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Sensorigenesis and Educational Therapy for Children with Neurodevelopmental Disorders

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Abstract

Neurodevelopmental disorders (NDDs) affect sensory, cognitive, and motor functions, thereby impairing learning and self-regulation. This paper introduces sensorigenesis as a four-phase therapeutic framework (motoric, graphic, orthographic, symbolic-linguistic) to guide educational therapy (EdTx) by aligning interventions with neural and sensory development. Sensory subtyping also helps tailor support for children with varying sensory responses. The approach emphasizes interdisciplinary collaboration to improve developmental outcomes and uphold cultural responsiveness and dignity in therapeutic education.

Keywords: Sensorigenesis, neurodevelopmental disorders, educational therapy, sensory integration

Introduction

Neurodevelopmental disorders (NDDs) affect multiple domains of development. It encompasses a heterogeneous group of conditions which includes intellectual disability (ID) and more specific domains such as attention-deficit hyperactivity disorder (ADHD), autism spectrum disorder (ASD), communication disorders (CD), specific learning disorder (SLD), and motor disorders (MDs), including tics and stereotypic movement disorders [1]. These conditions are typically identified before age 18 and affect several functions of brain development, which include cognition, motor control, emotional regulation, and sensory processing. NDDs are often chronic and underdiagnosed in many children. Children with NDDs may meet criteria for more than one condition, increasing the complexity of intervention planning [1]. The co-occurrence with other conditions makes NDDs more complex, as they commonly disrupt a child's educational progress, behavioural self-regulation, and social relationships. For some children with NDDs, symptoms improve or shift with age, while the difficulties remain lifelong for others [2].

Reported prevalence estimates include ID (0.63%), ADHD (5–11%), ASD (0.70–3%), SLD (3–10%), CDs (1–3.42%), and MDs (0.76–17%) [1]. Although extensive research exists on specific disorders, fewer studies have examined their shared neurological and sensory underpinnings.

Sensory processing forms the neurobiological foundation for learning and behavioural regulation. Genetic and developmental research shows that variations in genetic expression can reorganise sensory pathways, suggesting the influence of neural organisation, function, and plasticity across multiple sensory systems [3]. Genetic susceptibility often interacts with prenatal and environmental factors such as maternal stress, smoking, and exposure to toxins like lead and phthalates [3]. Pregnant mothers who are exposed to such toxins are at risk of having children who may potentially develop NDDs [4]. The gene–environment interaction shows the multifactorial aetiology of NDDs such as ADHD and ASD, where both are frequently associated with atypical sensory processing profiles that affect learning and adaptive behaviour [3,4]. These findings support sensory-integration-based approaches as a core component of intervention.

In child development, multisensory processing and sensorimotor experiences shape both learning and behaviour. Mental processes such as cognition, conation, and affect are interconnected through the sensory system, in which sensory input, neural processing, and motor output influence one another [2]. The integration of senses is dynamic, allowing a child's brain to adapt and respond to changing environments in real time. The connection between multisensory processing and sensorimotor will enable children to stay regulated, sustaining attention, motivation, and cognitive endurance.

As children mature, multisensory spatial processing becomes more refined through experience, allowing faster perceptual decisions and more efficient integration of sensory information [5]. However, children with NDDs often exhibit under- or over-responsiveness to sensory stimuli in one or more of their seven senses: visual, auditory, olfactory, gustatory, kinesthetic, proprioceptive, and vestibular. Children with NDDs who experience atypical sensory functioning may develop either sensory-seeking (e.g., flapping, spinning) or sensory-avoiding behaviours (e.g., food or touch). Sensory-integration-based interventions, therefore, aim to strengthen the brain's capacity to organise and respond to multisensory input effectively [6].

In this paper, I propose *sensorigenesis* as a developmental and therapeutic approach for Educational therapists (ETs) to support children with NDDs who exhibit atypical sensory processing. The concept emphasises the use of developmentally appropriate activities to stimulate sensory receptors, which convert environmental stimuli into electrical signals that guide neural communication [7]. Sensory signals shape synaptic refinement and myelination, strengthening neural networks across the brainstem and cortex, allowing the retention and integration of information and forming the foundation for integrated learning and self-regulation. For children with NDDs, disruptions in these processes can delay learning and place greater demands on compensation, increasing learning vulnerability.

