Research Review
EDUCATIONAL SERIES™

Multi-sensory stimulation and infant development

About the Experts

Dr Nandini Mundkur

MBBS MD (Pediatrics) Delhi University

Dr. Nandini Mundkur is a developmental pediatrician based in Bangalore and is considered one of the pioneers in developing this specialty for the Indian Academy of Pediatrics who she now advises on the development of guidelines for pediatricians in ASD, Learning disorders and ADHD.

She currently practices in Bangalore where she is the Director of Center for Child Development & Disabilities (CCDD), a referral centre for developmental disorders, with a wide referral rate from South Asian regions, and has regularly conducted workshops and seminars on various topics in development disorders throughout India.

Dr Nandini has published a number of papers and authored books on developmental pediatrics including *Your Child - Parents guide to First Five years of Life and Bring up Baby from Birth to One year* and is the recipient of many awards.

She is also a Director of International Children's Peace council, which works on socio emotional learning in children and co-founder of totsguide.com an online child development portal.

Swati Popat Vats

B.Ed., M.A. (Sociology) Mumbai University, Honorary PhD (Education) Ecole Superiere Robert de Sorbon, France.

Swati Popat Vats is the founder President of Early Childhood Association India and President of Podar Education Network. She is also National representative for the World Forum Foundation. She has received many accolades and awards for her contribution to Early Childhood Education. She helped set up TATASKY's children's television activity channel-ACTVE WHIZKIDS. Swati is also the founder expert on the video based parenting website www.born-smart.com that helps parents understand and nurture brain development in the first 1000 days.

Swati has authored many books for parents and children and is a strong advocate of nature based learning in the early years and promotes brain research based teaching and parenting in her workshops across the globe. Swati tweets and blogs on education and parenting and can be followed @swatipopat or www.kiducationswatipvats.blogspot.in

The focus of this review is the science of sensory development and stimulation in neonates and infants, especially the importance of multisensory stimulation. The primary senses discussed are touch, hearing, vision, balance, and smell. This review is intended as an educational resource for primary healthcare professionals involved in neonatal and infant care development.

Introduction

Sensory development is a complex process involving both morphological and neurological components.[1,2] The basic physical structure of the sensory receptors develops early in pregnancy; however, most development of the senses occurs during the last 16-20 weeks of gestation, in response to *in utero* stimuli. The sensory systems then mature rapidly in the first year of life and continue to mature with time, experience, and brain maturation (**Figure 1**).[1,2] External experiences and stimulation of sensory systems via physical, chemical, and social/emotional environments play a key role in shaping the development of the infant brain.[2]

Experiences in early life are related to how successfully a child will perform socially, emotionally, and academically later in life,[3] and the brain is more responsive to stimulation during the first three years of post-natal life than at any other stage of life.[4,5] For example, home-based developmental interventions during the first three years of life have been demonstrated to benefit cognitive development, including in children living in rural areas of India and Pakistan and in children from low- to middle-resource families.[6,7] In addition, early intervention programmes for pre term infants produce beneficial cognitive outcomes during infancy and persisting into childhood.[8]

Moreover, early life experiences influence gene expression, which in turn determines brain architecture.[9] Early life experiences also shape the development of lower level neural circuits upon which higher level circuits (that are responsible for more sophisticated mental functions) are dependent for the input of precise and high-quality information (**Figure 1**).[3,9] Low birth-weight infants have been shown to be at particularly high risk of neurosensory deficit and failure to thrive.[10]

The major influence that early life experiences and external stimuli have on brain and sensory system development underscores the important role of sensory stimulation in facilitating infant growth and development.

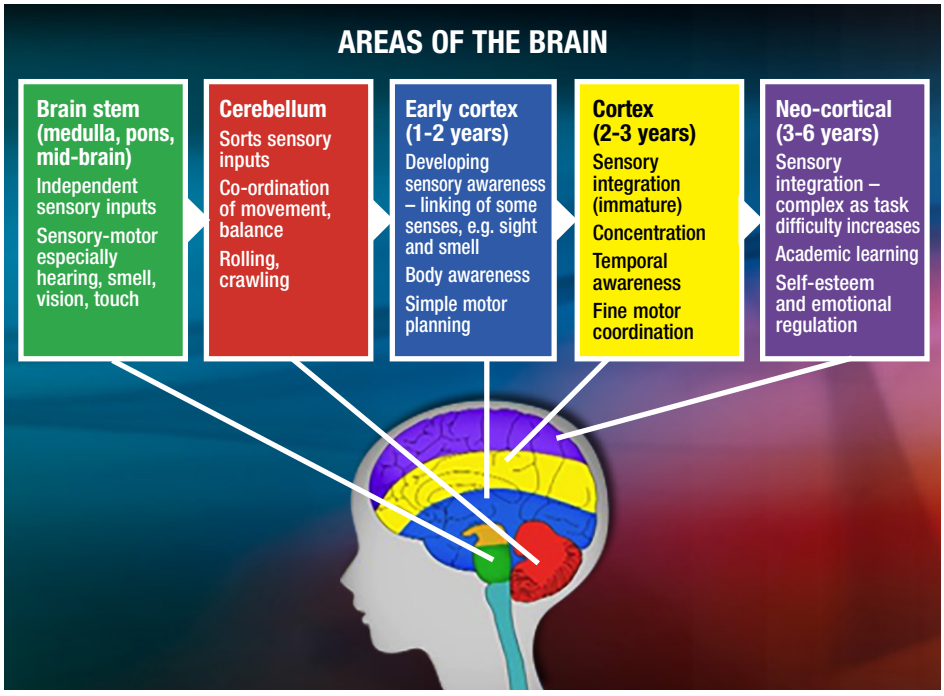

Figure 1. Sensory systems develop with time, experience, and brain maturation and higher level brain development is dependent on lower level development.[1-3,9]

