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Therapeutic Listening for Preterm Children with Sensory Dysregulation, Attention and Cognitive Problems

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Abstract

Introduction
Is Therapeutic Listening effective for children born preterm presenting with sensory dysregulation, attention and cognitive problems?
Methods
22 children (BW<1500g) 3-4 years were enrolled in a single centre, prospective, assessor-blinded RTC. Outcome measures: Winnie-Dunn Sensory Profile; Peabody Developmental Motor Scales; Reynell Attention Scale; Preschool Language Scales – 3; RAPT; WPPSI – IV; Parent Review Questionnaires.
Results
The intervention group (n=9) showed better improvement in sensory processing, compared to controls (n=9) (6.4 fold improvement in sensation seeking; 5.0 in auditory processing; 4.0 in tactile processing). Six intervention children (67%) improved in vestibular processing. Attention levels improved for 9 (100%) children in the intervention group and for 7 (78%) in the control group. Higher level domains (Peabody motor skills, Auditory Comprehension, Expressive Communication, RAPT scale, and WPPSI scores) showed mixed results. Parents reported positive changes in their child's development.
Conclusion
Therapeutic Listening (TL) is a feasible intervention for preterm children to improve attention levels and sensory processing skills.

Introduction

Children born preterm have a higher rate of attention problems and learning difficulties at school age compared to term infants[1,2,3,4]

They are at increased risk of below average levels of executive functioning,[1,3] even when their general IQ is normal. Sensory integration dysfunction[5], developmental coordination disorder,[6] issues with motor learning, working memory, executive functioning and attention[1] are established outcome expressions for the preterm population.

Recent studies[5, 7] support findings that preterm infants have atypical auditory, tactile and vestibular processing. (46% of infants (median age = 26 wks GA)[6] and 39% of infants born (GA= $\leq$ 32 wks)[7]).

This is the first study to use TL as a home intervention programme for children born preterm. The primary goal was to establish domains which may respond to the intervention, and to estimate outcome instrument characteristics in this population to permit design of future trials.

The TL programme[8] is an auditory intervention programme which uses music specifically designed to support children who experience challenges with sensory processing, listening, attention and communication. It is designed to tap into the orienting response to prime approach behaviour which is the gateway to attention[9]. The treatment effect is attributed to electronic modifications and qualities within the music to trigger attention and activate body movement[9] In the context of auditory interventions, the music is processed using alternating high/ low pass filter, sliding high-pass filter, spatial enhancement and binaural beat. The high/low filter set at 1,000hz is the optimal range for eliciting the orienting response[8]. It is hypothesized to trigger mechanisms involved in selective attention through triggering the orienting response and activating the middle ear mechanism to contract to focus on higher sounds nearby and to relax to monitor stimuli that trigger a shift in focus. The sliding pass filter is hypothesized to enhance processing of higher ranges of sound and sustained attention for refined discrimination. Spatial enhancement is hypothesized to increase the listener's spatial awareness needed to access the environment. A binaural beat is hypothesized to lead to subconscious entrainment of the listener's brainwaves to the neural alpha state, thereby regulating the listener's arousal level and promoting a calm alert state[8]. Alternating between low-pass and high-pass filters trains the ear to shift back and forth between focal and ambient processing and sharpens the parts of sound signals that assist in the perception of time and space. They create a flow between focusing to listen and taking a break (subconscious monitoring) between tuning in and tuning out.[9]

Methods

This was a single centre, prospective, assessor-blinded, randomised controlled trial of therapeutic listening (ISRCTN ref no: 99326699) approved by the hospital's Ethics Committee. The study group were preterm infants BW <1500g (from NMH, Dublin) who were 3-4 years of age. The exclusion criteria were Cerebral Palsy, hearing impairment, congenital malformations, autism and epilepsy. The inclusion criteria was a concerning Bayley-III (low average scoring, sensory/behavioural issues) performance at 2 years corrected age.

The Intervention was a Home Therapeutic Listening (TL) Programme[8]. This involved listening to modified music[9] using specialized headphones for 5 consecutive days per week, for a period of 6 months. The children could continue normal daily activities while listening to the music. A time interval of 3 hours was advised between listening times. The programme was reviewed every 6 weeks (5 reviews) by the intervention therapist (KO'C) and adjusted according to each child's needs. The therapist was assured of full commitment and participation in the programme by each family.

