

PREPARING THE BODY FOR BEGINNING LITERACY: A NEUROSCIENTIFICALLY INFORMED, MULTISENSORY APPROACH TO SPEECH, HANDWRITING AND READING

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Abstract

Beginning literacy is often approached as the direct teaching of sounds, letters, syllables, words and graphic forms. Yet a child enters every literacy task with a whole body that must regulate arousal, maintain posture, orient attention, coordinate gaze and hand movements, listen, speak, remember and connect symbols with meaning. This article presents a neuroscientifically informed and classroom-oriented framework for preparing children for beginning speech, handwriting and reading. It does not claim that movement or sensory activities teach reading independently. Instead, it argues that brief, purposeful bodily preparation can reduce avoidable motor and attentional demands and can create favorable conditions for explicit, systematic instruction in phonological awareness, letter-sound correspondences, handwriting, decoding and comprehension. The article integrates research on neuronal recycling, handwriting and symbol learning, executive function, fine motor development, motor-enriched encoding, and the relationship between visual behaviors and reading. Practical examples include body regulation, cross-midline movement, left-to-right directionality, tactile letter formation, oral language and a twenty-minute Body-Voice-Letter-Word sequence suitable for the first years of primary school. Particular attention is given to neurodiverse and multilingual learners, who may benefit from predictable routines, multiple forms of representation, and carefully graded participation. The central professional message is that the body should neither be ignored nor mythologized: it is a support system for learning, while evidence-based literacy teaching remains the core of instruction.

Keywords: beginning literacy, embodied learning, multisensory teaching, handwriting, phonological awareness, neurodiversity

Introduction

When a beginning reader is asked to identify a letter, blend sounds, copy a word, or follow a line of print, the task may look purely linguistic. In practice, the child must remain sufficiently alert but not overwhelmed, stabilize the trunk and head, control the shoulders and hands, direct the eyes, inhibit distractions, hold instructions in working memory, retrieve speech sounds and connect an unfamiliar visual form with language and meaning. A difficulty in any one of these supporting processes can consume attention that would otherwise be available for learning. For this reason, preparing the body for literacy should be understood as an attempt to organize the conditions in which direct literacy teaching occurs, not as an alternative curriculum.

Research on reading acquisition consistently places phoneme awareness, letter knowledge, decoding, vocabulary, oral language, fluency, and comprehension at the center of successful instruction (Castles et al., 2018; Foorman et al., 2016; Hulme et al., 2012). In transparent orthographies such as Slovenian, grapheme-phoneme relationships are relatively consistent, but children still need rapid and accurate recognition of letters, efficient blending, fluent word reading and access to meaning (Borleffs et al., 2017; Erbeli & Joshi, 2022). Explicit teaching therefore remains essential. A child does not discover the alphabetic principle merely by moving, touching materials or looking at attractive

illustrations. Movement becomes educationally valuable when it is deliberately linked to the sound, shape, direction, name and use of the symbol being learned.

The need for such integration is especially visible in heterogeneous first-grade classrooms. Some children arrive with extensive book experience, mature oral language and well-developed pencil control. Others are learning the language of instruction, have had fewer opportunities for shared reading, avoid fine-motor tasks, seek or avoid sensory input, tire quickly or need more time to coordinate listening and action. A uniform demand such as *"sit still and complete the worksheet"* may therefore measure regulation and motor endurance as much as emerging literacy. A more equitable lesson offers a short route into readiness, then teaches the literacy target explicitly and checks whether each child can use it independently.

This professional article brings together relevant research and classroom practice in a cautious way. It explains why reading is a distributed brain achievement, describes bodily and sensory supports that can be used without overstating their effects and proposes a practical sequence from regulation and oral language to letters, words, and meaning. The framework is intended for teachers, not as diagnosis or therapy. Persistent difficulties with vision, hearing, speech, motor control, attention or literacy require collaboration with the appropriate specialists and should not be reduced to a single exercise programme.