Tactile sense (touch)

There is a connection between touch, the skin, and brain development, with the developing cerebral cortex being influenced by tactile (somatic) stimulation.[11] Maturing physiological, biochemical, and psychological functions are affected by touch.[12] The importance of tactile stimulation is emphasised by the WHO recommendation to provide skin-to-skin contact starting at birth to facilitate child development.[13]

Early mother-infant skin-to-skin contact has been demonstrated to reduce crying and benefit breastfeeding outcomes and cardio-respiratory stability in healthy new-born term infants, according to a meta-analysis of randomised trials that compared early skin-to-skin contact with standard care.[14]

Infant massage is a traditional practice on the Indian subcontinent, with the potential benefits including weight gain, a better sleep-wake pattern, improved neuromotor development, and enhanced emotional bonding.[15] Studies by Indian researchers have demonstrated that massage, mostly with oil, has benefits on growth in preterm and term infants,[16-20] with one randomized study suggesting that massage with oil produces greater growth benefits than massage without oil.[17] However, it is important to be aware that some oils can have a detrimental effect on neonatal skin barrier structure and function.[21,22]

In preterm infants, randomised controlled studies have shown that skin-to-skin contact via moderate-pressure massage can reduce stress behaviours in preterm infants[23] and facilitate weight gain.[24-26] Increased vagal activity, gastric motility, and insulin levels following moderate-pressure massage are possible mechanisms underlying the observed weight gain in preterm infants.[27]

Tactile stimulation is important throughout infancy as evidenced by developmental deficits in children raised in environments in which they were deprived of touch.[28]

Auditory sense (hearing)

Hearing is the most developed sense at birth and the first exposed to stimulation that drives development of the neural pathways.[1] Functional hearing develops at 25-27 weeks' gestation, with low-frequency sounds, such as the mother's heartbeat and speech, eliciting physiological responses in utero. The maturing foetus responds to a wider range of sound frequencies through to the third trimester. In infants, sounds generate memory in the auditory and language regions of the cerebral cortex and stimulate the development of neurological connections to the limbic system.[2]

In clinical investigations of the effects of auditory stimulation on autonomic and neurobehavioral development in early life, randomised and longitudinal case-control studies have shown that maternal sounds, such as singing or speaking in a soft soothing voice, result in reduced heart rate in pre term infants.[29-31] Maternal sounds were also associated with improved feeding behaviours and enhanced mother-infant bonding, thereby reducing parental stress associated with pre term infant care.[29]

Visual sense (sight)

Vision is poorly developed at birth but matures rapidly with stimulation in the first few months of life.[32,33] Maturation of the visual system, including neurological and ocular components, is influenced by many factors including prenatal and postnatal nutrition and postnatal visual stimulation.[33] The visual cortex is the part of the brain responsible for processing visual information.[32]

There is experimental evidence that, from birth, infants prefer direct eye contact as a form of communication and that enhanced neural processing occurs during infant-parent direct eye contact.[34] Indeed, the WHO recommends that parents should engage in direct eye contact with their infant starting at birth.[13] This early sensitivity to mutual gaze is likely to support the development of social skills later in life.[34] Visual stimulation also appears to enhance auditory processing in infants.[35]

Olfactory sense (smell)

The development of smell in infants has not been as well researched as that of other senses; however, some general observations include babies preferring sweet odours such as lavender and vanilla and exhibiting an acute avoidance response to foul odours.[1]

There is accumulating evidence of a particularly strong connection between olfactory stimulation and emotional processing. Studies indicate that, in humans, memories recalled by odours are more emotionally potent than those recalled by the same cue presented visually or as sound,[36] with the specific emotions able to be elicited through the olfactory pathway being happiness, disgust, and anxiety.[37] It has also been shown that, in neonates, learning is enhanced when olfactory stimulation is combined with tactile stimulation.[38]

Against this background, it is perhaps not surprising that an infant's ability to smell is an important part of the early infant-mother bonding process.[1,39] Indeed, components of the maternal diet reach the amniotic fluid, are swallowed, and become familiar to the foetus and thus may contribute to the scent of the mother, including her breast milk.[1] Infant-maternal attachment relies on infants acquiring learned preferences to the maternal odour.[39] As early as 2-days-old, complex associative olfactory learning is observed in newborns[38] and infants who experience skin-to-skin contact with their mothers are able to recognize their own mother's axillary odour.[40] Moreover, presentation of the maternal odour to a distressed infant has been shown to reduce crying and increase mouthing, which may facilitate feeding in newborns.[41] In another study, infants' social attention to faces was enhanced in the presence of maternal odour.[42] When looking at a face, the infants looked longer at the eyes than at any other facial region but they looked at the eyes significantly longer in the presence of maternal odour. Also, just as there is evidence that infants can identify their mother's odour, there is also evidence that mothers can identify their infant's odour.[43] Collectively, these observations emphasise the role of odour in facilitating the infant-mother bonding process.