The Control Group did not receive TL intervention. Six children, 4 in the intervention group and 2 in the control group had received some early intervention (physiotherapy and OT) but this was mild and fragmented.

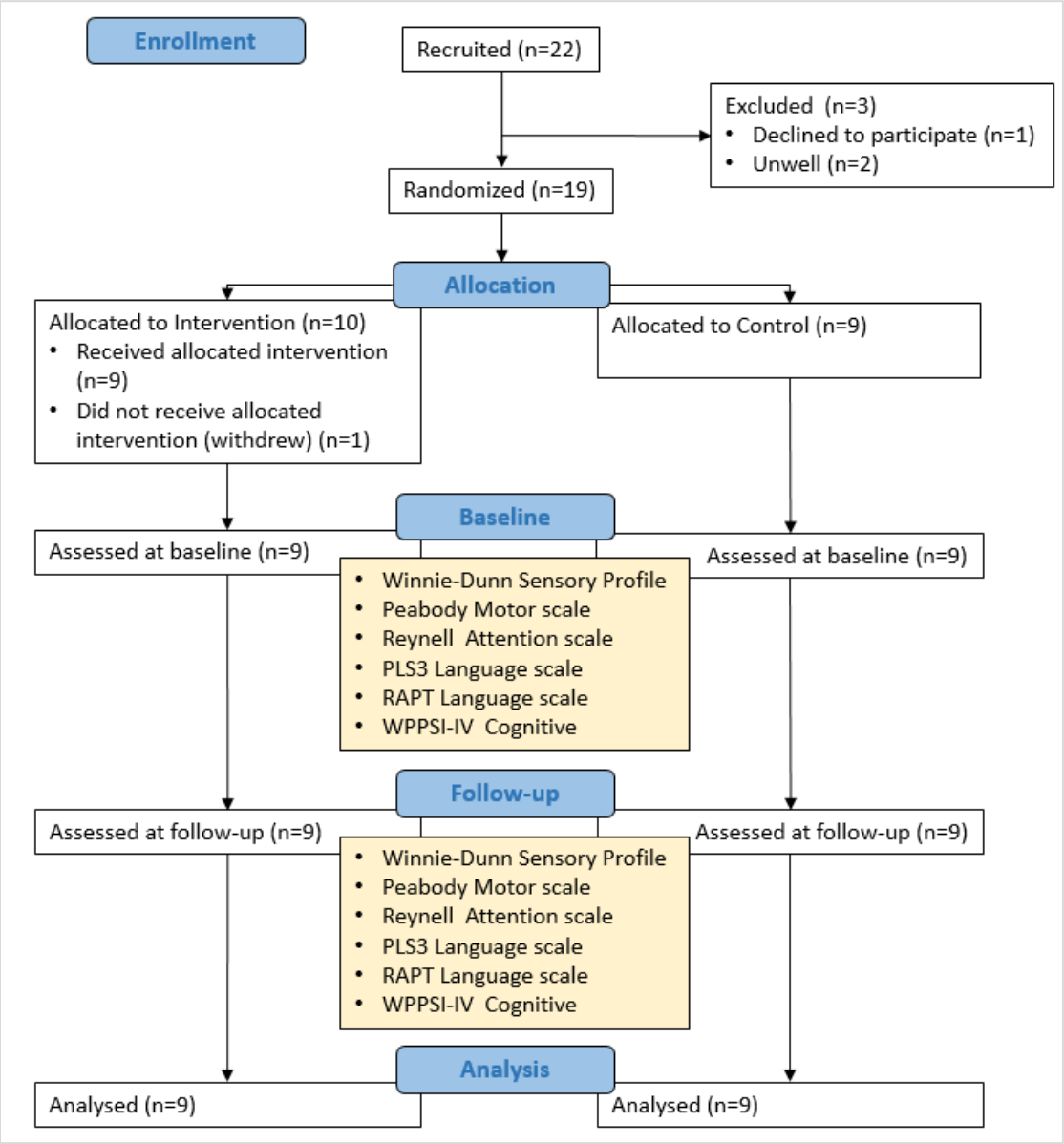
Most of the children were at home full time. **(Table 1)**

When designing a TL programme, the treatment goals of the child influence the choice of music, the manner in which the music has been altered, the duration and frequency of the listening sessions. A variety of music selections may be used (classical, jazz or contemporary) varying in tone, rhythm, melody, harmony and timbre. Optimum listening duration ranges from 20-30 minutes twice per day. This decision is guided by clinical judgement factoring in the child's age, level of sensitivity, developmental needs, and response to previous musical selections - 'just right fit or just right challenge'. Each child receives the amount of listening that their nervous system requires to optimise function.

