



# Supporting and enhancing NICU sensory experiences (SENSE): Defining developmentally-appropriate sensory exposures for high-risk infants

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## ABSTRACT

**Introduction:** There is evidence to support the use of positive sensory exposures (music, touch, skin-to-skin) with preterm infants in the neonatal intensive care unit (NICU), but strategies to improve their consistent use are lacking. The Supporting and Enhancing NICU Sensory Experiences (SENSE) program was developed to promote consistent, age-appropriate, responsive, and evidence-based positive sensory exposures for the preterm infant every day of NICU hospitalization.

**Methods:** A systematic and rigorous process of development of the SENSE program included an integrative review of evidence on sensory exposures in the NICU, stakeholder feedback, expert opinion, and focus groups.

**Results:** SENSE implementation materials consist of parent education materials, tailored doses of sensory exposures for each postmenstrual age, an infant assessment of tolerance, bedside logs and implementation considerations for integrating the SENSE program into the NICU.

**Discussion:** Research is needed to evaluate the SENSE program as an implementation strategy and to assess its impact on parent and infant outcomes.

## 1. Introduction

The intrauterine environment provides the fetus with developmentally timed sensory exposures modulated by protective physical barriers and maternal activity that are likely critical to optimal growth and health of the infant. These early exposures occur during complex intrauterine sensory development, in which a predictable pattern occurs, with variation in the timing of the development of each sense [1]. The protected environment is replaced by the neonatal intensive care unit (NICU) environment when an infant is born prematurely. The very preterm infant's sensory environment includes exposure to and experiences of procedural touch/handling, movement, smell, sound, light, frequent nociceptive pain, and disruption of sleep [2]. The mismatch between the underdeveloped coping skills of the infant and the intensely stimulating NICU environment may cause physiologic instability, adversely affect growth and development, and ultimately impact long term neurodevelopmental outcomes [3–7].

Although poorly timed or noxious sensory exposures can negatively impact the development of the preterm infant [7,8], appropriate

positive sensory experiences drive brain development [9]. Functional relatedness of different brain regions is immature in infants born preterm, and prematurity can lead to a reduction in neuronal activity. However, during the time from preterm birth until term equivalent age, there is an age-dependent pattern of neuronal development with increasing strength and organization with advancing postmenstrual age (PMA), which can potentially be optimized with appropriate sensory experiences [10–12]. It is during the missed 2nd and 3rd trimester of pregnancy when neural circuit formation, including synaptogenesis, axonal growth, and late neuronal migration are taking place for preterm infants in the NICU [13]. While some processes of brain development occur automatically at the molecular level, other aspects of brain development are activity-dependent, relying on sensory exposures in the environment around the infant [14]. Based on an increase or decrease of activity, there can be structural plasticity, axonal sprouting, and changes in the number of dendritic spines and synapses in the primary sensory cortex [15]. Therefore, sensory exposure within the NICU is a modifiable factor that can potentially be used to optimize brain development and reverse the high rates of morbidity among

**Abbreviations:** NICU, neonatal intensive care unit; SENSE, Supporting and Enhancing NICU Sensory Experiences; PMA, postmenstrual age

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preterm infants.

While appropriate early sensory exposures are important for the very preterm infant in the NICU, parent interaction is also critical. The infant's need for human contact and nurturing have long been understood. Animal studies have identified that even brief periods of maternal separation can result in emotional disturbances and decreased motor activity among offspring [16,17]. Clinical studies on early parent-infant interactions have also demonstrated positive effects of parent interaction on motor and attentional responses of the infant [18]. Early deprivation of social and caregiver interaction has been shown to have lasting consequences, with poor physical growth, developmental delay and increased emotional and neurocognitive difficulties [19–22], in addition to abnormalities on magnetic resonance imaging [23]. Although the vulnerable preterm infant differs from a child who has been institutionalized or deprived of caregiving attention after full term birth, there are striking similarities with altered temporal structures [23], in addition to high risk of developmental impairment [24,25]. Further, studies conducted with children born preterm have demonstrated that caregiver engagement is positively and strongly correlated with child engagement in daily activities [21]. Likewise, NICU's in which parents are present and engaged demonstrate more favorable outcomes [26,27].