It is not only maternal odour that can influence responses in infants. According to three controlled studies, other odours, including pine, baby powder, lavender, and vanilla, can ameliorate emotional distress and support mood regulation in infants.[44-46] Familiarity of odour (whether maternal or other) may be a factor in the calming effects of odours in infants.[46,47] For example, presentation of a familiar odour (e.g. vanilla) to infants during a minor painful procedure (heel prick or venipuncture) was associated with less crying relative to infants presented with an unfamiliar or no odour during venepuncture.[47]

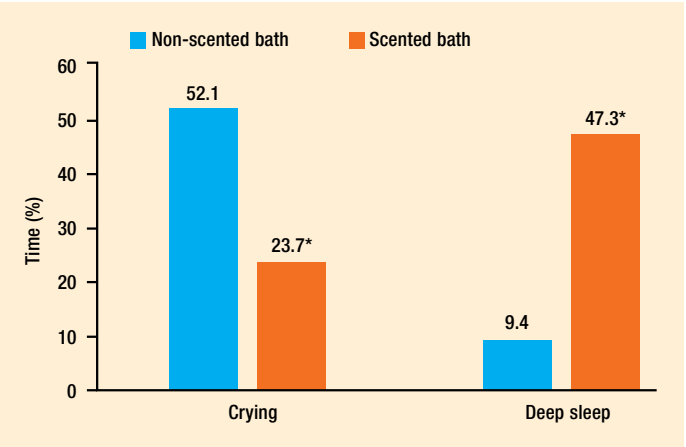

Figure 2. Post-bath behavior (percentage of time crying and in deep sleep) in infants bathed with lavender-scented bath oil (n=10) versus infants bathed with unscented bath oil (n=10) in a randomised study.[45] $p<0.05$ versus unscented bath.

In one of the controlled studies of the effects of non-maternal odours in infants, infants (aged 1 week to 4.5 months) were randomly assigned to be bathed by their mothers either with or without lavender-scented bath oil.[45] Infants in the lavender bath oil group spent a significantly ($p<0.05$) greater percentage of the bath time looking at their mothers than infants in the unscented bath oil group, and they also cried less and spent more time in deep sleep after the bath (**Figure 2**). Moreover, the mothers in the lavender bath oil group were more relaxed and smiled and touched their infants more during the bath than their counterparts in the unscented bath oil group. The behavioural data indicating increased relaxation of the infants and their mothers were supported by their salivary cortisol levels being significantly reduced during the scented bath time (**Figure 3**).

There is also evidence that odour may contribute to infant learning. The presence of odour (pine or baby powder) has been demonstrated to increase attention (looking time) to an audio-visual presentation of a woman expressing happiness and sadness,[44] and the presence of maternal odour to increase an infant's attention (looking time) to faces and eyes.[42] These findings are supported by the observation in adults that odour enhances attention towards visual objects congruent with that odour.[48] It is suggested that these results have implications for optimizing infant environments for and cognitive development.[44]

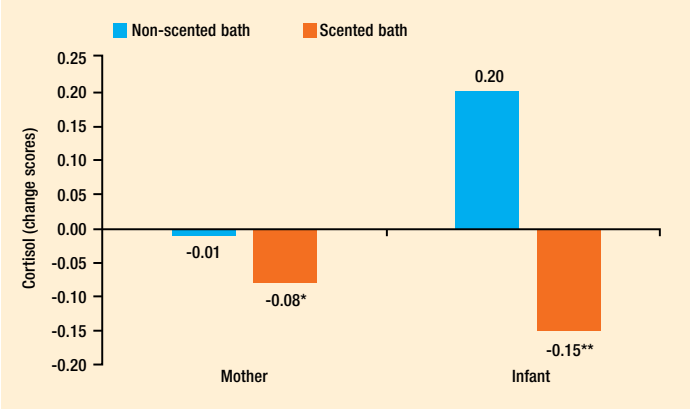

Figure 3. Relaxation measured as salivary cortisol levels in infants (n=10) and their mothers (n=10) after bathing the infants using lavender-scented bath oil in a randomized study.[45] *$p<0.05$ versus unscented bath; **$p<0.005$ versus unscented bath

Vestibular sense (balance and movement)

The vestibular structures are morphologically well developed at birth but continue to develop during the first post-natal month.[49] The vestibular system has a close relationship with the cerebellum, which is critical for motor control co-ordination and the timing of movement. Important functions of the vestibular system are perception of movement, oculomotor and postural control, and spatial memory, all of which are influenced by gravity. Indeed, there is accumulating evidence that vestibular dysfunction may delay the achievement of head control and independent walking in infants.[50] The vestibular system may also be involved in regulating the autonomic system, including arterial pressure regulation and bone mineralisation.[49]

Arousal levels, visual alertness, visual tracking behaviour, and motor and reflex development in infants have all been shown to be influenced by vestibular stimulation in the form of rocking, spinning, or other movement experiences.[51] As an example of vestibular stimulation facilitating motor development during infancy, daily postural and movement activity training rapidly advanced head control (a major motor milestone) as early as 4-6 weeks of age in a randomised controlled study, with caregiver handling and caregiver-infant interactions being contributing factors.[52]

Furthermore, there is clinical study evidence that, presumably by inducing a calm or sleeping state, vestibular stimulation in the form of rocking before an acutely painful procedure can ameliorate pain behaviours in neonates.[53] For example, in a randomized controlled study, Mathai et al. showed that rocking was more effective than massage in reducing crying and pain scores in neonates requiring a heel prick.[54]

Multisensory stimulation

A large evidence base exists that supports the association of multisensory stimulation (also known as multimodal sensory stimulation), i.e. concurrent stimulation of auditory, tactile, visual, vestibular, and/or olfactory senses, with a broad range of benefits, including improved social, emotional, cognitive, and physical development in infants.[55-63] For example, multisensory stimulation in preterm infants has been demonstrated to improve language and motor skills at age 2 to 3 years.[55] Another example of multisensory stimulation is the demonstration that gaze and infant-directed speech experienced together stimulate the development of early social skills.[56] Vision and hearing are the most important senses for effective learning.[1] Examples of structured multisensory stimulation modalities, which include both visual and auditory stimulation components, are the ATVV intervention and bedtime routine.