The scales used were: 1) Winnie-Dunn Sensory Profile [10] 2) Peabody Developmental Motor Scales[11] 3) Reynell Attention Scale [12] 4) Preschool Language Scales 3 [13] 5) Renfrew Action Picture Test (RAPT) [14] 6) Wechsler Preschool and Primary Scale of Intelligence (WPPSI – IV) [15]. Each group was assessed using these 6 scales, pre- and post-intervention on the same day. **(Chart 1)**

The Intervention Group responses to the programme were qualitatively analyzed in terms of noted motor, speech and language, behavioural, social, self-care routine and learning changes using Home Listening Follow-up Forms completed by the parents at each review date.

Chart 1: Recruitment, randomization, allocation of TL and Control Groups and assessment process



12 participants per group were chosen as a feasible sample sufficient for estimation of effects and variances (RS). The participants were randomly (RS) allocated to either the intervention or control Group by computer-generated block randomization. Sequentially numbered, sealed, opaque envelopes were prepared containing an identifier and group allocation, were opened as each participant was enrolled in the study.

Descriptive statistics were generated for pre- and post-intervention scores, as the mean and standard deviation, or median and interquartile range, and number and percentage for categorical outcomes (Attention level). Difference scores were calculated for each outcome by subtracting the post-intervention measurement from the pre-intervention, which are reported per group. A raw and standardised (Cohen's d) effect size for the difference between groups was

calculated. For categorical measures (Attention level), participants were collapsed into those that improved, versus those that stayed at the same level or dis-improved presented as Risk Ratios, with 95% confidence intervals.

Results

Twenty two children (3-4 years) were recruited. Nineteen attended for their pre-intervention testing and were randomised: 10 to the intervention group and 9 to the control group. Three children were unwell. One randomised child withdrew, leaving 9 children per arm with pre and post assessments completed (completion rate: 82%). Clinical characteristics: **(Table 1).**

Table 1. Infant Characteristics of TL Intervention and Control Groups

Characteristic		**Intervention Group (n=9)**	**Control Group (n=9)**
Mean GA (wks)		26.5	26.6
Mean BW (g)		851	1034
Mean Age at 1st assessment (mths/days)		38/11	37/6
Female sex (n)		4	5
Delivery	SVD (n)	2	3
	EM C-section (n)	7	6
Apgar Score @	1min	6	6
	5min	8	7
ANS Dexamethasone use (n)		7	9
PNS Surfactant use (n)		8	4
$MgSO_4$ given (n)		4	5
Mean Ventilation days (SD)		107 (8)	110 (2)
CLD (n)		5	4
ROP requiring laser surgery (n)		2	0
Patent Ductus Arteriosus (n)		4	3
Intraventricular Haemorrhage 1-2 (n)		4	1
Intraventricular Haemorrhage 3-4 (n)		0	1
Periventricular Leukomalacia (n)		0	1
Childcare/ EIS			
At Home (n)		7	8
Creche: part time (n)		2	1
Receiving Early Intervention (n)		4	2
Bayley Scores @2yrs corrected age			
Cognitive (mean)		86.6 Low Average Range	87.7 Low Average Range
Language (mean)		73.1 Borderline Range	89.4 Low Average Range
Motor (mean)		84.4 Low Average Range	91.0 Average Range

GA: Gestational Age; BW: Birth Weight; SVD: Spontaneous Vaginal Delivery; EM C-section: Emergency Caesarian Section; ANS: Antenatal Steroids; PNS: Postnatal Steroids; CLD: Chronic Lung Disease; ROP: Retinopathy of Prematurity; EIS: Early Intervention Services

Differences arose between the groups during randomisation, in birthweight and in baseline psychometric measurements with the intervention group having more difficulties. **(Table 1)**