Reading as a coordinated brain achievement

Human brains did not evolve with a dedicated, genetically specified reading organ. Reading is a cultural invention that uses and reorganizes neural systems originally developed for vision, spoken language, attention, memory, and action. The neuronal recycling hypothesis describes how learning to read progressively tunes parts of the visual system to recognize orthographic patterns and connects them with phonological and semantic networks (Dehaene & Cohen, 2007, 2011). This does not mean that each component of reading is located in one colored area of the brain. Rather, fluent reading emerges from rapid cooperation among distributed systems.

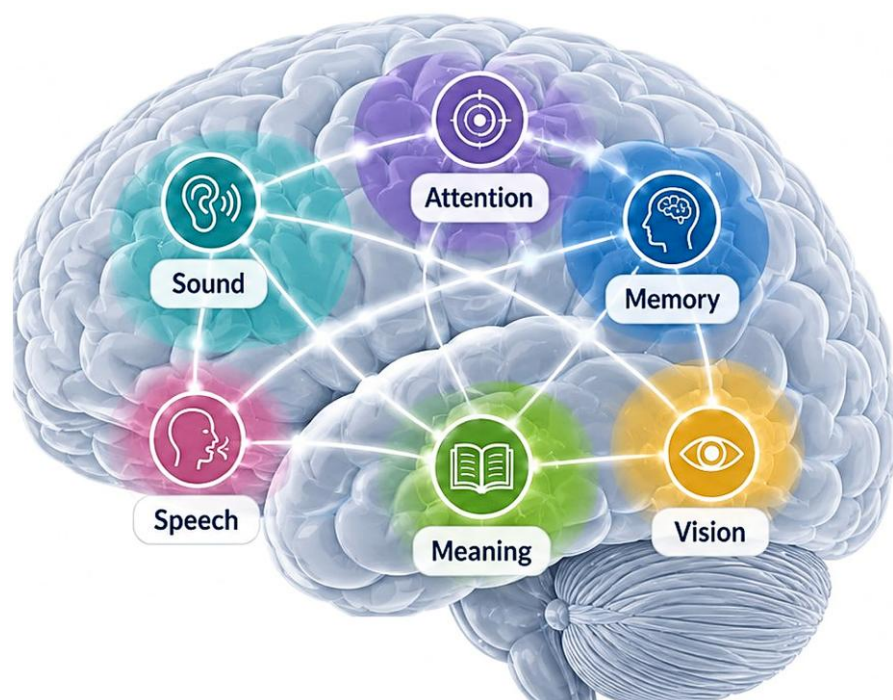


Figure 1: A conceptual illustration of reading as a coordinated network of visual, auditory, linguistic, attentional and memory processes. The image is created with the assistance of artificial intelligence.

For a novice reader, this cooperation is slow and effortful. A printed letter must be discriminated from visually similar forms, its orientation must be respected, the corresponding speech sound must be

retrieved, and the result must be held long enough to blend with neighboring sounds. With repeated accurate practice, orthographic mapping binds spelling, pronunciation and meaning so that known words can be recognized with increasing automaticity (Ehri, 2014). Automatic recognition is important because working memory is limited. When a child spends most available attention identifying each letter, little remains for sentence meaning, inference or enjoyment.

Attention and self-regulation are consequently not peripheral to literacy. They influence whether the child notices the relevant sound, follows the teacher model, persists through uncertainty and checks an answer. Executive functions and fine motor skills both contribute to early school achievement, although their relationships are complex and do not justify simple causal claims (Blair and Raver, 2015; Cameron et al., 2012; Grissmer et al., 2010). The practical implication is modest but important: before asking children to perform a demanding symbolic task, the teacher can reduce unnecessary distraction, establish a predictable sequence and use a brief movement or breathing activity to help the group reach a workable level of alertness.

What it means to prepare the body

Preparing the body begins with regulation. Some children enter a lesson under-alert and need energizing movement; others are over-aroused and need slower, predictable actions. A one-minute routine can include pressing the feet into the floor, lengthening the spine without rigidity, rolling the shoulders, opening and closing the hands and taking two unforced breaths. The teacher can then state the literacy goal in concrete language: *"Today we will hear, say, write and read the sound /m/."* This link is crucial. The routine is not a generic brain break placed beside learning; it is a transition into the exact content that follows.