ATVV intervention

The auditory-tactile-visual-vestibular (ATVV) intervention typically involves infant-directed talk via a soothing female voice (auditory stimulation) during a 10-minute massage (tactile stimulation) followed by 5 minutes of horizontal rocking (vestibular stimulation).[61,62] It has been studied mainly as a preterm infant multisensory intervention.

In two randomised controlled studies, the ATVV intervention has been demonstrated to promote nipple feeding,[58,61] and to increase alertness and reduce the duration of hospitalisation[61] in preterm infants. Improved maturation of oral feeding in preterm infants indicated by a faster transition to complete nipple feeding was an important finding of both studies.[58,61] ATVV as a short-term intervention in the first year of life of preterm infants has also been shown to have important benefits for mothers and their infants in a randomised controlled study that examined the effects of maternally-administered ATVV intervention on maternal distress and the mother-infant relationship.[57]

The underlying benefit of multisensory stimulation may be in the reduction of infant stress. The ATVV multisensory stimulation intervention has also been demonstrated in a randomised controlled trial to reduce stress levels as measured by salivary cortisol levels in healthy term infants.[57] This is a desirable effect given the potential for stress to negatively affect brain development.[11] Also, in practical terms, the results provide indirect support for the important role that multisensory maternal/caregiver comforting can play in reducing infant stress in commonly encountered clinical situations such as blood draws and vaccinations.[62]

The mechanism of stress reduction involves the hypothalamic hormone, oxytocin, which is associated with increased social interaction and well-being as well as anti-stress effects.[64] Oxytocin is released in response to tactile stimulation such as touch, stroking, and massage. It is also released during contact between mothers and infants involving seeing, hearing, and smelling, and in response to suckling and food intake. The presence of increased levels of oxytocin in the brain, in response to sensory stimulation associated with these types of interactive behaviours, contributes to everyday infant wellbeing and mother-infant bonding.

Another potential benefit of the ATVV intervention is a positive effect on neuromotor development. Feeding problems in preterm infants have been demonstrated to be significantly associated with early hypotonia.[65] In a randomised controlled study, multisensory stimulation via the ATVV intervention facilitated tonal maturation in preterm infants.[63]

Kangaroo mother care

Kangaroo mother care (KMC), which is a common form of infant nurture, is inherently multisensory. It provides tactile stimulation through skin-to-skin contact, olfactory-gustatory stimulation via breastfeeding, olfactory stimulation through being in close proximity to the mother's odour, and auditory stimulation by way of the mother's voice.[66]

A meta-analysis of studies indicates that KMC reduces mortality and morbidity in infants, including beneficial effects on some measures of infant growth and facilitation of mother-infant bonding.[67] Although its effects on neurodevelopment have not been well researched, a recent 20-year follow-up study in low-birth weight infants has demonstrated long-lasting positive effects of KMC on neurologic, cognitive, and social functioning.[68]

Bedtime routine

Another example of structured multisensory stimulation is that of the daily bedtime routine, and its potential benefit in the facilitation of night-time sleep in infants, maternal mood, and the mother-infant relationship.

Epidemiological studies suggest that 20-30% of infants and toddlers experience problems sleeping.[69-72] There is also considerable evidence that behavioural interventions for the treatment of sleep problems in children are efficacious, including a bedtime routine as a part of a multicomponent treatment programme.[71,73] Against this background, establishing a consistent bedtime routine is often recommended to parents to improve sleep quality in their children.

The efficacy of a bedtime routine (as an independent intervention) on infant and toddler sleep, and on maternal mood, was assessed in a randomised study performed in the US.[60] Using a two-age group design, mothers and their infant (ages 7-18 months) or toddler (ages 18-36 months) were randomly assigned to follow their usual bedtime routine or to follow a specific bedtime routine for a period of two weeks after a 1-week baseline period. The bedtime routine involved three sequential steps:

1. Bath using a provided wash product.
2. Massage using a provided massage product.
3. Quiet activities such as cuddling, singing, lullaby.

Such a routine can be considered multisensory since it combines the demonstrated benefits of stimulation of an infant's tactile (skin-to-skin contact with mother33), visual (direct eye contact with mother[34,35]), auditory (mother's voice[74]), and olfactory (familiar scents – that of the mother[41] and/or the bath products used[45]) senses.

In the infant cohort, the pre-bedtime routine resulted in significant ($p<0.001$) reductions in the number and duration of night waking (**Figure 4**) and in time to sleep onset compared with baseline.[60] Sleep continuity also increased and there was a significant reduction in the number of mothers who rated their child's sleep as problematic. Similar improvements in sleep quality and quantity were observed in the toddler group. Maternal mood was also significantly improved in the infant cohort. In contrast, sleep patterns and maternal mood in the control group did not significantly change versus baseline over the 3-week study period.

