective engagement in stories and describe how the children controlled the intensity of sensorial input by for example smelling closer, touching or removing the story props from their bodies. Future sensory reading studies require both a micro focus on individual children's sensorial engagement in stories, as well as a systematic treatise of the wider socio-political meanings of sensory engagement that frame children's experiences.

We represent the micro-macro process in Figure 2 with a frame around the micro levels of sensory-reading engagements. The interplay between studies at the micro-level represented by quadrant A (Figure 2) and studies at the macro level represented by quadrant B in Figure 3 is absent from current literature. In the future, more research on the multisensorial aspects of reading at the macro-level (B) *and* their mutually influencing roles are important.

Figure 3 to be inserted about here

Our conceptualisation of the "m(ai)cro" process in multisensory reading emerged from the findings of the present systematic review and as such, is a starting-point for integrating the literature that needs to be empirically validated. In conclusion, Rogers et al. (2021, p.276) call researchers to 'recognize where and how the "macro" is nested in all of the "micro" processes we study', and we locate senses as part of this necessary location. For example, how might attention to structural ideologies, reveal the connections between multisensory engagement, such as children's attention to visual, rather than haptic aspects of reading? The macro-micro distinction in sensory stimulation was absent from the reviewed papers, showing a mismatch between the theoretical potential of multisensorial research for human development. If we understand reading as a sensuous phenomenon that is part of the macro-as-micro process, then we need to study the ways in which reading and politics dovetail and influence each other. We suggest that the emphasis on both how human-computer interactions are inscribed in the body and enacted in context and extended networks and interactions, is a good fit for children's sensory reading studies in the future. This research can help us better understand how multisensoriality can be used to better understand children's reading.

Acknowledgments:

The Figures were adapted from Ladroue et al.'s (2009) representation of complexes in a regulatory network. Ladroue, C., Guo, S., Kendrick, K., & Feng, J. (2009). Beyond element-wise interactions: identifying complex interactions in biological processes. PloS one, 4(9), e6899.

References

Papers included in the systematic review are marked with an asterisk

*Adams, A.M., Glenberg, A.M., Restrepo, M.A. (2019) Embodied reading in a transparent orthography. *Learning and Instruction.* 62, pp. 27-36

*Aspán, M. (2020) The Tale of Red Riding Hood and the Wolf as a Multi-Literacy Tool for Reflection and Embodied Learning. *International Journal of Education & the Arts* . 21(18) Bahrick, L. E., & Lickliter, R. (2012). The role of intersensory redundancy in early perceptual, cognitive, and social development. In Andrew J. Bremner, David J. Lewkowicz, Charles Spence (Eds). *Multisensory development* (pp. 183-206). London: Routledge.

*Bara, F., Gentaz, E., Colé, P., Sprenger-Charolles, L. (2004) The visuo-haptic and haptic exploration of letters increases the kindergarten-children's understanding of the alphabetic principle. *Cognitive Development*. 19(3), pp. 433-449

Bedford, R., Saez de Urabain, I. R., Cheung, C. H., Karmiloff-Smith, A., & Smith, T. J. (2016). Toddlers' fine motor milestone achievement is associated with early touchscreen scrolling. *Frontiers in psychology*, 1108.

*Blomert, L. and Willems, G. (2010) "Is There a Causal Link from a Phonological Awareness Deficit to Reading Failure in Children at Familial Risk for Dyslexia?" *DYSLEXIA*. 16 pp. 300–317

*Bøga, M., Dietrichsonb, J. and Isakssonc, A. (2021) A multi-sensory tutoring program for students at risk of reading difficulties: Evidence from a randomized field experiment. *The Journal Of Educational Research*. 114, (3), pp 233–251

Burnett, C., Merchant, G., Pahl, K., & Rowsell, J. (2014). The (im) materiality of literacy: The significance of subjectivity to new literacies research. *Discourse: Studies in the Cultural Politics of Education*, *35*(1), 90-103.

*Caselli, N. and Pyers, J. (2019) Degree and Not Type of Iconicity Affects Sign Language Vocabulary Acquisition. *Journal of Experimental Psychology: Learning, Memory, and Cognition*. 46, (1), pp. 127–139

Chatterjee, H. J., Hannan, L., & Thomson, L. (2016). An introduction to object-based learning and multisensory engagement. In *Engaging the senses: Object-based learning in higher education* (pp. 15-32). London: Routledge.