Postural stability matters because controlled hand movement depends on a reasonably stable base. When a child must use excessive effort merely to remain upright, the grip may become tense, the head may move too close to the page and writing may be slow or uncomfortable. Classroom support can be simple: feet supported, table and chair at workable heights, paper positioned to suit the writing hand and permission to work briefly at a vertical surface. Large movements on a wall, whiteboard or floor can introduce the direction of a form before the child produces it within narrow lines. However, large motor practice should lead toward actual handwriting, because the educational target is controlled symbol production, not movement for its own sake.

Cross-midline actions and bilateral coordination can also be used as warm-ups. Passing a beanbag from one side of the body to the other, touching the opposite knee or tracing a wide horizontal path encourages the child to organize space around a central body axis. Such activities are often described in exaggerated terms, for example as *"integrating the hemispheres."* That language should be avoided. Both cerebral hemispheres already communicate continuously. The defensible classroom purpose is more practical: to rehearse coordinated movement, directional vocabulary and sustained attention before a left-to-right literacy task.

Directionality becomes meaningful when it is attached to print. Children can walk along a path from left to right, move a finger along a line, slide picture cards in reading order and finally track a printed word. The teacher should explicitly name the start point and direction. In languages written from left to right, these repeated cues help organize page navigation, but they do not replace instruction in letter identity or decoding. They are most effective when the transition from body movement to print is immediate.



Figure 2: Left-to-right movement, visual directionality and eye-hand coordination activities that can precede direct work with print. Image is created with the assistance of artificial intelligence.

Vision, gaze, and responsible interpretation

Reading requires repeated fixations and saccades across a line of text. Children with delayed reading skills may show different eye-movement patterns, but these patterns must be interpreted carefully. In many cases, inefficient eye movements reflect the difficulty of decoding rather than constitute its primary cause (Vinuela-Navarro et al., 2017). Performance on visual tracking tests may also depend strongly on fixation, attention, naming and task understanding, not only on the mechanics of the eyes (Tanke et al., 2021). It is therefore inappropriate to promise that eye exercises will prevent or cure dyslexia.

Teachers can still support functional visual behavior. Useful practices include uncluttered materials, adequate print size, strong contrast, short lines for beginners, a finger or card used as a temporary guide and planned changes of focus between near and far targets. Children may follow a slowly moving object, locate symbols in a horizontal array or point to pictures in sequence, provided the activity is brief and followed by reading. Complaints of double vision, headaches, frequent loss of place, unusual head posture or persistent visual discomfort warrant professional assessment. Educational support and clinical care should complement rather than replace one another.

Multisensory letter learning and handwriting

A multisensory approach is not simply the use of many attractive materials. It is the coordinated presentation of the same learning target through compatible channels. For a new letter, the child sees the form, hears its sound, says the sound, feels or constructs the form, writes it and then identifies it in words. The teacher maintains a stable verbal cue for the starting point and movement direction. This consistency helps the child notice what remains invariant across different sizes, colours, textures and examples.

Handwriting has a distinctive role in symbol learning because it requires the learner to generate a form rather than merely select or view it. Studies with pre-literate children indicate that handwriting experience can influence neural activation during letter perception and can support later recognition

(James and Engelhardt, 2012). Handwritten forms are naturally variable and learning to recognize the letter across one's own imperfect productions may help build a flexible category of what the symbol can look like (Li and James, 2016). Comparisons of handwriting and typing likewise suggest that forming letters by hand can provide advantages for letter recognition, spelling or early literacy under some conditions (Kiefer et al., 2015; Longcamp et al., 2005; Ouellette and Tims, 2014).



Figure 3: Multisensory pathways for learning letter forms through movement, touch, construction, writing, and object matching. Source: Author's own photograph.

The appropriate conclusion is not that keyboards are harmful or that every child must produce perfect penmanship before reading. Digital tools can increase access, reduce transcription demands and support children with motor difficulties. Rather, beginning instruction should preserve meaningful opportunities to form letters by hand, while adapting tools, surface, size and required quantity. A child may first trace a large form in the air, shape it with clay, draw it in sand, construct it from sticks, write it on a vertical board and finally produce it on paper. Each transition should include the letter sound and should culminate in recognition within real words.