These findings are supported by those of a large multinational study that recruited 10,085 mothers from 14 countries, including India.[59] It demonstrated a regular nightly bedtime routine to be associated with improved sleep in young children (aged 0–5 years), and that the benefit was dose-dependent – the earlier and more consistently the routine was instituted the better the response.

Sensory overstimulation

While sensory stimulation is clearly important for infant neurodevelopmental outcomes, excessive or inappropriately timed stimulation can have deleterious effects on premature infants whose brains are immaturely developed and unskilled in the filtering of sensory inputs. In particular, the environment, schedules, and procedures of the traditional neonatal intensive care unit (NICU) present the potential for sensory overload and absence of neuro-biological rhythms, both of which are incompatible with the developing nervous system's expectations during a sensitive time of brain development.[75,76]

Individual infant assessment and application of sensory stimulation interventions in NICUs as well as adoption of procedures that avoid stimulatory overload or inappropriate patterns of stimulation have been advocated.[75,77]

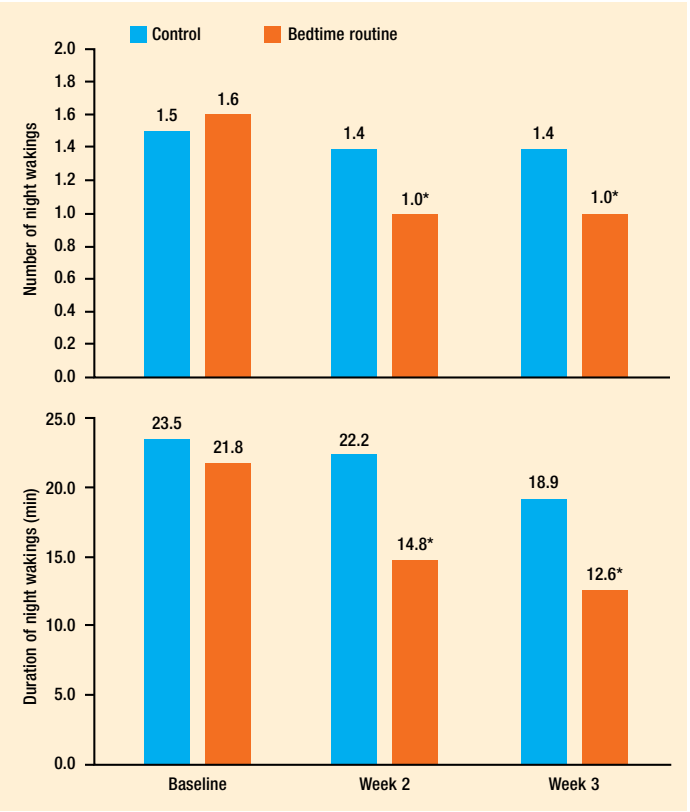

Figure 4. Number and duration of night wakings in infants (n=206) following a consistent bedtime routine.[60] *$p<0.001$ versus baseline

ABOUT RESEARCH REVIEW

Research Review is an independent medical publishing organisation producing electronic publications in a wide variety of specialist areas.

Research Review scans 10,000 global medical journals to bring the most important clinical papers and advancements to your email inbox with advice and commentary from local specialists.

Publications are free to receive for health care professionals, keeping them up to date with their chosen clinical area.

Research Review receives funding from a variety of sources including Government departments, pharmaceutical companies, insurers and other organisations with an interest in health. Content is created independently of sponsor companies with assistance from leading local specialists.

Education Series are a summary of the most important international and local literature which impacts on treatment of a specific medical condition. These Reviews provide information on a disease, current treatment and local/international guidelines. They are intended as an educational tool.

Please send us any feedback or comments to admin@researchreview.com
We also welcome any expressions of interest in becoming a reviewer.

SUBSCRIBE FREE of CHARGE AT RESEARCH REVIEW
www.researchreview.com/India

Privacy Policy: Research Review will record your email details on a secure database and will not release them to anyone without your prior approval. Research Review and you have the right to inspect, update or delete your details at any time.

Research Review publications are intended for Indian healthcare professionals.

RESEARCH REVIEW™
Making Education Easy

EXPERT COMMENTARY: SWATI POPAT VATS

The article concretely summarizes the importance of infant multisensory stimulation and lays a much-needed emphasis on the concurrent stimulation of auditory, tactile, visual, vestibular, and olfactory senses. The impact of such multisensory stimulation has long-term benefits on social, emotional, cognitive, and physical development that are clearly evident up to age 2 to 3 years and beyond. Young parents of infants are usually focused on toileting and feeding needs and tend to ignore the importance or relevance of these early multisensory stimulations and this article provides evidence that these experiences relate to the child's future success socio-emotionally and academically.

In India, and many other countries, there is very little emphasis on home-based developmental interventions and this article clearly outlines not only the potential benefits but also how each of the senses can be involved in multisensory infant stimulation. I highly recommend that this should be given to every new mother whether in urban or rural settings so that both parents can understand science-based reasons behind common cultural practices such as having eye contact while feeding or talking to a baby or having skin-to-skin contact during breast feeding or daily infant massage. All are linked to potential benefits including weight gain, a better sleep-wake pattern, improved neuromotor development, and enhanced emotional bonding.

Another important point in the article is the research related to olfactory stimulation and its impact on emotional processing. Parents and caregivers in daycare centres can benefit hugely by ensuring that an infant's stimulation includes olfactory stimulation with tactile stimulation; for example, using a vanilla/lavender-based massage oil or lavender-scented baths. Infants are rocked and sung to in all cultures and this article helps label this casual everyday activity as vestibular stimulation that enhances visual alertness, visual tracking behavior, and motor and reflex development in infants.