In sensory processing measures, the intervention group showed better improvement, compared with controls with a 6.4 fold improvement in sensation seeking, a 5.0 fold improvement in auditory processing and a 4.0 improvement in tactile processing. **(Table 2)**

Table 2: Sensory Profile: Pre and Post TL: (Winnie-Dunn SPS)

Sensory Processing		Group				Risk Ratio (95% CI)
		Control		Intervention		
		Pre	Post	Pre	Post	
Sensation Seeking	Normal	6 (67%)	2 (22%)	4 (44%)	5 (71%)	
	Probable Differences	2 (22%)	5 (56%)	3 (33%)	1 (14%)	
	Definite	1 (11%)	2 (22%)	2 (22%)	1 (14%)	
	Improvers	1 (11%)		5 (71%)		6.4 (1.0, 43.3)
Auditory	Normal	4 (44%)	2 (22%)	2 (22%)	6 (67%)	
	Probable Differences	3 (33%)	2 (22%)	1 (11%)	1 (11%)	
	Definite Differences	2 (22%)	5 (56%)	6 (67%)	2 (22%)	
	Improvers	1 (11%)		5 (56%)		5.0 (0.7, 34.7)
Visual	Normal	7 (78%)	6 (67%)	5 (56%)	7 (78%)	
	Probable Differences	1 (11%)	2 (22%)	4 (44%)	1 (11%)	
	Definite Differences	1 (11%)	1 (11%)	0 (0%)	1 (11%)	
	Improvers	0 (0%)		2 (22%)		N/A
Tactile	Normal	4 (44%)	5 (56%)	4 (44%)	7 (78%)	
	Probable Differences	4 (44%)	1 (11%)	1 (11%)	2 (22%)	
	Definite Differences	1 (11%)	3 (33%)	4 (44%)	0 (0%)	
	Improvers	1 (11%)		4 (44%)		4.0 (0.5, 29.1)
Vestibular	Normal	4 (44%)	3 (33%)	2 (22%)	8 (89%)	
	Probable Differences	5 (56%)	2 (22%)	4 (44%)	0 (0%)	
	Definite Differences	0 (0%)	4 (44%)	3 (33%)	1 (11%)	
	Improvers	0 (0%)		6 (67%)		N/A
Oral Sensory	Normal	6 (67%)	4 (44%)	5 (56%)	4 (44%)	
	Probable Differences	1 (11%)	3 (33%)	1 (11%)	2 (22%)	
	Definite Differences	2 (22%)	2 (22%)	3 (33%)	3 (33%)	
	Improvers	1 (11%)		2 (22%)		2.0 (0.2, 18.3)

No improvements were observed for visual or vestibular processing in the control group so a risk ratio could not be calculated, however 67% of the Intervention group improved. Smaller differences were noted for oral sensory processing for the Intervention group. **(Table 2)**

Attention level improved by two levels for 7 (78%) out of the 9 children in the Intervention Group and by one level for 2 (22%) children. In the Control Group, attention level improved by two levels for 2 (22%) children and by one level for 5 (56%) children. The outcomes on this scale linked in with improved sensory profiles for the intervention group. **(Table 3)**

Table 3: Attention Levels: Pre and Post TL (Reynell Attention Scale: 1978)

Attention Level	Group				Cumulative Risk Ratio
	Control		Intervention		
	Pre	Post			
1 (0-1 yrs)	1 (11%)	0 (0%)	4 (44%)	0 (0%)	
2 (1-2 yrs)	4 (44%)	0 (0%)	3 (33%)	0 (0%)	
3 (2-3 yrs)	3 (33%)	5 (56%)	2 (22%)	5 (56%)	
4 (3-4 yrs)	1 (11%)	4 (44%)	0 (0%)	3 (33%)	
5 (4-5 yrs)	0 (0%)	0 (0%)	0 (0%)	1 (11%)	
6 (5-6 yrs)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	
Improved 1 level:		5 (56%)		2 (22%)	0.4
Improved 2 levels:		2 (22%)		7 (78%)	3.5

The Peabody measures showed moderate group differences in motor skills, particularly Gross Motor (d = 0.63), with the intervention group improving their scores less than controls except for the Grasp Scaled Score which had a positive difference but low Cohen's d score (d = 0.05). There was a large group difference (d = 1.11) in the locomotion scaled score, with the intervention group improving less than controls.