Motor-enriched encoding can improve early letter recognition when the movement is directly related to the symbol being learned (Damsgaard et al., 2020). Broader physical education programmes may also support motor and pre-literacy development, but findings from small or non-randomized studies should be treated as promising rather than definitive (Battaglia et al., 2019). The classroom criterion is therefore specificity: jumping randomly before a letter task may change alertness, while walking the letter path, saying the sound at the turning point and then writing the same form creates a clearer learning connection.

Fine-motor work should be brief, purposeful and free from unnecessary perfectionism. Manipulating pegs, tongs, clay, buttons, blocks or cards can strengthen control and endurance, but it should not delay access to authentic literacy. A five-year-old does not need months of generic pre-writing patterns before encountering meaningful letters. The teacher can develop motor control and teach print concurrently, adjusting the size and tool so that the child can experience success.

From sound awareness to syllables, words, sentences and meaning

Body preparation is only valuable if it leads into the architecture of literacy. Children need to notice that spoken words can be analyzed into smaller sound units and that letters represent those units. Phonological awareness, particularly at the phoneme level, and letter-sound knowledge have a causal role in learning to read (Hulme et al., 2012; Melby-Lervag et al., 2012). Instruction should therefore include listening for initial and final sounds, blending, segmenting and mapping sounds onto graphemes. Oral activities can be accompanied by movement, but the movement should make the sound structure more visible: one step for each phoneme, one counter for each sound or one hand movement as sounds are blended together.

In Slovenian, simple consonant-vowel syllables provide an efficient bridge from isolated correspondences to connected reading. Once children know the relevant letters and sounds, the teacher can model continuous blending rather than allowing a long pause between sounds. Familiar syllables are combined into words, words into short sentences and sentences into meaningful messages. The progression should be cumulative: texts use mostly correspondences that have already been taught, while oral language and picture discussion can remain richer than the decodable print itself.

Meaning must be present from the beginning. Decoding an unfamiliar sequence is an essential skill, but reading is not complete until the child knows what was communicated. After reading a word or sentence, the teacher can ask the child to select a matching object, act out the message, explain it, draw it or connect it with personal experience. This avoids a false choice between phonics and comprehension. Accurate decoding opens the door to meaning; vocabulary and oral language allow the child to walk through it.

The sequence should also include spelling. Asking the child to build or write a word from heard sounds strengthens the bidirectional relationship between reading and writing. The teacher can dictate a familiar syllable, guide segmentation and then compare the child's production with the printed form. Errors become information: a missing sound may indicate segmentation difficulty; a reversed form may require a clearer motor cue and a correct oral response with slow visual recognition may call for more cumulative retrieval practice.