While single sensory exposures (music, touch, skin-to-skin) have been studied, few multisensory exposure programs that address more than one sensory system have been defined for high-risk infants [28,29]. Positive sensory exposures in the NICU are often done for limited periods of time that encompass only a fraction of the infant's time spent in the NICU. These exposures are also not systematically changed based on what is age-appropriate across PMA and can be limited in their applicability to co-occupations of parenting and activities of daily living within the context of the NICU environment. Co-occupations are shared and meaningful activities between parent and child. New approaches, mostly implemented outside of the United States, have identified specific amounts of time parents should be present in the NICU and defined processes toward parents assuming care of the infant, but specific doses of sensory exposure provided to the infant have not been defined within these approaches [30]. Differences in the use and interpretation of available evidence, as well as differences in parent education and empowerment in the NICU, are prevalent. Due to the complex environment, there is also significant variability in the application of sensory-based interventions, often reducing their benefit to the most vulnerable infants. Finally, consistent application of positive sensory exposures throughout the entire NICU hospitalization is lacking.

Combining the need for parent engagement in the NICU environment with the infant's need for consistent positive sensory exposures, this manuscript outlines the process used to develop the Supporting and Enhancing NICU Sensory Experiences (SENSE) program, an evidence-based, parent delivered guideline for consistent application of positive sensory exposures across every day of NICU hospitalization.

## 2. Methods

A systematic and rigorous process was used to develop the SENSE program. The steps used to define the SENSE program included 1) defining evidence-based sensory exposures in the NICU, 2) defining what sensory interventions are used by other NICU health care professionals, when they are used, and under what circumstances they are applied, 3) getting expert input on important considerations when developing a sensory-based guideline for application in the NICU, 4) getting parent perceptions about the use of a sensory-based guideline in the NICU, and 5) using focus groups to determine perceptions about feasibility. This information was then used by a neonatal occupational therapist with 25 years of clinical experience and 12 years of research experience in the NICU and two neonatal nurse practitioners, one with 30 years of clinical experience and 10 years of research experience in the NICU and

the other with 40 years of clinical experience in the NICU to define the SENSE program.

### 2.1. Review of the evidence

First, evidence on positive sensory exposures for preterm infants in the NICU was defined with an integrative review [32]. In preterm infants born  $\leq 32$  weeks gestation, studies defining the impact of sensory interventions were identified and included studies related to *tactile* (kangaroo, skin-to-skin care, containment, massage, acupressure, gentle human touch, facilitated touch, M Technique, Yakson, and touch), *auditory* (live or recorded music, maternal voice recordings, and reading), *vestibular* (rocking, bouncing, swinging, and movement); *visual* (cycled light, light, visual, eye-contact, color or black and white patterns, engagement); *olfactory/gustatory* (smell, taste), and/or *kinesthetic* (range of motion, movement of extremities or body, therapeutic facilitation of muscles) interventions. Databases searched included MEDLINE, Cumulative Index to Nursing and Allied Health Literature (CINAHL), Cochrane Database, and Google Scholar. Studies that imposed a sensory intervention that commenced in the NICU prior to 36 weeks PMA and investigated outcomes related to infant neurodevelopment or maternal health were identified. Further organization of the PMA that the interventions were done, the doses of the intervention, and the outcomes evaluated was conducted. From this, appropriate tactile, auditory, visual, kinesthetic, vestibular, and olfactory interventions were identified along with the age (PMA) that they were introduced.

### 2.2. Stakeholder Feedback (health care professionals in the NICU)

Next, the evidence supporting different sensory interventions were presented to a multidisciplinary team of NICU professionals at the Graven's Conference on the Physical and Developmental Environment of the High Risk Infant on March 5, 2015 and to a group of neonatal therapists during a webinar through the National Association of Neonatal Therapists on May 19, 2015 [31]. These stakeholders were asked for their perceptions of sensory exposures they use in the NICU. The institutional review board (IRB) at Washington University approved this part of the study, and consent was obtained. From this, gaps in the evidence were filled in with current practice by health care professionals in the NICU.