Educational therapy (EdTx) provides an integrative framework that connects neuroscience with structured, child-centred assessment and intervention [2] to enable adaptive and persistent learning behaviours for children with

NDDs. Through the lens of sensorigenesis, ETs can align sensory and cognitive activities to a child's stage of neural readiness, supporting gradual mastery across domains of perception, language, and self-regulation.

Sensorigenesis in Educational Therapy

Educational therapy (EdTx) is a 'treatment approach that delivers structured and evidence-based measures designed to address psycho-educational and psycho-behavioral challenges' in children [8]. It bridges education, therapy, and neuroscience by utilizing medical and child development knowledge to deliver tailored, goal-oriented interventions aligned with each child's neurodevelopmental profile.

The aim of EdTx with children with NDDs is to strengthen a child's capacity to regulate sensory functions while remaining adaptable within learning environments. This process involves activating and reinforcing neural systems responsible for sensory perception, planning and modulation [2]. For children with NDDs, these functions are often compromised by under activation or dysregulation in specific neural circuits. By applying structured, multisensory strategies, ETs promote self-direction, independence, and engagement in learning—functions usually neglected in purely cognitive or behavioral programs.

The sensorigenesis conceptual model is based on the literature on multisensory development, sensory integration, and neuroplasticity [9, 12] and is applied as a developmentally aligned approach for EdTx. It allows ETs to select therapeutic strategies that align with the child's current neurosensory readiness. These strategies function as sensory-informing actions that support adaptive responses for daily life. This includes basic self-care tasks like feeding and grooming, as well as more complex skills such as building objects, accomplishing practical goals, or handling work-related activities [11].

In early childhood, the brain's sensorimotor networks matured before the associative and prefrontal cortices. This foundational development is essential, as it later supports socioemotional and executive function skills, like planning and attention [10]. The brainstem and the early sensory pathways establish the initial framework for the later integration of information in the telencephalon [6]. Meanwhile, our multisensory systems continue to develop and refine through experience-dependent plasticity, a process that spans from infancy well into adolescence [11]. The neural basis of sensory integration also shows that synaptic refinement and rhythmic coordination within sensory networks enable dynamic interactions among perception, emotion, and movement [12].

Phases of Sensorigenesis

Sensorigenesis is structured into four developmental phases that mirror the hierarchical maturation of the nervous system from primary sensory to higher association cortices. The phases are (i)motoric, (ii) graphic, (iii) orthographic, and (iv) symbolic–linguistic. Each phase represents a functional milestone linking sensory processing, motor control, and cognition. In the motoric phase, tactile, vestibular, and proprioceptive systems organise postural and body awareness, forming the foundation for coordinated movement and attention. The graphic phase marks the emergence of visual–motor integration as parietal and cerebellar regions synchronise to support intentional control of drawing and shape formation. In the orthographic phase, cerebello-cortical pathways help automate fine-motor writing sequences, hence reducing cognitive effort and allowing the child to focus more on planning and composing ideas. The symbolic–linguistic phase builds on this foundation, drawing on temporoparietal and prefrontal networks that support abstract thinking, language processing, and executive control.

ETs can observe and screen areas such as arousal regulation, postural control, visual–motor integration (VMI), handwriting automaticity, and sound–symbol mapping to determine a child's developmental phase and track progress within this framework [13, 15]. These practices reflect evidence that functional connectivity develops along a sensorimotor-to-association pathway, in which early sensory and motor experiences form the foundation for later language and executive functioning [16, 18]. The model allows ETs to match interventions to neural readiness and use developmental sequencing to take advantage of periods of heightened neuroplasticity.

1. **Motoric Phase:** Exploration and Sensory Mapping The motoric phase is closely associated with sensorimotor development in infants and young children from birth to approximately 18 to 24 months. Infants and young children depend on tactile, proprioceptive, and vestibular inputs to establish early sensorimotor loops to develop body schema and balance. The vestibular system contributes to early multisensory and motor integration [19], while proprioceptive feedback rapidly organises to stabilise postural control and coordinate movement [20,21]. The brainstem sensory systems, especially the trigeminal, vestibular, and auditory pathways, establish early neural circuits that integrate with higher cortical areas and support more complex learning [22]. The brainstem also has a key role in regulating dopaminergic activity, which shapes arousal levels, motivation, and hormonal balance throughout development [2]. These pathways influence reward anticipation and sensory processing [2, 23].