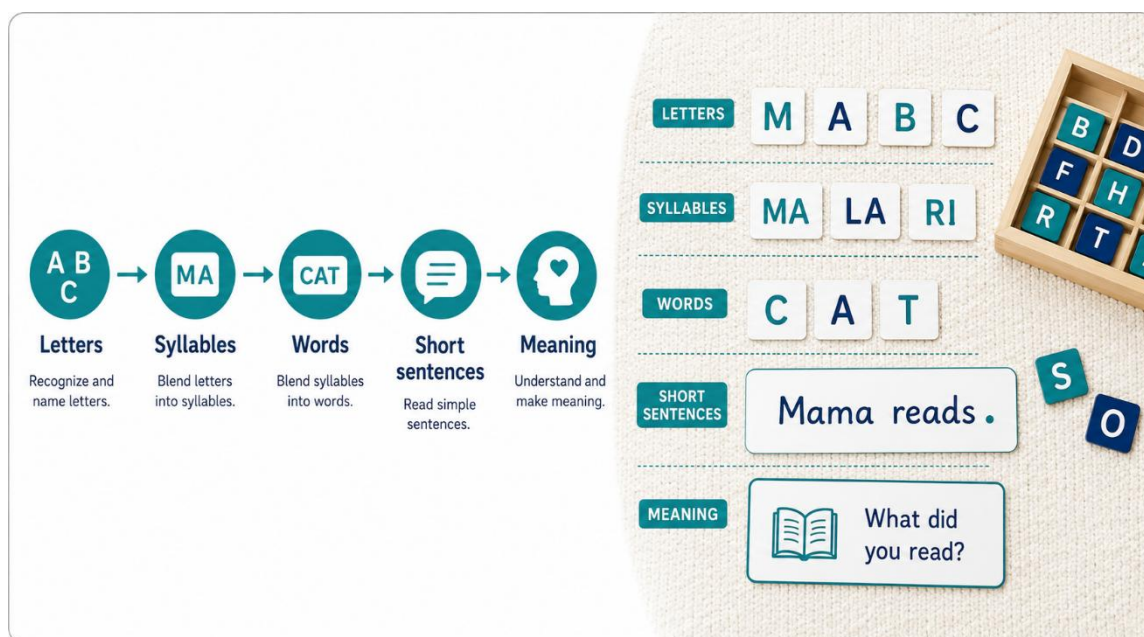


Figure 4: A scaffold from familiar letters and syllables to words, short sentences and meaning. Image is created in Canva.

A twenty-minute Body-Voice-Letter-Word sequence

The following example demonstrates how bodily preparation and explicit literacy teaching can form one coherent lesson. It is written for a first-grade group learning the letter M and the sound /m/, but the structure can be adapted. The sequence is intentionally short so that movement supports rather than displaces instruction.

Time	Phase	Teacher and learner actions
2 min	Regulate and orient	Children press both feet into the floor, lengthen the spine, relax the shoulders, open and close the hands, and take two quiet breaths. The teacher names the goal: hear, say, write, and read /m/.
3 min	Move and listen	Children march slowly while the teacher says a mixture of words. They stop and place both hands on the abdomen when a word begins with /m/. The teacher immediately checks the sound orally without movement.
3 min	Form the letter	The teacher models uppercase and lowercase M, naming the starting point and direction. Children trace the form in the air, shape it with two or three materials, and say /m/ during each formation.
4 min	Write and retrieve	Children write a small number of carefully formed letters on a vertical surface and then on paper. Between attempts, they point to M among distractor letters and state the sound. Quantity is adjusted to motor endurance.
4 min	Blend and build	Using known letters, children blend MA, MI, and MO, then construct one or two familiar words. They slide a finger beneath the letters as the sounds are blended without long pauses.
3 min	Read for meaning	Children read a short decodable sentence containing known correspondences. They match it to a picture or act it out and answer one simple meaning question.
1 min	Exit check	Each child identifies M, gives /m/, writes or traces it once, and reads one taught syllable. The teacher records who need a different cue or more practice.

Table 1: Example of an integrated twenty-minute literacy sequence.

The exit check is a critical part of the sequence. Enjoyment, participation and attractive products do not reveal whether the target was learned. The teacher needs a very small independent sample: Can the child recognize the letter without the material? Can the child recall its sound after a brief delay? Can the child form it or select it in a word? These observations guide the next lesson. A learner who succeeds during movement but not on paper may need a more explicit bridge, while a learner who decodes accurately but cannot explain the sentence may need vocabulary and oral language support.

Cumulative review should be built into every new sequence. The letter M is mixed with previously taught letters, syllables are revisited across days and words return in new short sentences. Retrieval should gradually become less dependent on color, texture, gesture or teacher prompting. Supports are successful when they help the child reach independent and flexible use, not when the child can respond only within the original activity.

Observation, formative assessment, and responsive planning

A body-informed literacy lesson should be evaluated through literacy evidence rather than through the appearance of engagement alone. A child may participate enthusiastically in a movement game yet remain uncertain about the target sound, while another may choose minimal movement and still demonstrate secure learning. Formative assessment therefore focuses on what the learner can recognize, recall, produce, read and explain after the support is reduced. The teacher observes both the final response, and the amount of prompting required to obtain it.