### 2.3. Expert input

Three external experts in developmental care were identified. All three were nurses. The goal of identifying a guideline for application of evidence-based, positive sensory exposures in the NICU was communicated, and probing was conducted to elicit dialogue to define perceptions. From this, the need for parent education that included understanding infant behavioral cues, along with when to do sensory interventions and when not to, was better understood.

### 2.4. Stakeholder feedback (parents)

Next, 20 parents of preterm infants were interviewed within 8 weeks of NICU discharge on their experiences with providing sensory exposures to their infants in the NICU, and they were probed on their feelings about there being an established guideline on positive sensory exposures to do every day of hospitalization. IRB approval was achieved for this part of the study, and consent was obtained. Most parents identified skin-to-skin care as their favorite and earliest experience with their infant in the NICU. Most said that nurses were exceptionally helpful in assisting them in learning to do sensory-based interventions with their infant. Most parents identified that having a guideline would help them better know what to do, when to do it, and for how long. From this process, the importance of the parents as implementers was fully realized along with identifying the importance of

making the guideline practical and easy to apply. This information is being organized into a manuscript, which is in preparation.

### 2.5. Focus groups (perceptions about feasibility)

Finally, focus groups and interviews were conducted with NICU health care professionals to flush out details of a sensory-based intervention plan, to identify specific dosing and intensity for sensory interventions, and to determine perceptions about how the intervention would be accepted into practice. This part of the study had IRB approval, and consent was obtained. Three separate focus groups of 2–7 NICU professionals each were conducted. A total of 11 health care professionals participated (4 neonatologists, 4 nurses, 1 neonatal nurse practitioner, one occupational therapist and one physical therapist). The process of guideline development and what the guideline entailed was presented, and feedback was sought. The focus groups were audio-recorded, transcribed, and coded into themes using NVivo V.12 qualitative analysis software. Health care professionals felt the sensory-based guideline would be feasible to implement, and perceptions were positive. Additional suggestions included 1) having a back-up plan if parents did not engage in providing sensory-based interventions with their infants and ensuring that parents were not made to feel guilty, 2) ensuring that the use of the guideline aligned with the schedule and workload of nursing staff within the NICU, 3) making sure that the guideline aligned with current neonatal therapy practice in the NICU, and 4) ensuring that dosages of positive sensory exposures did not detract from establishing warmth and reciprocity. This data is being organized into a manuscript, which is in preparation.

### 2.6. Iterative process

From this process a guideline for appropriate positive sensory exposures was established, with careful contemplation among the three authors of this manuscript. The goal of the SENSE program is to engage parents in consistently providing positive, developmentally-appropriate sensory exposures to their high-risk infant in the NICU every day of hospitalization. The guideline was developed with the intention of optimizing parent engagement, while maximizing daily positive sensory exposures to improve infant development, parent-infant interaction, and parent mental health.

## 3. Results

The SENSE program consists of a choice of tactile, auditory, visual, olfactory, and vestibular/kinesthetic exposures, so parents can choose what they prefer to use as well as to provide different options, based on the tolerance of the infant. A week-by-week sensory plan is part of the SENSE program and defines what should occur each day of hospitalization, with specific dosages of different sensory exposures specifically tailored to each PMA. The smallest dose of each sensory exposure represents the minimum amount recommended for infants as early as 23 weeks PMA, and the highest dose represents the minimum dose recommended for infants who are 40 weeks PMA (see Table 1 for different choices of sensory exposures and the range of daily dosages for those sensory exposures contained within the SENSE program).

### 3.1. Tactile

Largely four tactile interventions were identified in the literature: gentle human touch, massage, holding, and skin-to-skin care [32]. Studies on gentle human touch have a treatment length and duration ranging from 10 to 15 min over a course of 5 to 15 days, and there are studies of gentle human touch starting as early as 27 weeks PMA. Most studies on massage consist of 15-min treatments 1–3 times per day, with most studies not starting massage until 32 weeks PMA, but some starting as early as 28 weeks PMA. The duration of skin-to-skin care

interventions ranged from 30 min to continuous kangaroo care after the infant stabilized, starting as early as 24 weeks PMA [32]. Most health care professionals reported skin-to-skin care and holding as the most common tactile interventions used in their NICUs, starting at 24–26 weeks PMA [31].