Coiro, J. (2021). Toward a multifaceted heuristic of digital reading to inform assessment, research, practice, and policy. *Reading Research Quarterly*, *56*(1), 9-31.

Courage, M. L. (2019). From print to digital: The medium is only part of the message. In *Reading in the digital age: Young children's experiences with E-books* (pp. 23-43). Springer, Cham.

Craik, F. I., & Lockhart, R. S. (1972). Levels of processing: A framework for memory research. *Journal of verbal learning and verbal behavior*, *11*(6), 671-684.

Cuturi, L. F., Cappagli, G., Yiannoutsou, N., Price, S., & Gori, M. (2022). Informing the design of a multisensory learning environment for elementary mathematics learning. *Journal on Multimodal User Interfaces*, *16*(2), 155-171.

Daniels, K. (2014). Cultural agents creating texts: a collaborative space adventure. *Literacy*, 48 (2), pp.103-111

Dekker, T., & Lisi, M. (2020). Sensory development: integration before calibration. *Current Biology*, *30*(9), R409-R412.

*DiLorenzo, K., Rody, C., Bucholz, J. and Brady, M. (2011) Teaching Letter-Sound Connections With Picture Mnemonics: Itchy's Alphabet and Early Decoding. *Preventing School Failure*. 55 (1), p28-34.

*Ecalle, J., Boisson, A., Labat, H., Versace, R., Magnan, A. (2021) Spatial sonification of letters on tablets to stimulate literacy skills and handwriting in 5 y-o children: A pilot study. *Human Movement Science.* 79, 102,844

Ernst, M. O. (2008). Multisensory integration: a late bloomer. *Current Biology*, *18*(12), 519-521.

Fletcher, K. L., & Reese, E. (2005). Picture book reading with young children: A conceptual framework. *Developmental review*, *25*(1), 64-103.

Furenes, M. I., Kucirkova, N., & Bus, A. G. (2021). A comparison of children's reading on paper versus screen: A meta-analysis. *Review of educational research*, *91*(4), 483-517.

Gallagher, M., Hackett, A., Procter, L., & Scott, F. (2018). Vibrations in place: Sound and language in early childhood literacy practices. *Educational Studies*, *54*(4), 465-482.

Gee, J. P. (2015). The new literacy studies. In J. Rowsell, & K. Pahl (Eds.), *The Routledge handbook of literacy studies* (pp. 35–48). Abingdon: Routledge.

Gibson, J. J., & Carmichael, L. (1966). *The senses considered as perceptual systems* (Vol. 2, No. 1, pp. 44-73). Boston: Houghton Mifflin.

Goldinger, S. D., Papesh, M. H., Barnhart, A. S., Hansen, W. A., & Hout, M. C. (2016). The poverty of embodied cognition. *Psychonomic bulletin & review*, 23, 959-978.

*Glenberg, A., Goldberg, A. and Zhu, X. (2011) Improving early reading comprehension using embodied CAI. *Instructional Science.* 39 (1), p27-39.

*Guzmán-Simón, F., Pacheco-Costa, A. (2022) 'Like, I'm playing, but with this'. Materialization and affect in early childhood literacy. *Journal of Early Childhood Literacy 54*(4), pp. 1082-1106

Hackett, A. (2021) *More-Than-Human Literacies in Early Childhood*. London: Bloomsbury Academic.

Hakimi, L., Eynon, R., & Murphy, V. A. (2021). The ethics of using digital trace data in education: A thematic review of the research landscape. *Review of educational research*, 91(5), 671-717.

*Hedemark, Å., Lindberg, J. (2017) Babies, bodies, and books—Librarians' work for early literacy *Library Trends* 66(4), pp. 422-441

Hillesund, T., Schilhab, T., & Mangen, A. (2022). Text materialities, affordances, and the embodied turn in the study of reading. *Frontiers in Psychology*, *13*.