A concise observation record can follow five questions. First, can the child regulate sufficiently to enter the task, and which environmental adjustment helps? Second, can the child discriminate and retrieve the target sound? Third, can the child recognize the grapheme among visually similar alternatives? Fourth, can the child form it with a workable movement pattern? Fifth, can the child use

the correspondence in blending, spelling and meaningful reading? These questions prevent a common error: interpreting slow pencil control as weak phonological knowledge or, conversely, assuming that neat copying demonstrates reading.

The pattern of response to support is often more informative than a single score. When performance improves after visual clutter is reduced, the teacher can simplify the page while continuing to teach the same content. When the child remembers the sound after saying and writing it but not after touching a textured letter, the less effective support can be discontinued. When recognition remains inconsistent across several well-taught sessions, the child may need smaller teaching steps, more cumulative retrieval and a closer review of hearing, speech-language, attention or visual access. Classroom observations do not diagnose a disorder, but they make referral conversations more precise.

Progress should be judged over time and across contexts. Useful evidence includes a brief letter-sound check, a dated handwriting sample, one dictated syllable or word, a short decoding item and a simple meaning question. The collection need not be burdensome. A rotating focus on a few children each day allows the teacher to identify who is becoming independent and who remains dependent on color, gesture, modelling or peer imitation. The next lesson can then retain the successful cue, change the ineffective one or increase direct practice.

Collaboration strengthens interpretation. Classroom teachers, special educators, speech-language specialists, occupational therapists, psychologists and families may observe different aspects of the same learner. Shared language is more useful than broad labels such as *"not ready."* Descriptions such as *"recognizes M in isolation but loses it in a four-letter array"* or *"segments two sounds orally but cannot yet record both"* lead to clearer decisions. The aim is not to make the child pass a readiness test before reading instruction; it is to adjust instruction while preserving immediate access to meaningful literacy.

Inclusive use with neurodiverse and multilingual learners

Neurodiverse learners may differ in sensory thresholds, motor planning, attention, language processing and tolerance for uncertainty. Inclusion does not require every child to perform the same movement. A child may watch, point, trace with a tool, work seated, use a larger surface or take fewer repetitions. The teacher should explain the purpose, offer predictable choices and avoid forced touch, rapid spinning, loud stimulation or public comparison. Sensory activities are supports, not rewards that must be earned after compliance.

For multilingual learners, the distinction between conceptual knowledge and knowledge of the instructional language is essential. A child may understand the concept represented by a picture but not know its Slovenian name or may hear a phoneme differently because it is not contrastive in the home language. Teachers can preview vocabulary with real objects and gestures, invite the use of the home language when useful, articulate the target sound clearly and compare mouth position without presenting an accent as a deficit. Repeated sentence frames and partner rehearsal reduce linguistic load while preserving high expectations.

Universal design principles strengthen the approach for the whole class: visible lesson steps, concise instructions, models that remain available, several ways to respond and materials that reduce rather than increase visual clutter. Children who need intensive intervention still require structured, cumulative teaching delivered with sufficient frequency. A lively multisensory whole-class lesson is not automatically an adequate intervention for dyslexia or a developmental language disorder.

Professional boundaries and the responsible use of artificial intelligence

Embodied and multisensory literacy is vulnerable to neuromyths. Claims that a particular movement switches on a brain area, integrates an unused hemisphere, eliminates primitive reflexes in all learners or cures reading disorders should not guide school practice without strong evidence. Teachers can use movement because it supports attention, participation, motor experience and

meaningful encoding, while remaining honest about the limits of current research. The question is not whether an activity sounds neuroscientific, but whether it is safe, inclusive, linked to the learning goal, and followed by observable literacy practice.

The illustrations in this article were produced with the assistance of generative artificial intelligence and subsequently edited for clarity. Such images can communicate a sequence quickly, but they can also contain inaccurate anatomy, malformed letters, inconsistent hands, implausible objects, or culturally narrow representations. They should therefore be treated as conceptual teaching visuals rather than scientific evidence. A teacher or author remains responsible for checking every label, removing misleading details, protecting children's privacy and disclosing AI assistance transparently.