As skin-to-skin care has significant benefits to both the parent and infant and aids in temperature stability when the infant is out of the incubator, this was the tactile intervention encouraged prior to 32 weeks PMA as part of the SENSE program. A minimum of one continuous hour is proposed for skin-to-skin holding early in PMA, to enable benefit following the potential stress of the transition from bed to parent's chest. There is also an option of use of gentle human touch during this period of development, as it can be provided with ease in the incubator. Holding is added as an option for tactile exposure, starting at 28 weeks PMA, but for short durations (15 min), due to the potential for infant temperature instability. The time for holding can be extended if the infant is regulating his/her temperature, starting at 32 weeks PMA. Massage is added as a choice for tactile exposure, starting at 32 weeks PMA. Tactile interventions that may disrupt sleep, such as initiation of massage and transitions for holding, are clustered during care times. However, skin-to-skin care (when done for several hours) and gentle human touch can be done in between care times, as they may help to facilitate sleep [33].

A minimum of 3 h of tactile stimulation is recommended at term equivalent age based on the literature, expert opinion, and exposures that might be reflective of that of a full-term infant. During the neonatal period, infants often eat 8 times per day, each of which may range from 20 to 30 min each, meaning the infant will receive 3–4 h of tactile exposures from this activity of daily living. Given the altered environment of the NICU, a minimum of 3 h of tactile exposure ensures that infants who may not be orally feeding receive positive touch through the tactile interventions described in the SENSE program.

### 3.2. Auditory

Auditory interventions that are described in the literature largely consist of language exposure, maternal voice recordings, and music. Most studies investigating maternal voice or sounds began the interventions at 30 weeks PMA with some starting as early as 27 weeks PMA. Most studies on live or recorded music started at 32 weeks PMA, with some starting as early as 25 weeks. However, most studies investigated auditory exposures over a limited period of time, ranging from 45 s to 45 min over a period of 1 to 3 weeks [32]. Most health care professionals reported using auditory interventions starting at 30–32 weeks, with the most common auditory intervention being recorded music/singing [31].

Auditory exposure is often too intense in the NICU [34], and infants early in gestation are often too fragile to tolerate intense exposures [8,35]. Therefore, other auditory exposures beyond language at the bedside are not defined in the SENSE program until after 28 weeks PMA. At 28 weeks PMA, short duration (20 min) of reading to, singing to, or speaking to the infant can begin. However, use of CD or sound players for music or recorded voice is not recommended until 32 weeks PMA in the SENSE program. This is because direct auditory exposures, such as speaking to the infant, are done in a reciprocal manner. When an infant begins to show signs of stress, the speaker naturally pauses and attends to the infant, returning to the auditory exposure once the infant has settled. However, CD or sound players do not enable this reciprocation. Infants at 32 weeks PMA are more mature and potentially able to better tolerate such stimuli. The dose of auditory exposure at term equivalent age was defined by a recent study conducted by the authors of the study (manuscript currently under review) who observed 3 h, 16 min less language exposure in the NICU environment at term equivalent age compared to the full-term labor and delivery floor. Therefore, a minimum of 3 h of auditory exposures are part of the SENSE program at term equivalent age.