2. **Graphic Phase:** Representation and Visual–Motor Integration The Graphic Phase typically emerges between the ages of three and six. As visual and proprioceptive systems mature, children begin to exercise purposeful control over hand movements. Having reasonable hand control enables children to reproduce dots, lines, and simple shapes that serve as precursors to handwriting. Random scribbles gradually develop into intentional forms, and children become able to copy circles, straight lines, and, over time, more complex patterns. Children also begin forming pre-writing strokes (e.g., horizontal, vertical, and diagonal lines, including crosses) as their visual and motor skills integrate. This process, called Visual-Motor Integration (VMI), is essential for building a child's pre-writing and object-manipulation skills and lays the foundation for early reading and math skills [24]. Interventions targeting VMI skills can significantly improve the accuracy and coordination of Children with NDDs [25].

3. **Orthographic Phase:** Automatization of Fine-Motor Control The Orthographic Phase typically appears in the early to middle primary years, around six to nine

years of age. During this period, handwriting pace transitions from slow, effortful movements to smoother, more automatic letter formation. Writing becomes rhythmic and bilateral, supported by cerebello-cortical and premotor pathways that allow one hand to stabilise the page while the other writes. As children gain speed and accuracy in handwriting, they need far less mental effort to form letters. When writing becomes automatic, overall cognitive load decreases, freeing working memory to support planning, spelling, building sentences, and generating ideas rather than focusing on motor movements. [26,27]. Handwriting fluency also strengthens letter recognition, which contributes to the development of reading and spelling. In contrast, typing does not yield the same neural benefits associated with handwriting practice [28].

4. **Symbolic Linguistic Phase:** Cognitive and Linguistic Integration This phase is typically seen between seven and ten years of age, when handwriting has become fluent and motor sequences are largely automatic. As writing requires less effort, children have more capacity to focus on language. They can expand their vocabulary, build more complex sentences, understand texts more deeply, and express their ideas with greater ease. During this period, grapheme–phoneme associations are established as the brain undergoes rapid learning-related changes in the dorsal–temporal pathways that support reading and language comprehension. [29]. With ongoing practice, children's reading fluency and spelling become accurate, and they use multisensory information more flexibly as the brain coordinates activity across different sensory pathways [30]. Effective literacy interventions at this stage can produce measurable functional and structural neuroplasticity across core language networks [31].

These four phases illustrate how neural complexity develops from ideation and motor planning to task execution and abstract thinking [11]. Brain development follows an overlapping trajectory that begins with primary sensory and motor maturation, advances through socio-emotional networks, and culminates in higher-order cognitive and executive control [18,19]. Functional networks mature hierarchically, from sensory and motor systems to socio-emotional and executive control networks. These developments happen from childhood through adolescence [16, 18, 32]. Efficient sensory processing supports core cognition.

When sensory processing is efficient, children often show stronger working memory, quicker processing speed, and better cognitive stamina. In contrast, children with neurodevelopmental conditions who experience sensory modulation difficulties usually present with fatigue, slower processing, and working memory vulnerabilities [11,33,34]. Heightened sensory reactivity—whether in the form of hypersensitivity or the strain of sustained listening—can drain cognitive resources and reduce the ability to maintain attention over time [23]. At the same time, research shows that multisensory approaches to working-memory tasks can help children manage distraction and maintain better control over their learning processes [24].

In contrast, multisensory working-memory encoding can improve control over memory-driven distraction in children with NDDs [24]. EdTx, therefore, provides developmentally aligned, multisensory pathways that stabilise arousal, enhance learning readiness, and strengthen higher cognition.

Applying Sensorigenesis in Educational Therapy

In EdTx with children with NDDs, sensorigenesis can be applied through two complementary pathways: (i) phase-based therapeutic progression and (ii) sensory-subtyping intervention. The phase-based approach follows a developmental sequence that supports the child's ability to perceive information, plan, and execute daily tasks. It also supports their ability to carry out these actions, reinforcing the sensory groundwork needed for learning and everyday tasks (see Table 1)

Sensory-subtyping intervention, on the other hand, addresses the modulation patterns often seen in these children, such as hypersensivity (being over-responsive), hyposensitivity (being under-responsive), or a mixed profile (see Table 2). By planning interventions that match each child's sensory profile and stage of readiness, educational therapists can shape multisensory experiences that encourage neural pruning, promote plasticity, and support meaningful functional gains [13,16,18].