It is also important for parents and caregivers to understand from the research in this article that the underlying benefit of multisensory stimulation is the reduction of infant stress.

EXPERT COMMENTARY: NANDINI MUNDKUR

The importance of brain development in early years and the factors influencing it are best understood by the transactional model by Sameroff and Chandler.[78] To quote: "At birth, a child's biological endowment includes sensory, motor, and neurological capacities intact or impaired for organising experience and interacting with the environment." This model assumes that the infant, caregiver, and environment determine a child's development and behaviour. This is supported by research on brain development, which shows that caregiving and social factors mediated by the sensory system and genetic influences shape the developing brain architecture associated with the changes in development and behaviour. An enriched environment ensures growth and maintenance of synaptic connections during early development when the central neural connections are formed rapidly and unused connections are pruned. Stressful experiences can result in neurochemical changes that can lead to structural changes in the brain.

In this context, we can appreciate the advantages a child can gain if it receives proper stimulation of the sensory system.

There are traditional practices in India, and a few other countries, of considering the first 49 days of motherhood as a valuable time for her to bond with her infant. Traditionally, this period is meant to give her the privilege and support to slowly and respectfully recover from birthing, and enjoy a cozy time building a loving relationship with her newborn. This confinement period has been traditionally a part of several cultures around the world including our own rich Indian culture and is still widely practiced throughout Asia and few other parts of the world. Be it 'Zouyuzei' in the Chinese culture, 'kyrkynan shygaru' in the Kazakh culture, or 'cuarentena' in parts of Latin America, even though the customs and exact duration may differ, all are aimed at protecting the new mother and the newborn baby. This confinement period, where the mother has the luxury to spend all her time with her baby, is equally crucial for the baby's social, sensory, and cognitive development, which begins with understanding and recognising the mother's voice, touch, smell, and face/expressions. Several activities such as rocking the baby, singing lullabies, speaking to the baby while feeding on the breast, the mother wearing a big red bindi on the forehead perhaps to help the baby focus on her face, and tying a hammock with the mother's soft saree are some of the activities to encourage this bonding.

The time spent together will also enable the mother to notice any early signs of delay or deviance in the baby's development. Considering all the above, it may be wise to encourage this traditional practice in new moms everywhere. The following are some of the red flags to watch for in a newborn child during the first few weeks:

- Lethargy.
- Lack of interaction.
- No response to loud noise.
- Trouble moving the eyes or following moving objects.
- Quivering lower jaw.

TAKE-HOME MESSAGES:

- **Maturation of the brain and sensory systems occurs after birth and is heavily influenced by early life experiences and environmental interactions.**
- **Tactile, auditory, visual, vestibular, and/or olfactory stimulation contributes to the social, emotional, and cognitive development of infants.**
- **Establishment of a consistent nightly bedtime routine that encompasses multisensory stimulation can result in improved night time sleep and fewer sleep problems in infants.**
- **Multisensory stimulation has also been shown to promote maturation of oral feeding in preterm infants and reduce mother and infant stress.**
- **Primary healthcare professionals involved in neonatal and infant care have an important role to play in supporting appropriate sensory development in infants.**