**Table 1**  
SENSE program: choices of exposures and ranges of daily dosages.

	Choices of sensory exposures	Daily dose (based on lowest PMA, 23 weeks PMA)	Daily dose (based on highest PMA, 40 weeks PMA)
Touch (tactile)	<ul style="list-style-type: none"> <li>• Skin-to-skin contact</li> <li>• Holding</li> <li>• Gentle human touch</li> <li>• Massage</li> </ul>	<ul style="list-style-type: none"> <li>• Minimum of one hour</li> </ul>	<ul style="list-style-type: none"> <li>• Minimum of three hours</li> </ul>
Hearing (auditory)	<ul style="list-style-type: none"> <li>• Quiet conversations</li> <li>• Reading</li> <li>• Singing</li> <li>• Speaking to</li> <li>• Playing soft music</li> </ul> <p>*45 dB</p> <p>**No sound players until 32 weeks PMA</p>	<ul style="list-style-type: none"> <li>• No added sound except quiet conversations at bedside</li> </ul>	<ul style="list-style-type: none"> <li>• Minimum of three hours</li> </ul>
Smell (olfactory)	<ul style="list-style-type: none"> <li>• Scent cloth</li> <li>• Close contact with parents</li> </ul>		
Seeing (visual)	<ul style="list-style-type: none"> <li>• Dim environment until 32 weeks PMA</li> <li>• Cycled light starting at 32 weeks PMA</li> <li>• Avoiding direct and bright lights</li> <li>• Encouraging visual attention through human interaction</li> </ul> <p>*Cycling with low level of light (25–100 Lux)</p> <p>*Encouraging visual interaction starting at 36 weeks PMA</p>	<ul style="list-style-type: none"> <li>• Dim environment</li> </ul>	<ul style="list-style-type: none"> <li>• Encouraging infant to focus and follow human face</li> </ul>
Movement and body awareness (vestibular and kinesthetic)	<ul style="list-style-type: none"> <li>• Allowing free, unrestricted movement</li> <li>• Rocking</li> </ul>	<ul style="list-style-type: none"> <li>• 2 min one time per day just prior to diaper change</li> <li>• Transfers only</li> </ul>	<ul style="list-style-type: none"> <li>• 2 min eight times per day just prior to diaper change</li> <li>• A minimum of seven minutes</li> </ul>

Another important factor related to auditory exposures that was considered was intensity. The American Academy of Pediatrics (AAP) recommends that NICU sound levels not exceed an average of 45 dB (dB) [36]. Physiological consequences from sound have been reported at intensities exceeding 68 dB [8,35,37]. Therefore, the auditory exposures, as part of the SENSE program, were defined as being at 45 dB. This intensity, being the sound of a whisper, is likely to enable positive sound without disrupting infant sleep.

### 3.3. Olfactory

Olfactory exposures defined in the literature include maternal scent/breast milk and colostrum [32]. Treatment durations ranged from providing a brief exposure every 3 h to providing scent continuously. Use of a scent cloth is part of the SENSE program, starting at the earliest PMA. Use of the scent cloth can be replaced by close maternal contact, such as through holding and skin-to-skin contact, when it can be accomplished.

### 3.4. Visual

Visual interventions described in the literature center on modifying the light environment though dim light, bright light, or cycling light [32]. A dim environment prior to 32 weeks PMA, followed by cycling light (12 h lights on and 12 h lights off) starting at 32 weeks PMA, has been related to improved outcome [32]. Forty percent of health care professionals indicated they use cycled light, with varied practices among the others including dim environments, light environments, and alternating between bright and dim [31]. It is well-understood that direct light should be avoided except when needed for adequate provision of care [38]. While some need for light exposure has been described starting at 28 weeks PMA, this naturally occurs in the context of the NICU. The AAP recommends ambient lighting < 646 Lux (60 fc) for each neonate [39], and there are different intensities of light that have been studied within cycled light protocols that range from an average of 78.4 (± 24.7) [40] to 499.3 (± 159.2) [41] Lux during the 'lights on' cycle. 'Lights off' cycles appear to have more consistent light levels across studies of < 25 Lux.

The SENSE program includes use of a dim environment prior to 32 weeks PMA and cycling light starting at 32 weeks PMA. To determine the intensity of light for the SENSE program, there was consideration of current evidence and guidelines in addition to observation of light levels within a Level IV NICU. In a recent study conducted by the authors (manuscript in preparation), 23 light measurements were recorded with a light meter over 3 separate days and under different conditions. The median (interquartile [IQ] range) amount of light across the whole sample was 38.0 (3.0–93.0) Lux. There was significantly less light in the single patient rooms (9.0 (1.4–43.7)) compared to the open ward (52.0 (14.7–128.0)) ( $p = 0.01$ ), in the incubator (2.0 (0.5–7.8)) compared to the open crib (52.1 (13.6–120.5)) ( $p = 0.002$ ), and with use of side lighting (55.0 (38.0–120.0)) compared to overhead lighting (93.0 (13.4–148.9)) ( $p = 0.002$ ). This evidence provided information on what was feasible. Infants are not supposed to be exposed to light until full-term birth, and there is evidence that exposure too soon can disrupt sensory systems and development [1,42]. Therefore, utilizing the cycled light protocol established by Boo, et al. [40] enabled a conservative approach to the intensity during the 'lights on' cycle of cycled light. The SENSE program includes a 'lights on' intensity between 25 and 100 Lux and a 'lights off' intensity of < 25 Lux.