In Auditory Comprehension, the Intervention group improved their score less than the controls, but the opposite was observed for Expressive Communication (d = 0.39).

On the Renfrew Language scale, the control group generally increased their score more than the intervention children substantially so, for the Information scale (verbal formulation).

The WPPSI scores generally increased more for the Intervention group than for controls, which didn't translate into a substantial difference on the Visuo-Spatial Index, however (d = 0.35). A large effect size seen for the Block Design scaled score (d = 1.08) was due to less of a decrease in the Intervention group rather than an absolute improvement.

Parents reported positive changes in all areas of their child's development (improved eye-contact; social engagement; speech; attention; energy levels; better at running; drawing; eating; sleeping and completing tasks) relative to other intervention/therapies used previously.

Discussion

Therapeutic Listening (TL) is a feasible intervention for preterm children to improve attention levels and sensory processing skills. The processing and regulation of sensory information at a basic level of the nervous system lays the foundation for development and regulation of attention skills which are foremost in terms of acquiring later skills of motor development, speech and language development, social skills and academic learning. TL improved the Intervention group's ability to regulate or modulate sensory information more than the control group as evidenced by their improved sensory profile results, attention and parental reports. This enabled them to be more regulated and calmer triggering the orientating response[9] thus improving their attention and focus. When a child can regulate their attention levels, their sensory processing improves[16]. This sensory modulation process appears to work across the

spectrum of senses from auditory to vestibular to oral with the vestibular sense showing the greatest benefit. This is consistent with an optimization of learning potential as per Williams and Schellensberger's Pyramid of Learning model [16]

Attention and sensory processing are two notable challenges for the preterm child who has had a good outcome but who is not achieving their potential in terms of language development, learning and quality motor development.
It is possible that TL addressed attention and processing difficulties. The music in sound therapy turns on and enhances the connections between brain areas that process positive award and the insula, a cortical area of the brain that is involved in '*paying attention'*[17]*.* Stimulating the vestibular system with music and movement therapy causes it to send signals to another subcortical area, the basal ganglia, which is part of the attention circuit. The vagus system is also stimulated, which turns on the parasympathetic nervous system to calm children down [18] and stimulates the "smart vagus" [19] to allow children to pay close attention, communicate and get ready to learn.

Scores reflecting language and cognitive ability showed either mild advantage, or a mixed picture, indicating that improving these abilities may be challenging for this group of children. No benefits from TL were encountered in receptive/expressive communication. Our intervention and control groups scored poorly on the Renfrew Action Picture Test (RAPT) indicating their challenges with language. Adequate attention is required in order for language to occur. The differences in expressive language between preterm and full term children becomes evident around the end of their second year.[20] A stronger Low Registration pattern - flat or dull "affect" is related to delayed early cognitive development including dampened responses to the environment, potentially affecting developmental opportunities in areas such as language.[21]

Improvement was minimal in terms of motor outcome. In our study, both groups demonstrated low levels of functioning on the test battery at 3-4 years of age. Pre-assessment results showed that all 18 children (Intervention and Controls) had poor motor development, all performing below peer group standards. No child in either group reached normal Total Motor Quotient scores. Motor deficits are noted to persist for some preterm children[22]
Comparison of the groups is not the most important component of this pilot study. The principal limitation was that the randomisation generated rather different mean levels of ability between the groups, which should not occur in a larger study.

The results of this study, Eeles'[21] and Crozier's[6] studies show that it is increasingly evident that we should be screening for sensory sensitivities within the preterm population during their 2 year follow-up. The Winnie – Dunn Sensory Profile Questionnaire has proven effective in assessing these skills. This perspective is beneficial [23], as in the case of sensory processing, it is the subjective experiences of the child and family that impact quality of life. Poor sensory processing affects motor, language and cognitive development. 46%[6] and 39%[7] of the preterm populations studied have been reported as having sensory sensitivities. TL could be an effective treatment option for this group of sensory sensitive preterm children. As a home programme it facilitates more intensive intervention than conventional treatment methods, with less therapist input than clinic based treatment programmes. It is cost and time efficient. We observed a good response and motivation to engage from parents.

Declaration of Conflicts of Interest:
The author have no conflicts of interest to declare.

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