REFERENCES

1. Clark-Gambelunghe MB, et al. Sensory development. Pediatr Clin North Am. 2015;62(2):367-84.
2. Graven SN, et al. Sensory development in the fetus, neonate, and infant: Introduction and overview. Newborn Infant Nurs Rev. 2008;8(4):169-72.
3. Shonkoff JP, et al. From neurons to neighbourhoods: The science of early childhood development. 2nd ed. Washington D.C.: National Academy Press. 2000.
4. Lexmond J, et al. Building character: Parents are the principal architects of a fairer society. London: Demos. 2009:1-99.
5. McCain MN, et al. Early years study 2: Putting science into action. Toronto: Council for Early Childhood Development. 2007:1-185.
6. Bann CM, et al. Home-Based Early Intervention and the Influence of Family Resources on Cognitive Development. Pediatrics. 2016;137(4).
7. Wallander JL, et al. Development of children at risk for adverse outcomes participating in early intervention in developing countries: a randomized controlled trial. J Child Psychol Psychiatry. 2014;55(11):1251-9.
8. Spittle A, et al. Early developmental intervention programmes provided post hospital discharge to prevent motor and cognitive impairment in preterm infants. Cochrane Database Syst Rev. 2015(11):Cd005495.
9. Fox SE, et al. How the timing and quality of early experiences influence the development of brain architecture. Child Dev. 2010;81(1):28-40.
10. Sharma PK, et al. Growth and neurosensory outcomes of preterm very low birth weight infants at 18 months of corrected age. Indian J Pediatr. 2011;78(12):1485-90.
11. Kolb B. Brain and behavioural plasticity in the developing brain: Neuroscience and public policy. Paediatr Child Health. 2009;14(10):651-2.
12. Nelson CA. A neurobiological perspective on early human deprivation. Child Development Perspectives. 2007;1(1):13-8.
13. Jones L. Guidance note for integrating ECD activities into nutrition programmes in emergencies. Why, what, and how? Geneva: World Health Organization. 2014: 1-16. Available from: http://www.who.int/mental_health/emergencies/ecd_note.pdf
14. Moore ER, et al. Early skin-to-skin contact for mothers and their healthy newborn infants. Cochrane Database Syst Rev. 2012;5:CD003519.
15. Kulkarni A, et al. Massage and touch therapy in neonates: the current evidence. Indian Pediatr. 2010;47(9):771-6.
16. Agarwal KN, et al. Effects of massage & use of oil on growth, blood flow & sleep pattern in infants. Indian J Med Res. 2000;112:212-7.
17. Arora J, et al. Effect of oil massage on growth and neurobehavior in very low birth weight preterm neonates. Indian Pediatr. 2005;42(11):1092-100.
18. Kumar J, et al. Effect of oil massage on growth in preterm neonates less than 1800 g: a randomized control trial. Indian J Pediatr. 2013;80(6):465-9.
19. Mathai S, et al. Effects of tactile-kinesthetic stimulation in preterms: a controlled trial. Indian Pediatr. 2001;38(10):1091-8.
20. Sankaranarayanan K, et al. Oil massage in neonates: an open randomized controlled study of coconut versus mineral oil. Indian Pediatr. 2005;42(9):877-84.
21. Danby SG, et al. Effect of olive and sunflower seed oil on the adult skin barrier: implications for neonatal skin care. Pediatr Dermatol. 2013;30(1):42-50.
22. Darmstadt GL, et al. Impact of topical oils on the skin barrier: possible implications for neonatal health in developing countries. Acta Paediatr. 2002;91(5):546-54.
23. Hernandez-Reif M, et al. Preterm infants show reduced stress behaviors and activity after 5 days of massage therapy. Infant Behav Dev. 2007;30(4):557-61.
24. Diego MA, et al. Vagal activity, gastric motility, and weight gain in massaged preterm neonates. J Pediatr. 2005;147(1):50-5.
25. Diego MA, et al. Preterm infant weight gain is increased by massage therapy and exercise via different underlying mechanisms. Early Hum Dev. 2014;90(3):137-40.
26. Diego MA, et al. Preterm infant massage elicits consistent increases in vagal activity and gastric motility that are associated with greater weight gain. Acta Paediatr. 2007;96(11):1588-91.
27. Field T, et al. Preterm infant massage therapy research: a review. Infant Behav Dev. 2010;33(2):115-24.
28. Field T. Touch. 2nd ed. Cambridge, Massachusetts: MIT Press. 2014:1-250.
29. Loewy J, et al. The effects of music therapy on vital signs, feeding, and sleep in premature infants. Pediatrics. 2013;131(5):902-18.
30. Picciolini O, et al. Early exposure to maternal voice: effects on preterm infants development. Early Hum Dev. 2014;90(6):287-92.
31. Rand K, et al. Maternal sounds elicit lower heart rate in preterm newborns in the first month of life. Early Hum Dev. 2014;90(10):679-83.
32. Atkinson J. Human visual development over the first 6 months of life. A review and a hypothesis. Hum Neurobiol. 1984;3(2):61-74.
33. Bremond-Gignac D, et al. Visual development in infants: physiological and pathological mechanisms. Curr Opin Ophthalmol. 2011;22 Suppl:S1-8.
34. Farroni T, et al. Eye contact detection in humans from birth. Proc Natl Acad Sci U S A. 2002;99(14):9602-5.
35. Hyde DC, et al. Visual stimulation enhances auditory processing in 3-month-old infants and adults. Dev Psychobiol. 2010;52(2):181-9.
36. Herz RS. A naturalistic analysis of autobiographical memories triggered by olfactory visual and auditory stimuli. Chem Senses. 2004;29(3):217-24.
37. Croy I, et al. Basic emotions elicited by odors and pictures. Emotion. 2011;11(6):1331-5.
38. Sullivan RM, et al. Olfactory classical conditioning in neonates. Pediatrics. 1991;87(4):511-8.
39. Landers MS, et al. The development and neurobiology of infant attachment and fear. Dev Neurosci. 2012;34(2-3):101-14.
40. Marin MM, et al. Two-day-old newborn infants recognise their mother by her axillary odour. Acta Paediatr. 2015;104(3):237-40.
41. Sullivan RM, et al. Clinical usefulness of maternal odor in newborns: soothing and feeding preparatory responses. Biol Neonate. 1998;74(6):402-8.
42. Durand K, et al. Eye-catching odors: olfaction elicits sustained gazing to faces and eyes in 4-month-old infants. PLoS One. 2013;8(8):e70677.