No studies have investigated the effect of visual stimulation using objects or people to focus visual attention and pursuit in preterm infants prior to term equivalent age [32]. The visual system is the sensory system that develops last, and visual stimulation has been deemed inappropriate and potentially harmful for preterm infants prior to term equivalent age [38]. Although neonates have been shown to attend more to a black/white pattern over a gray, unpatterned surface [43], an infant's ability to respond does not mean they should be stimulated in that manner. Since the immature brain becomes increasingly responsive to specific characteristics of the visual environment, the consequence of exposure to black/white patterns could reinforce a less mature response of increased attending time [43]. Long attending periods to black/white checker-boards have been related to visual processing difficulties, which are associated with poorer cognition at 8 years old [44]. By exposing an infant to black/white patterns, it is argued that this could reinforce a less mature visual response in addition to being stressful for



preterm infants, whose visual development is immature [45]. This, in addition to the visual system being the last to develop and not activated until full-term birth, is why visual stimulation with inanimate objects is not part of the SENSE program.

However, the SENSE program does include the addition of face-to-face interaction, starting at 36 weeks PMA. Parent-infant interaction is a critical part of development and begins in the NICU environment for the parent-infant dyad. Increased parent engagement in the NICU has been related to improved developmental outcome [26]. Most infants are able to engage in the en face position and have developed the ability to interact by 36 weeks PMA [46]. Face to face interaction can be an important part of fostering the foundation for the parent-child relationship. Therefore, the SENSE program includes encouraging the infant to focus on and follow the parents, as in parent-infant interaction, starting at 36 weeks PMA.

### 3.5. Vestibular

There is a paucity of research isolating the effects of vestibular interventions in the NICU, however, vestibular stimulation is described as part of the Auditory, Tactile, Vestibular, Visual (ATVV) intervention. Most studies describe a duration of ATVV, which includes rocking as a vestibular stimulus, of 3–7 min starting at 33 weeks PMA [47–51]. The most common vestibular interventions identified by health care professionals were rocking and use of infant swings, with most using vestibular interventions starting at 33–34 weeks PMA [31].

While the impact of vestibular interventions on the preterm infant is not well-understood, the amount of vestibular exposure in utero can be appreciated. Vestibular exposure can be initiated through transferring the immature infant to and from holding positions, which is part of the SENSE program as early as 23 weeks PMA [47,48]. Vestibular stimulation is then expanded to include rocking, with the initiation of 2–3 min starting at 32–33 weeks PMA and progressing to a minimum of 7 min at term-equivalent age.

### 3.6. Kinesthetic

The literature describes kinesthetic interventions that largely involve physical activity, passive movement and joint compression with the main emphasis being on outcomes related to bone health [32]. Health care professionals identified that physical and occupational therapy are largely used for kinesthetic interventions, starting at 27 weeks PMA [31]. Physical and occupational therapy are largely part of service delivery in NICUs in the United States and can be important in the delivery of sensory-motor interventions in the NICU [52]. Due to a lack of evidence on kinesthetic interventions related to improved developmental status, coupled with the stress that passive movement might induce among immature preterm infants, kinesthetic interventions were carefully considered. Heinz Prechtl describes normal patterns of writhing movements that occur during the neonatal period and are mediated by central pattern generators deep within the brain [53]. When infants are contained, as in tight swaddling, they may be unable to demonstrate their normal writhing movements freely, which could interrupt the sensory experiences associated with them. It remains unclear how this might impact the developmental trajectory. To enable infants to have free writhing movements, the SENSE program includes 2 min of free movements prior to a diaper change as early as 23 weeks gestation, if tolerated, advancing to 2 min before every diaper change (8 times per day) by term equivalent age. Initiating free movement at the earliest time point is consistent with the emergence of fetal general movements, which have been observed in the first trimester [54,55]. While free writhing movements are the goal of this sensory exposure, caregiver hands can foster improved movement patterns in infants demonstrating cramped synchronized patterns, with guidance from the physical or occupational therapist.