1. Phase-Based Therapeutic Progression

In the Motoric Phase (Phase 1), therapy focuses on proprioceptive and vestibular input to establish postural control, bilateral coordination, and sustained attention. Balance exercises, rhythmic swinging, and guided drawing tasks are used to stabilise arousal and integrate sensory feedback. This approach is consistent with findings that sensorimotor training enhances neural connectivity and self-regulation in children with neurodevelopmental disorders (NDDs) [20,22]. Activities such as heavy-work circuits (e.g. pushing, pulling, lifting, or carrying) and rhythmic swinging help modulate arousal and improve attention span. These activities engage large muscle groups, provide deep pressure and joint compression, activating the brainstem and cerebellar pathways that help children achieve a calm y*et al*ert state. This regulation lays the groundwork for later visual–motor and cognitive tasks, which are essential for attention and learning readiness. To measure progress, ETs can take note of the settling latency (i.e. time taken for the child to become calm) and sustained attention (i.e. time taken for the child to maintain attention)

Progressing to the Graphic and Orthographic Phases (Phases 2–3), interventions refine fine-motor and visual–spatial integration. This will help the parietal regions, cerebellar timing systems, and the dorsal visual stream become more coordinated. ETs can now introduce handwriting readiness activities, tracing, and structured play to consolidate kinesthetic and visual feedback that underpin reading and writing skills. Repetitive word or sentence writing practice and pegboard sequencing help children build automaticity in their penmanship, allowing cognition to focus on comprehension and higher-level thinking [24–28]. Progress indicators, such as smoother stroke formation, longer sustained writing, and increased accuracy, reflect improvements in cerebello-cortical coordination.

Finally, in the Symbolic–Linguistic Phase (Phase 4), children rely more on temporoparietal and prefrontal areas that support sound–symbol mapping, verbal working memory, and literacy comprehension. Through multisensory spelling and phonological play, learners strengthen cognitive integration and linguistic fluency, demonstrating improved decoding and retention performance [29–31].

Table 1: Sensorigenesis Framework for Educational Therapy

Phase	Core Neural Systems	Typical Sensory Signals	Primary Therapy Goals	Example Activities	Progress Indicators
1. Motoric	Brainstem vestibular nuclei, spinal–cerebellar tracts	Hypo/hyper vestibular reactivity, poor body schema	Stabilise arousal and posture	Heavy-work circuits, rhythmic swinging, scooter-board play	Settling latency, sustained attention
2. Graphic Phase	Parietal visuospatial, cerebellar timing, dorsal visual stream	Poor visual tracking, low proprioceptive feedback	Calibrate eye–hand coordination	Guided drawing, tracing, and mazes	Smoother strokes, improvement in visual tracking time
3. Orthographic	Cerebello-cortical loops, premotor networks	Hand fatigue, variable pressure	Automate fine-motor rhythm	Pegboard sequencing, repetitive sentence writing	Word-per-minute rate, accuracy
4. Symbolic–Linguistic:	Temporoparietal and prefrontal area	Phoneme–grapheme difficulty, distractibility	Strengthen sound–symbol mapping, working memory	Multisensory spelling, phonological play	Improved decoding accuracy and retention

2. Sensory Subtyping-based intervention

Children with NDDs also exhibit sensory modulation disorders (e.g., hypersensitivity, hyposensitivity [11]). Some may also have mixed profiles depending on the environment they are in. Sensory modulation disorders may interfere with engagement in daily activities such as eating, grooming, and socializing. Understanding these subtypes allows ETs to match intervention intensity and environmental setup to each child's regulation needs, as summarized in Table 2. For example, learners who are hypersensitive often respond well to calming activities like deep pressure or gentle linear swinging in quieter spaces. In contrast, those who are hyposensitive usually need more stimulating inputs—such as rhythmic movement or simple obstacle courses—to stay engaged and focused. Children with mixed profiles may require alternating between sensorimotor and academic circuits to stabilize performance variability [25, 32].

Table 2: Sensory Subtyping-based intervention

Subtype	Regulation Focus	Environment Setup	Therapy Activities	Monitoring Focus
Hypersensitive	Down-regulate arousal	Calm lighting, predictable routine	Deep-pressure input, linear swinging	Reduced avoidance, faster settling
Hyposensitive	Alerting and orienting	Bright visuals, rhythmic movement	Obstacle courses quick-stop spins	Faster orientation, more extended engagement
Mixed	Stabilise dominant pattern	Flexible seating, visual schedules	Eye Tracking games (e.g. rolling ball Finger isolation, pencil grasp, Sound Discriminatory training Maze navigation activities using finger or pencil	Decreased variability, better tolerance

Discussion

Sensorigenesis integrates neuroscience, education, and therapeutic practice to address the sensory and cognitive challenges in children with NDDs. Early sensory and motor experiences play a crucial role in shaping the brain's development, gradually connecting motor, parietal, and prefrontal regions. These connections support higher-level thinking and learning abilities [7,16, 18]. By designing interventions that align with developmental patterns, ETs help build the neural foundation needed for self-regulation, attention, and flexible learning [5,13,31]. Structured therapeutic routines—such as activities that stimulate the vestibular or proprioceptive systems—provide timely sensory input that can strengthen neuroplasticity. This, in turn, strengthens executive functions such as planning, organisation, and impulse control, helping children with NDDs [19, 20, 22].