Hirsh-Pasek, K., Zosh, J. M., Golinkoff, R. M., Gray, J. H., Robb, M. B., & Kaufman, J. (2015). Putting education in "educational" apps: Lessons from the science of learning. Psychological Science in the Public Interest, 16, 3-34. doi:10.1177/1529100615569721

Ivić, I. (2019). Printed and digital media: Printed and digital textbooks. *Center for Educational Policy Studies Journal*, *9*(3), 25-49.

Jewitt C, Price S, Leder Mackley K, et al. (2020) *Interdisciplinary Insights for Digital Touch Communication*. Switzerland: Springer.

Kapoor, S. (2022). The Smells of Caste–Body, Self and Politics. In Di Stefano, N. & Russo, M. T. (eds). *Olfaction: An Interdisciplinary Perspective from Philosophy to Life Sciences* (pp. 21-34). Cha, Switzerland: Springer.

Kiefer, M., & Trumpp, N. M. (2012). Embodiment theory and education: The foundations of cognition in perception and action. *Trends in Neuroscience and Education, 1*(1), 15-20.

*Kim, Y. and Tscholl, M. (2021) Young children's embodied interactions with a social robot *Educational Technology Research & Development*. 69 (4), p2059-2081

*Kim, K. and Kim, K. (2017) Multimodal play–literacy: a pre-schooler's storytelling, drawing, and performing of dinosaur extinction theories. *Early Child Development and Care*. 187(3-4), pp. 568-582

Korat, O., & Falk, Y. (2019). Ten years after: Revisiting the question of e-book quality as early language and literacy support. *Journal of Early Childhood Literacy, 19*(2), 206-223.

Krcmar, M., & Cingel, D. P. (2014). Parent–child joint reading in traditional and electronic formats. *Media Psychology, 17*(3), 262-281. doi:https://doi.org/10.1080/15213269.2013.840243

Kucirkova, N. (2021). Socio-material directions for developing empirical research on children's e-reading: A systematic review and thematic synthesis of the literature across disciplines. *Journal of Early Childhood Literacy, 21(*1), 148-174.

Kucirkova, N. (2022). The explanatory power of sensory reading for early childhood research: The role of hidden senses. *Contemporary Issues in Early Childhood*, 14639491221116915.

Kucirkova, N., & Kamola, M. (2022). Children's stories and multisensory engagement: Insights from a cultural probes study. *International Journal of Educational Research*, *114*, 101995.

Kuzmičová, A. (2014). Literary narrative and mental imagery: A view from embodied cognition. *Style*, *48*(3), 275-293.

Kuzmičová, A., Supa, M., Segi Lukavská, J., & Novák, F. (2022). Exploring children's embodied story experiences: a toolkit for research and practice. *Literacy*.

Kwakye, L. D., Foss-Feig, J. H., Cascio, C. J., Stone, W. L., & Wallace, M. T. (2011). Altered auditory and multisensory temporal processing in autism spectrum disorders. *Frontiers in integrative neuroscience*, *4*, 129.

*Labat, H. Vallet, G., Magnan, A. and Ecalle, J. (2015) Facilitating effect of multisensory letter encoding on reading and spelling in 5-year-old children. *Applied Cognitive Psychology.* 29(3), pp. 381-391

* Labat, H., Boisson, A., Brunel, L., Ecalle, J. Versace, R., Magnan, A. (2020) Multisensory letter integration and implicit learning of reading with 5-year-old children. *Revue Europeenne de Psychologie Appliquee*. 70(1), 100477

Leander, K. M., & Ehret, C. (Eds.). (2019). *Affect in literacy learning and teaching: Pedagogies, politics and coming to know*. London: Routledge.

Lehmann, S., & Murray, M. M. (2005). The role of multisensory memories in unisensory object discrimination. *Cognitive Brain Research*, *24*(2), 326-334.

Lockhart, R. S., & Craik, F. I. (1990). Levels of processing: A retrospective commentary on a framework for memory research. *Canadian Journal of Psychology/Revue canadienne de psychologie*, *44*(1), 87.

*Loubser, A., Pienaar, A., Klopper, A. and Ellis, S. (2016) The effect of a learner-support intervention on perceptualmotor skills of kindergarten learners from deprived environments *Australasian Journal of Early Childhood*. 41 (1), pp54-63.