43. Corona R, et al. Chemical olfactory signals and parenthood in mammals. Horm Behav. 2015;68:77-90.
44. Coffield CN, et al. Adding odor: Less distress and enhanced attention for 6-month-olds. Infant Behav Dev. 2014;37(2):155-61.
45. Field T, et al. Lavender bath oil reduces stress and crying and enhances sleep in very young infants. Early Hum Dev. 2008;84(6):399-401.
46. Rattaz C, et al. The calming effect of a familiar odor on full-term newborns. J Dev Behav Pediatr. 2005;26(2):86-92.
47. Goubet N, et al. Olfactory experience mediates response to pain in preterm newborns. Dev Psychobiol. 2003;42(2):171-80.
48. Seo HS, et al. Odors enhance visual attention to congruent objects. Appetite. 2010;54(3):544-9.
49. Jamon M. The development of vestibular system and related functions in mammals: impact of gravity. Front Integr Neurosci. 2014;8:11.
50. Kaga K, et al. Influence of labyrinthine hypoactivity on gross motor development of infants. Ann N Y Acad Sci. 1981;374:412-20.
51. Sandler A, et al. Vestibular stimulation in early childhood: A review. J Early Interv. 1981;3:48-55.
52. Lee HM, et al. Early intensive postural and movement training advances head control in very young infants. Phys Ther. 2012;92(7):935-47.
53. Pillai Riddell RR, et al. Non-pharmacological management of infant and young child procedural pain. Cochrane Database Syst Rev. 2015(12):Cd006275.
54. Mathai S, et al. A comparative study of nonpharmacological methods to reduce pain in neonates. Indian Pediatr. 2006;43(12):1070-5.
55. Gabis LV, et al. The influence of a multisensory intervention for preterm infants provided by parents, on developmental abilities and on parental stress levels. J Child Neurol. 2015;30(7):896-903.
56. Guellai B, et al. Cues for early social skills: direct gaze modulates newborns' recognition of talking faces. PLoS One. 2011;6(4):e18610.
57. Holditch-Davis D, et al. Maternally administered interventions for preterm infants in the NICU: effects on maternal psychological distress and mother-infant relationship. Infant Behav Dev. 2014;37(4):695-710.
58. Medoff-Cooper B, et al. Multisensory intervention for preterm infants improves sucking organization. Adv Neonatal Care. 2015;15(2):142-9.
59. Mindell JA, et al. Bedtime routines for young children: a dose-dependent association with sleep outcomes. Sleep. 2015;38(5):717-22.
60. Mindell JA, et al. A nightly bedtime routine: impact on sleep in young children and maternal mood. Sleep. 2009;32(5):599-606.
61. White-Traut RC, et al. Effect of auditory, tactile, visual, and vestibular intervention on length of stay, alertness, and feeding progression in preterm infants. Dev Med Child Neurol. 2002;44(2):91-7.
62. White-Traut RC, et al. Salivary cortisol and behavioral state responses of healthy newborn infants to tactile-only and multisensory interventions. J Obstet Gynecol Neonatal Nurs. 2009;38(1):22-34.
63. Kanagasabai PS, et al. Effect of multisensory stimulation on neuromotor development in preterm infants. Indian J Pediatr. 2013;80(6):460-4.
64. Uvnas-Moberg K, et al. Self-soothing behaviors with particular reference to oxytocin release induced by non-noxious sensory stimulation. Front Psychol. 2014;5:1529.
65. Crapnell TL, et al. Factors associated with feeding difficulties in the very preterm infant. Acta Paediatr. 2013;102(12):e539-45.
66. Ramachandran S, et al. Early developmental care interventions of preterm very low birth weight infants. Indian Pediatr. 2013;50(8):765-70.
67. Conde-Agudelo A, et al. Kangaroo mother care to reduce morbidity and mortality in low birthweight infants. Cochrane Database Syst Rev. 2016(8):Cd002771.
68. Charpak N, et al. Twenty-year Follow-up of Kangaroo Mother Care Versus Traditional Care. Pediatrics. 2017;139(1).
69. Bayer JK, et al. Sleep problems in young infants and maternal mental and physical health. J Paediatr Child Health. 2007;43(1-2):66-73.
70. Teng A, et al. Infant and toddler sleep in Australia and New Zealand. J Paediatr Child Health. 2012;48(3):268-73.
71. Mindell JA, et al. Behavioral treatment of bedtime problems and night wakings in infants and young children. Sleep. 2006;29(10):1263-76.
72. Sadeh A, et al. Sleep and sleep ecology in the first 3 years: a web-based study. J Sleep Res. 2009;18(1):60-73.
73. Morgenthaler T, et al. Practice parameters for the psychological and behavioral treatment of insomnia: an update. An american academy of sleep medicine report. Sleep. 2006;29(11):1415-9.
74. Dehaene-Lambertz G, et al. Language or music, mother or Mozart? Structural and environmental influences on infants' language networks. Brain Lang. 2010;114(2):53-65.
75. Als H, et al. The Newborn Individualized Developmental Care and Assessment Program (NIDCAP) with Kangaroo Mother Care (KMC): Comprehensive Care for Preterm Infants. Curr Womens Health Rev. 2011;7(3):288-301.
76. Aucott S, et al. Neurodevelopmental care in the NICU. Ment Retard Dev Disabil Res Rev. 2002;8(4):298-308.
77. Linn PL, et al. Stimulation in the NICU: is more necessarily better? Clin Perinatol. 1985;12(2):407-22.
78. Sameroff AJ, et al. Chapter: Reproductive risk and the continuum of caretaker casualty. In: Horowitz FD, et al., editors. Review of Child Development Research. Vol. 4. Chicago, IL: University of Chicago Press. 1975: 187-244.
79. Piaget J. Origins of intelligence in the child. London: Routledge & Kegan Paul. 1936.
80. Stein BE, et al. The Merging of the Senses. Cambridge, MA: MIT Press. 1993.
81. Delafield-Butt JT, et al. Sensorimotor intentionality: The origins of intentionality in prospective action. Dev Rev. 2013;33(4):399-425.
82. Prechtl HF, et al. An early marker for neurological deficits after perinatal brain lesions. Lancet. 1997;349(9062):1361-3.
83. Als H, et al. Early experience alters brain function and structure. Pediatrics. 2004;113(4):846-57.

Johnson & Johnson

This publication has been created with an educational grant from Johnson and Johnson Asia Pacific. The content is entirely independent and based on published studies and the writer and commentators' opinions.