The same principle applies when AI is used to prepare differentiated reading materials. Generated text must be checked for age appropriateness, linguistic accuracy, taught grapheme-phoneme correspondences, vocabulary, bias and factual correctness. No child data should be entered into an external system without an authorized basis and suitable safeguards. Technology can accelerate preparation, but professional judgement determines whether the result belongs in the classroom.

Conclusion

Beginning literacy is learned through explicit encounters with spoken language, print, writing and meaning, yet these encounters are carried out by a developing body. Regulation, posture, movement, gaze, hand control, attention, memory, speech and visual recognition interact whenever a child reads or writes. Purposeful preparation can reduce avoidable demands and invite active participation, especially for learners who need more time, more sensory clarity or more than one route into the task.

The most defensible approach is an integrated one. A brief bodily routine is followed immediately by a clearly stated literacy goal. Movement is connected to sound structure or print direction. Multisensory exploration leads to handwriting and recognition. Letter-sound knowledge leads to blending, spelling, words, sentences and comprehension. Independent exit checks reveal whether learning occurred, and supports are gradually faded as retrieval becomes automatic.

Teachers should also maintain clear boundaries. Movement does not replace phonics; eye exercises do not cure dyslexia, and a colorful brain image does not prove a classroom claim. When evidence is mixed, professional language should remain measured. When difficulties persist, families and teachers should seek appropriate assessment. Within these boundaries, preparing the body is not an additional programme competing for time. It is a way of organizing the first minutes of instruction so that more children can listen, act, write, read and understand.

References

- Battaglia, G., Alesi, M., Tabacchi, G., Palma, A., & Bellafiore, M. (2019). The development of motor and pre-literacy skills by a physical education program in preschool children: A non-randomized pilot trial. *Frontiers in Psychology*, 9, 2694. <https://doi.org/10.3389/fpsyg.2018.02694>
- Blair, C., & Raver, C. C. (2015). School readiness and self-regulation: A developmental psychobiological approach. *Annual Review of Psychology*, 66, 711-731. <https://doi.org/10.1146/annurev-psych-010814-015221>
- Borleffs, E., Maassen, B. A. M., Lyytinen, H., & Zwarts, F. (2017). Measuring orthographic transparency and morphological-syllabic complexity in alphabetic orthographies: A narrative review. *Reading and Writing*, 30, 1617-1638. <https://doi.org/10.1007/s11145-017-9741-5>
- Cameron, C. E., Brock, L. L., Murrah, W. M., Bell, L. H., Worzalla, S. L., Grissmer, D., & Morrison, F. J. (2012). Fine motor skills and executive function both contribute to kindergarten achievement. *Child Development*, 83(4), 1229-1244. <https://doi.org/10.1111/j.1467-8624.2012.01768.x>
- Castles, A., Rastle, K., & Nation, K. (2018). Ending the reading wars: Reading acquisition from novice to expert. *Psychological Science in the Public Interest*, 19(1), 5-51. <https://doi.org/10.1177/1529100618772271>
- Damsgaard, L., Elleby, S. R., Gejl, A. K., Malling, A. S. B., Bugge, A., Lundbye-Jensen, J., Poulsen, M., Nielsen, G., & Wienecke, J. (2020). Motor-enriched encoding can improve children's early letter recognition. *Frontiers in Psychology*, 11, 1207. <https://doi.org/10.3389/fpsyg.2020.01207>
- Dehaene, S., & Cohen, L. (2007). Cultural recycling of cortical maps. *Neuron*, 56(2), 384-398. <https://doi.org/10.1016/j.neuron.2007.10.004>