*Lozy, E.D., Holmes, S.C., Donaldson, J.M. (2020) The effects of paired kinesthetic movements on literacy skills acquisition with preschoolers. *Journal of Applied Behavior Analysis*. 53(3), pp. 1337-1353

Mackey, M. (2002) *Literacies across Media: Playing the text*. London: Routledge Falmer.

Mangen, A. (2008). Hypertext fiction reading: haptics and immersion. *Journal of research in reading*, *31*(4), 404-419.

Mangen, A., & Van der Weel, A. (2016). The evolution of reading in the age of digitisation: an integrative framework for reading research. *Literacy*, *50*(3), 116-124.

Mangen, A., & Kuiken, D. (2014). Lost in an iPad: Narrative engagement on paper and tablet. *Scientific Study of Literature*, 4(2), 150-177.

Mayer, & Moreno. (2003). Nine ways to reduce cognitive load in multimedia learning. Educational Psychologist, 38(1), 43 – 52

McLuhan, M.. (1962) *Understanding media: The extensions of man*. Reprinted in 1994 by Boston: MIT press.

Michael, E. B., Keller, T. A., Carpenter, P. A., & Just, M. A. (2001). fMRI investigation of sentence comprehension by eye and by ear: Modality fingerprints on cognitive processes. *Human brain mapping*, *13*(4), 239-252.

Miller, E. B., & Warschauer, M. (2014). Young children and e-reading: research to date and questions for the future. *Learning, Media and Technology*, *39*(3), 283-305.

Mills, K. A. (2015). Literacy theories for the digital age. Social, Critical, Multimodal, Spatial, Material and Sensory Lenses In *Literacy Theories for the Digital Age*. Multilingual Matters. DeGruyter.

Mills, K. A., Unsworth, L., & Exley, B. (2017). Sensory literacies, the body, and digital media. In *Handbook of writing, literacies, and education in digital cultures*. Taylor & Francis.

Moon, J. H., Cho, S. Y., Lim, S. M., Roh, J. H., Koh, M. S., Kim, Y. J., & Nam, E. (2019). Smart device usage in early childhood is differentially associated with fine motor and language development. *Acta Paediatrica*, *108*(5), 903-910.

Newen, A., Gallagher, S., & De Bruin, L. (2018). 4E cognition: Historical roots, key concepts, and central issues. In Newen, A., De Bruin, L., & Gallagher, S. (Eds.). (2018). *The Oxford handbook of 4E cognition*. Oxford University Press, pp.1-16.

*Neumann, M.M. (2014) Using environmental print to foster emergent literacy in children from a low-SES community. *Early Childhood Research Quarterly*. 29(3), pp. 310-318

* Neumann, M., Hood, M. and Neumann, D. (2009) The Scaffolding of Emergent Literacy Skills in the Home Environment: A Case Study. *Early Childhood Education Journal*. 36 (4), p313-319

Neuman, S. B., Wong, K. M., & Kaefer, T. (2017). Content not form predicts oral language comprehension: the influence of the medium on preschoolers' story understanding. *Reading and Writing*, *30*(8), 1753-1771.

Nguyen, D. J., & Larson, J. B. (2015). Don't forget about the body: Exploring the curricular possibilities of embodied pedagogy. *Innovative Higher Education*, *40*(4), 331-344.

*Oakley, G., Howitt, C., Garwood, R. and Durack, A. (2013) Becoming multimodal authors: Pre-service teachers' interventions to support young children with autism. Australasian Journal of Early Childhood. 38 (3), p86-96

*Oliva-Maza, A., Ayuso-Escuer, N., Coma-Rosello, T., Torres-Moreno, E.F. (2021) Mystery of the Runaway Letrabytes: Inclusive Assessment of Phonological Awareness with Tangible Gamification *Revista Iberoamericana de Tecnologias del Aprendizaje* 16(4), pp. 424-432

*Pacheco-Costa, A., Guzmán-Simón, F. (2021) The (im)materiality of literacy in early childhood: A socio-material approach to online and offline events. *Journal of Early Childhood Research.* 19(3), pp. 369-380

Pahl, K. & Rowsell, J. (2010) *Artefactual literacies: Every Object Tells a Story*. New York: Teachers College Press

*Pearman, C. (2008) Independent Reading of CD-ROM Storybooks: Measuring Comprehension With Oral Retellings. *Reading Teacher*. 61 (8), 594-602.