Using sensorigenesis as a therapeutic scaffold encourages ETs to capitalise on sensitive periods of neural readiness. During these windows, targeted sensory–motor activities stabilise neural circuits and optimise learning capacity. For example, proprioceptive and vestibular stimulation in the motoric phase supports body awareness and balance, which are foundational for literacy and numeracy development in later phases [19–21,25]. As children progress into the graphic and orthographic phases, structured handwriting and tracing exercises help strengthen cerebello-cortical coordination, resulting in smoother writing and better visual–motor control. [24–28]. Research also shows that handwriting practice supports letter recognition and reading fluency by coordinating visual and motor pathways. Developmental studies also show that handwriting practice strengthens letter recognition and reading fluency by coordinating visual and motor pathways [26, 27]. ETs can therefore use repetitive, rhythmic exercises to build cognitive endurance and neural efficiency during task execution.

Sensory-subtyping approaches enable ETs to tailor therapy to each child's sensory modulation profile. Children with NDDs who have hypersensitivity respond well to calming, predictable routines, while those with hyposensitivity benefit more from high-intensity, alerting activities. [25,32]. The ones with mixed profiles often require planned transitions between movement and academic activities to maintain balanced arousal and focused attention. This adaptive matching sensory input to individual profiles aligns with evidence showing that well-designed sensory environments improve regulation and participation when stimuli are intentionally calibrated to each child's needs [11, 28, 30].

An ecosystemic perspective adds further depth to this approach. Environmental deprivation, exposure to neurotoxins, and socio-economic barriers can disrupt neural development and widen disparities in learning outcomes [32]. These risks highlight the need for EdTx to take place in enriched, multisensory, and culturally responsive environments [3,4,32]. When ETs collaborate with educators, medical practitioners, psychologists, and allied health professionals, they can build comprehensive routines that integrate family partnership, movement-supported literacy work, and adaptable classroom design. Such interdisciplinary collaboration strengthens developmental outcomes and ensures that intervention plans reflect both cultural context and community realities.

Upholding dignity and cultural sensitivity is equally essential, particularly in contexts such as pediatric palliative care or specialized education. Intervention strategies must protect a child's sense of agency, identity, and emotional safety [2, 33]. By grounding assessment and intervention in neurodevelopmental findings, therapists can trace how sensory processing patterns influence motivation, affect regulation, and self-concept. These are domains that often influence school engagement and social belonging [2,33]. This perspective enhances the accountability of therapeutic decision-making while positioning the child as an active, respected participant in their own learning process.

Together, these findings affirm EdTx as both a developmental and rehabilitative practice grounded in neuroscience. By using sensorigenesis as a guiding framework, ETs can map therapeutic goals onto the brain's natural maturation sequence—progressing from sensory regulation to abstract cognition. This integrated approach allows Edtx to reduce symptoms of atypical sensory behaviors but also support long-term cognitive resilience and meaningful learning progress. When sensorigenesis principles are embedded in early-intervention and school-based programs, ETs and stakeholders are better equipped with knowledge and skills to support children with NDDs and nurture each child as a confident learner.

Conclusion

Sensorigenesis offers a cohesive framework for understanding and supporting children with NDDs by linking interventions to stages of sensory and neural development. This provides ETs with a clear pathway to help children move from sensory modulation to more complex cognitive skills while staying grounded in developmental principles. Using neurological tools and sensory profiles also sharpens clinical decision-making and makes progress easier to monitor.

From this perspective, Edtx becomes both a developmental and rehabilitative field, connecting insights from neuroscience, education, and clinical practice. When sensorigenesis-informed approaches are integrated into therapy services and school systems, they can strengthen public health responses to neurodiversity, expand access to meaningful support, and affirm every child's right to learn and grow with dignity. As with many sensory-based interventions, however, further single-subject and case-based research is needed to document intervention procedures clearly and support replicability.

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