### 3.7. SENSE administrator

For implementation of the SENSE program, a SENSE administrator at each site needs to be identified. The SENSE administrator is responsible for implementing the program, educating families, and ensuring infants receive appropriate sensory exposures every day of NICU hospitalization to optimize outcomes. They also conduct routine infant assessments and inform the team of necessary modifications. Neonatal therapists (occupational therapists, physical therapists, speech-language pathologists) are an important part of the NICU team, with the capacity to incorporate SENSE administrator duties into their work flow as they optimize outcomes of high-risk infants in the NICU. Due to their focus on optimizing the environment for performance, their expertise in sensory processing, and their focus on improving participation as a pathway to health, neonatal therapists would be ideal SENSE administrators.

### 3.8. Parent education

The 69-page parent education book highlights the importance of the parent's role in the infant's life, educates parents on sensory development as well as how to read and respond to infant cues, defines age-appropriate sensory exposures for each week of PMA, and provides specific instruction on how to carry out positive sensory exposures. An electronic version of the educational materials can be pushed to a smart phone, tablet, or personal computer and contains the same information as the printable parent education materials, but also includes instructional videos demonstrating different parts of the SENSE program. The parent educational materials are intended to be given to the parents shortly after their infant is admitted to the NICU. The SENSE administrator can use the materials to reinforce educational concepts and define what sensory exposures are appropriate each week of hospitalization.

### 3.9. Adapting the intervention/individualizing

The SENSE program provides guidelines for positive exposures at each developmental age (PMA), but some infants have concurrent medical complications or other factors that necessitate modifications. Therefore, another component of the SENSE program is the infant assessment, used to ensure that each infant can tolerate the sensory exposure types and dosages as defined in the guideline. Discoveries during the assessment can inform whether the infant can tolerate the SENSE program as outlined or can guide appropriate modifications to the SENSE program, based on the individual needs of each infant. Recommendations can then be made to the family and the sensory support team regarding what is best for the infant. Infant assessments can be completed by the SENSE administrator or an experienced neonatal clinician, such as a neonatal nurse, physical therapist, occupational therapist, or speech-language pathologist. After the initial assessment, ongoing assessments are recommended at least weekly or more frequently if the infant's status changes.

### 3.10. Bedside materials

SENSE bedside materials can aid in implementation of the SENSE program. The **week-by-week sensory exposure** plan outlines what type and timing of exposures are developmentally appropriate for the infant's PMA and can be printed and used each week. **Log sheets** can be used by parents, health care professionals, as well as members of the sensory support team in order to track positive sensory exposures that are conducted each day with the infant(s).

## 4. Discussion

The SENSE program consists of parent education materials, a week-

by-week guide of appropriate sensory exposures across PMA that was approached systematically and scientifically, an infant assessment to determine the need for modifications to the program, and bedside logs for parents and health care professionals to track sensory exposures. The aim of the SENSE program is to maximize parent engagement, so that parents can feel empowered to positively influence the outcomes of their infant(s); to foster early parent-child relationships to improve health and wellbeing; and to ensure positive sensory exposures to drive appropriate brain development during a critical period of time. The doses established for daily positive sensory exposures also necessitate a comprehensive implementation strategy that includes the use of parent education materials and the infant assessment. This is the first program that we know of that has been developed to ensure consistent application of evidence-based, age-appropriate, and positive sensory exposures every day of NICU hospitalization. It will be important to conduct appropriately powered studies to investigate the impact of the SENSE program on the infant and parents. In addition, by measuring implementation outcomes, its application within different types of NICUs can be better understood.

### Financial disclosure

The copyright for the SENSE program is held by the Washington University Office of Technology Management. SENSE materials are currently available to other hospitals and individuals for research and clinical applications 'at-cost' [https://wustl.resoluteinnovation.com/technologies/T018018\\_supporting-and-enhancing-nicu](https://wustl.resoluteinnovation.com/technologies/T018018_supporting-and-enhancing-nicu).

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### Conflict of interest

There are no conflicts of interest to disclose.

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