Pool, S., Rowsell, J. and Sun, Y., 2023. Towards literacies of immanence: Getting closer to sensory multimodal perspectives on research. *Multimodality & Society*, p.26349795231158741.

Pouw, W. T., Van Gog, T., & Paas, F. (2014). An embedded and embodied cognition review of instructional manipulatives. *Educational Psychology Review*, *26*(1), 51-72.

*Powell, S. and Somerville, M. (2021) Preschool zombies: embodied, socio-(re)enacted, productive spatial literacies. *Discourse* In Press

Qvortrup, L. (2006). Understanding new digital media: Medium theory or complexity theory?. *European Journal of Communication*, *21*(3), 345-356.

Quak, M., London, R. E., & Talsma, D. (2015). A multisensory perspective of working memory. *Frontiers in human neuroscience*, *9*, 197.

Reese, D. (2007) 'proceed with caution: using Native American folk tales in the classroom', *Language Arts* 83 (3), pp. 245-56

Roberts, A. P., Cross, L., Hale, A., & Houston-Price, C. (2022). VeggieSense: A non-taste multisensory exposure technique for increasing vegetable acceptance in young children. *Appetite*, *168*, 105784.

*Robinson, D., Moore, N. and Harris, C. (2019) The impact of books on social inclusion and development and well-being among children and young people with severe and profound learning disabilities: Recognising the unrecognised cohort. *British Journal of Learning Disabilities* 47 (2) p91-104.

Rogers, L. O., Niwa, E. Y., Chung, K., Yip, T., & Chae, D. (2021). M (ai) cro: Centering the macrosystem in human development. *Human Development*, *65*(5-6), 270-292.

*Roskos, K., Burstein, K. and Byeong-Keun, Y. (2012) A Typology for Observing Children's Engagement with eBooks at Preschool. *Journal of Interactive Online Learning.* 11 I(2), p47-66.

Rowsell, J. (2014). Toward a phenomenology of contemporary reading. *Australian Journal of Language and Literacy, The*, *37*(2), 117-127.

interaction, *12*, 24-29.

Salomon, G. (1984). Television is" easy" and print is" tough": The differential investment of mental effort in learning as a function of perceptions and attributions. *Journal of educational psychology*, *76*(4), 647.

Savva, M., Higgins, S., & Beckmann, N. (2022). Meta-analysis examining the effects of electronic storybooks on language and literacy outcomes for children in grades Pre-K to grade 2. *Journal of Computer Assisted Learning*, *38*(2), 526-564.

*Schlesinger, N.W. and Gray, S. (2017) The impact of multisensory instruction on learning letter names and sounds, word reading, and spelling. *2017 Annals of Dyslexia*. 67 (3), pp. 219-258

* Schröder, E., Gredebäck, G., Gunnarsson, J., Lindskog, M. (2020) Play enhances visual form perception in infancy–an active training study. *Developmental Science.* 23(3),e12923

Schwabe, A., Lind, F., Kosch, L., & Boomgaarden, H. G. (2022). No Negative Effects of Reading on Screen on Comprehension of Narrative Texts Compared to Print: A Meta-analysis. Media Psychology, 1-18.

Smeets, D. J., & Bus, A. G. (2015). The interactive animated e-book as a word learning device for kindergartners. *Applied Psycholinguistics*, *36*(4), 899-920.

Spence, C. (2013). Multisensory flavour perception. *Current Biology*, *23*(9), 365-369.

Spence, C., & Gallace, A. (2011). Multisensory design: Reaching out to touch the consumer. *Psychology & Marketing*, *28*(3), 267-308.

Stougaard Pedersen, B., Engberg, M., Have, I., Henkel, A. Q., Mygind, S., & Bundgaard Svendsen, H. (2021). To move, to touch, to listen: Multisensory aspects of the digital reading condition. *Poetics Today*, *42*(2), 281-300.