- Dehaene, S., & Cohen, L. (2011). The unique role of the visual word form area in reading. *Trends in Cognitive Sciences*, 15(6), 254-262. <https://doi.org/10.1016/j.tics.2011.04.003>
- Ehri, L. C. (2014). Orthographic mapping in the acquisition of sight word reading, spelling memory, and vocabulary learning. *Scientific Studies of Reading*, 18(1), 5-21. <https://doi.org/10.1080/10888438.2013.819356>
- Erbeli, F., & Joshi, R. M. (2022). Simple view of reading among Slovenian English foreign language learners: A latent interaction modeling approach. *Learning and Individual Differences*, 93, 101958. <https://doi.org/10.1016/j.lindif.2020.101958>
- Foorman, B. R., Beyler, N., Borradaile, K., Coyne, M., Denton, C. A., Dimino, J., Furgeson, J., Hayes, L., Henke, J., Justice, L., Keating, B., Lewis, W., Sattar, S., Streke, A., Wagner, R., & Wissel, S. (2016). Foundational skills to support reading for understanding in kindergarten through 3rd grade (NCEE 2016-4008). National Center for Education Evaluation and Regional Assistance, Institute of Education Sciences, U.S. Department of Education.
- Grismer, D., Grimm, K. J., Aiyer, S. M., Murrah, W. M., & Steele, J. S. (2010). Fine motor skills and early comprehension of the world: Two new school readiness indicators. *Developmental Psychology*, 46(5), 1008-1017. <https://doi.org/10.1037/a0020104>
- Hulme, C., Bowyer-Crane, C., Carroll, J. M., Duff, F. J., & Snowling, M. J. (2012). The causal role of phoneme awareness and letter-sound knowledge in learning to read: Combining intervention studies with mediation analyses. *Psychological Science*, 23(6), 572-577. <https://doi.org/10.1177/0956797611435921>
- James, K. H., & Engelhardt, L. (2012). The effects of handwriting experience on functional brain development in pre-literate children. *Trends in Neuroscience and Education*, 1, 32-42. <https://doi.org/10.1016/j.tine.2012.08.001>
- Kiefer, M., Schuler, S., Mayer, C., Trumpp, N. M., Hille, K., & Sachse, S. (2015). Handwriting or typewriting? The influence of pen- or keyboard-based writing training on reading and writing performance in preschool children. *Advances in Cognitive Psychology*, 11(4), 136-146. <https://doi.org/10.5709/acp-0178-7>
- Li, J. X., & James, K. H. (2016). Handwriting generates variable visual input to facilitate symbol learning. *Journal of Experimental Psychology: General*, 145(3), 298-313. <https://doi.org/10.1037/xge0000134>
- Longcamp, M., Zerbato-Poudou, M. T., & Velay, J. L. (2005). The influence of writing practice on letter recognition in preschool children: A comparison between handwriting and typing. *Acta Psychologica*, 119(1), 67-79. <https://doi.org/10.1016/j.actpsy.2004.10.019>
- Macdonald, K., Milne, N., Orr, R., & Pope, R. (2018). Relationships between motor proficiency and academic performance in mathematics and reading in school-aged children and adolescents: A systematic review. *International Journal of Environmental Research and Public Health*, 15(8), 1603. <https://doi.org/10.3390/ijerph15081603>
- Melby-Lervag, M., Lyster, S.-A. H., & Hulme, C. (2012). Phonological skills and their role in learning to read: A meta-analytic review. *Psychological Bulletin*, 138(2), 322-352. <https://doi.org/10.1037/a0026744>
- Ouellette, G., & Tims, T. (2014). The write way to spell: Printing vs. typing effects on orthographic learning. *Frontiers in Psychology*, 5, 117. <https://doi.org/10.3389/fpsyg.2014.00117>
- Semeraro, C., Coppola, G., Cassibba, R., & Lucangeli, D. (2019). Teaching of cursive writing in the first year of primary school: Effect on reading and writing skills. *PLOS ONE*, 14(2), e0209978. <https://doi.org/10.1371/journal.pone.0209978>
- Tanke, N., Barsingerhorn, A. D., Boonstra, F. N., & Goossens, J. (2021). Visual fixations rather than saccades dominate the developmental eye movement test. *Scientific Reports*, 11, 1162. <https://doi.org/10.1038/s41598-020-80870-5>
- Vinuela-Navarro, V., Erichsen, J. T., Williams, C., & Woodhouse, J. M. (2017). Saccades and fixations in children with delayed reading skills. *Ophthalmic and Physiological Optics*, 37(4), 531-541. <https://doi.org/10.1111/opo.12392>