Sweller, J., van Merriënboer, J. J., & Paas, F. (2019). Cognitive architecture and instructional design: 20 years later. *Educational Psychology Review*, *31*, 261-292.

Talsma, D. (2015). Predictive coding and multisensory integration: an attentional account of the multisensory mind. *Frontiers in Integrative Neuroscience*, *9*, 19.

Talsma, D., Senkowski, D., Soto-Faraco, S., & Woldorff, M. G. (2010). The multifaceted interplay between attention and multisensory integration. *Trends in cognitive sciences*, *14*(9), 400-410.

Tekin, E. (2022). Can Learners Allocate Their Study Time Effectively? It Is Complicated. *Educational Psychology Review*, 1-32.

Tieken, M. C., & Auldridge-Reveles, T. R. (2019). Rethinking the school closure research: School closure as spatial injustice. Review of Educational Research, 89(6), 917–953. https://doi.org/10.3102/0034654319877151

Tyler, L. K., & Moss, H. E. (2001). Towards a distributed account of conceptual knowledge. *Trends in cognitive sciences*, *5*(6), 244-252.

van der Weel, A., & Mangen, A. (2022). Textual reading in digitised classrooms: Reflections on reading beyond the internet. *International Journal of Educational Research*, *115*, 102036.

Vaessen, A. & Blomert, L., 2010. Long-term cognitive dynamics of fluent reading development. *Journal of experimental child psychology*, 105(3), pp.213-231.

Verhaar, E., Medendorp, W. P., Hunnius, S., & Stapel, J. C. (2022). Bayesian causal inference in visuotactile integration in children and adults. *Developmental Science*, *25(3)*, e13184.

*Walker, E., Adams, A., Restrepo, A., Fialko, S. and Glenberg, A. (2017) When (and How) Interacting With Technology-Enhanced Storybooks Helps Dual Language Learners. *Translational Issues in Psychological Science*. 3, (1), pp. 66 –79.

*Wall, D., Foltz, S., Kupfer, A and Glenberg, A. (2022) Embodied Action Scaffolds Dialogic Reading. *Educational Psychology Review* 34 pp. 401–419

Wang, C., Gao, J., Deng, Z., Zhang, Y., Zheng, C., Liu, X., ... & Chen, J. (2022). Extracurricular sports activities modify the proprioceptive map in children aged 5–8 years. *Scientific Reports*, *12*(1), 1-11.

*Wason-Ellam, L. (2010) Children's literature as a springboard to place-based embodied learning Environmental Education Research. 16, (3–4), pp. 279–294

Wellsby, M., & Pexman, P. M. (2014). Developing embodied cognition: Insights from children's concepts and language processing. *Frontiers in psychology*, *5*, 506.

*Zafrana, M., Nikoltsou, K., Daniilidou, E. (2000) Effective learning of writing and reading at preschool age with a multisensory method: A pilot study. *Perceptual and Motor Skills.* 91(2), pp. 435-446

*Zettler-Greeley, C., Bailet, L., Murphy, S., DeLucca, T. and Branum-Martin, L. (2018) Efficacy of the Nemours BrightStart! Early Literacy Program: Treatment Outcomes From a Randomized Trial With At-Risk Prekindergartners. *Early Education & Development* 29 (6), pp873-892.

Zhang, R., Zou, D., Xie, H., Au, O. T. S., & Wang, F. L. (2020). A systematic review of research on e-book-based language learning. Knowledge Management & E-Learning, 12(1), 106–128. https://doi.org/10.34105/j.kmel.2020.12.006

*Zhou, H.-Y., Yang, H.-X., Wei, Z., Wan, G-B., Lui, S.S.Y., Chan, R.C.K. (2022) Audiovisual synchrony detection for fluent speech in early childhood: An eye-tracking study. *PsyCh Journal*. In Press

*Zhou, Y. (2021) The effect of dialogic reading paired with multisensory learning of Chinese characters and morphological awareness skills for L2 Chinese young learners at Hong Kong kindergartens. *Foreign Language Annals* 54(4), pp. 1082-1106.

Zwaan, R. A. (2021). Two challenges to "embodied cognition" research and how to overcome them. *Journal of Cognition, 4*(1).